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Evaluation of performance, combustion and emission characteristics of blends of Sesame Biodiesel in a single cylinder Diesel Engine: An experimental approach

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Abstract

The study examines the performance, combustion, and emission characteristics of a diesel engine fueled with sesame biodiesel methyl ester (SBME)–diesel blends containing 0–100% SBME by volume (i.e., 0%, 10%, 20%, 30%, and 40% SBME blended with conventional diesel. The findings highlight significant improvements in combustion efficiency and emissions reduction with SBME compared to diesel, with 20 SBME emerging as the optimal blend. For 20 SBME, Brake Thermal Efficiency improves by 9.57%, and specific fuel consumption decreases by 7.94%, while Mechanical Efficiency increases by 0.618%. Indicated Power rises for 10, 30, and 40 SBME but slightly declines for 20 SBME by 0.66%. Emissions analysis shows reductions in CO, NO, and HC emissions for 10 and 20 SBME, with decreases of up to 3.5%, 19.18%, and 36.55%, respectively, while higher blends result in increased emissions. Combustion analysis reveals enhanced Cylinder Pressure Maximum (CPM) and Net Heat Release (NHR) for 20 and 30 SBME, alongside a reduction in Cumulative Heat Release (CHR) across all blends. Additionally, exhaust gas temperature and heat loss through radiation increase at higher loads. These results demonstrate that 20 SBME offers a balanced improvement in engine performance, combustion characteristics, and environmental impact, making it a viable alternative to conventional diesel.

1. Introduction

Transportation industry being one of the primary consumers of fossil fuel, is also one of the main producers of greenhouse emission. Carbon emission from automobiles and its massive consumption of fossil fuel has been discussed since ages as fossil fuels are non-renewable [1]. Biodiesel as an alternative fuel has become quite a sensation recently as it is made from renewable sources like vegetable oils, animal fats and has low emission. A lot of extensive research has been done to study potential feedstock such as edible oils from seed sources like sesame, soybean, sunflower, coconut, and others [2]. Non consumable oils like jatropha, waste oil, oil from sewage etc. can be harvested several times a year and do not compete directly with food [3]. Oils derived from microorganisms, algae, yeast, etc. are the third type of feedstock. They contribute to significant reduction in carbon emission [4].

Biodiesel is composed of fatty acid methyl esters and is prone to oxidation which reduces shelf life and causes gumming which affects engine performance. So, antioxidants are added to increase oxidative stability of biodiesel. Sesame (Sesamum indicum L) is an oil seed constituting oil and protein primarily. Oil content ranged from 57-63% and protein 23-27%. Sesame

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oil contains sesamin and sesaminol lignans which are naturally occurring antioxidants and play a huge role in oxidation stability of biodiesel. Sesame oil can be blended with other oils to increase oxidation stability of hybrid biodiesel overall. The fuel property of Sesame biodiesel compares well with ASTM and EN biodiesel standards so its blends can improve fuel property and engine performance [5].

Poor cold flow property is present in Biodiesel due to the long chain, saturated FA esters. Poor cold flow property of Biodiesel leads to clogging of fuel lines and filters which results in ignition problems, incomplete combustion [6]. The poor cold flow properties of other vegetable oils can be improved by blending Sesame oil during transesterification process enhancing the engine performance [7].

Vegetable oil contains high free fatty acids which form triglycerides, basically an ester. Vegetable oils are 10-15 times more viscous than petrol-diesel and due to high density, saturated and unsaturated fats, they cannot be used directly in engines. Various methods like transesterification, direct use and blending with diesel, microemulsions, pyrolysis, etc. have been extensively researched and used for producing biodiesel [2].

If the Fatty Acid Content is less than 2%, pretreatment can be avoided, and transesterification reaction will be done. Transesterification will convert the triglycerides to Fatty Acid Esters (FAE) and glycerol in the presence of alcohol and catalyst [1][8][9]. Transesterification is one of the most preferred methods for turning vegetable oils into biodiesel because it produces biodiesel with similar fuel property to diesel [10]. Methanol and ethanol are commonly used alcohols in transesterification. However, methanol is preferred due to its physical and chemical benefit due to short chains, and cost effectiveness. Also, it reduces viscosity, enhances pourpoint of biodiesel compared to ethanol. Depending on feedstock used, transesterification is done in a single stage using alkaline catalyst or double stage using alkaline catalyst followed by acidic catalyst [1][8].

The experiments conducted on Lombardini 6 LD 400, one cylinder, four-stroke, air-cooled, direct injection diesel engine showed that sesame biodiesel can be used successfully as fuel without any alteration in direct injection diesel engine. Engine was loaded with electrical dynamometer and tested at full load and engine speed ranging from 1800 to 3300 rpm [11].

The pure sesame biodiesel(B100%) showed lesser difference in performance parameters like fuel consumption, efficiency when compared to petroleum diesel. Although, the petroleum diesel showed highest torque in different RPM, difference was small when compared to blends (B5, B10 and B20) and pure biodiesel(B100) [12]. While using 50% blend of sesame oil and 50% diesel, it was observed that engine power and torque of the blend was similar to that of conventional diesel and also it showed reduction in emission so sesame oil can be used as an alternative fuel [11]. Among the sesame oil, 20% blend of sesame biodiesel and 80% diesel, it was found that 20% blend showed most efficient emission characteristics and showed significant reduction in CO, HC, CO_2 but increased NO_x [13]. When using sesame biodiesel and its various blends (5%, 10%, 20%), fuel consumption, efficiency is similar to that to diesel. Flow properties of blends were good and emission was also comparatively lesser [12].

Study of characteristics of sesame biodiesel blends in diesel engine showed that increasing the sesame biodiesel blend reduced specific fuel consumption (SFC) and carbon monoxide (CO) emissions while increasing nitrogen oxide (NO_x) emissions. Sesame biodiesel (B100) exhibited an 11% higher SFC and 39% lower CO emissions compared to diesel (B0).

Higher blends (B100 and B80) demonstrated higher SFC and emissions compared to lower Blend (B20), indicating that sesame biodiesel, particularly up to B20, is a viable alternative for partial diesel replacement. CO_2 emission of sesame biodiesel is more than that of diesel which might be due to more oxygen present in the biodiesel structure but the emission is not big deal as it is compensated by photosynthesis of plants. SFC of sesame biodiesel is greater as its heating value is less and required more amount of fuel to produce same amount of power as diesel. Srikanth Vadlamudi et al. [14] worked on performance of diesel engine using biofuel from sesame oil which found higher sesame content in the fuel blend lowers the peak pressure rise and heat release rate but increases fuel consumption due to its lower energy content. It also decreases the engine's thermal efficiency. Specific fuel consumption of sesame biodiesel increases due to lower heating vale of sesame biodiesel than that of diesel causing more of it required to produce same amount of power as diesel. Smoke density also increase with increase in blend which might be due to extra oxygen available in biodiesel. Also increase in biodiesel blend percentage, increase in exhaust gas temperature is observed. The extra oxygen in sesame biodiesel improves combustion, raising the engine temperature and increasing NO_x emissions while decreasing CO emission at the same time [15].

The novelty of this study lies in the experimental evaluation of the performance, combustion, and emission characteristics of sesame biodiesel blends in a single-cylinder diesel engine as only a limited research work are available in this area. By systematically analyzing different blend ratios, this work identifies optimal blend which achieve a balance between reduced emissions and maintaining equivalent performance characteristics as that of conventional diesel. The detailed investigation of combustion parameters, including peak pressure, heat release rate, and exhaust gas temperature, provides valuable insights into the effects of sesame biodiesel on engine performance. With its focus on a sustainable and locally available feedstock, this study significantly contributes to the development of alternative fuels, aligning with global efforts toward renewable energy and environmental sustainability.

2. Method and methodology

2.1. Biodiesel production

The process began with the collection of crude sesame oil which is a raw material for biodiesel production process. The crude oil was then filtered to remove any debris or solid contaminants present in the oil, thereby providing clean oil. Free Fatty Acid Test (FFA Test) of the oil was done to find out the content of free fatty acids in the oil. Free fatty acid of the sesame oil was found to be less than 2%, so the crude sesame oil undergoes transesterification reaction to produce Sesame Biodiesel Methyl Ester (SBME). The oil was allowed to react with Ethanol maintaining temperature of 60 degrees Celsius and KOH was used as catalyst whose concentration was 1% by weight of the total weight of reactants. The molar concentration ratio of Ethanol to oil (triglycerides) was set to 6:1. After the sesame biodiesel was produced, it was purified to remove the glycerol and unreacted alcohol to obtain Sesame Biodiesel Methyl Ester.

2.2. Experimental setup

The investigation was conducted on a single cylinder variable compression ratio (VCR) diesel engine. The engine is a four-stroke, single cylinder water cooled engine whose rated Brake Power is 3.5 KW and maintains a constant speed of 1500 rpm. It has Direct Injection System with Injection pressure of 220 bars. The engine's cylinder bore is 87.5 mm, stroke length is 110 mm, connecting rod length is 234 mm and swept volume is 661.45 cc. Specific Gas Constant is 1 kJ/kg. K and Adiabatic Index is 1.41. The data from Engine is averaged over 10 complete cycles to provide more accurate data values from the engine. The compression ratio was set to 17. Both the cylinder pressure reference and TDC reference is set to 0 degree Celsius. Smoothing factor of 2 degree Celsius is also incorporated to the pressure readings.

The test engine was coupled with an eddy current dynamometer as part of the standard engine test bench supplied by the manufacturer, which facilitates precise control of engine load and measurement of performance parameters. The reason for using an eddy current dynamometer was to obtain constant Brake Power in reference to which different performance parameters like Indicated Power - the engine power calculated from in-cylinder pressure, Brake Power (BP) – the usable power at the crankshaft, BSFC - fuel consumption per unit of brake power, Brake Thermal Efficiency - the ratio of brake power to fuel energy input, and Mechanical Efficiency - the ratio of brake power to indicated power; combustion parameters like Cylinder Pressure Maximum (CPM) -the peak in-cylinder pressure during combustion, Net Heat Release (NHR) - the rate of energy released per unit time in the cylinder, Cumulative Heat Release (CHR) - the total energy released over the combustion cycle. were computed.

Experiments of the fuels obtained from different blends of Sesame Biodiesel and Petroleum based Diesel, i.e. 0SBME (SBME 0% and Diesel 100%), 10SBME (SBME 10% and Diesel 90%), 20SBME (SBME 20% and Diesel 80%), 30SBME (SBME 30% and Diesel 70%), and 40SBME (SBME 40% and Diesel 60%), was performed in the VCR Test Engine present at the Combustion laboratory of Thapathali Campus which is manufactured by Kirloskar Company. Pressure Sensor and Temperature sensor were also fitted to measure the in-cylinder pressure and the exhaust gas temperatures respectively. Schematic diagram of experimental setup is shown in the Figure 1.

2.3. Blending operation

Blends of Sesame Biodiesel and petroleum-based diesel was prepared on volumetric basis (volumetric blend) in four ratios: 10SBME, 20SBME, 30SBME and 40SBME. For proper mixing, the blends were shaken for 5 minutes. Afterwards, visual inspection was done to ensure that blending had completed.

2.4. Emission measurement

To measure the emission, KANE Model: AUTO5-2 gas analyzer was used. The specification of the analyzer is illustrated in the Table 1.

3. Result and Discussion

3.1. Biodiesel characterization

From Table 3, it is observed that, major components of sesame biodiesel were found to be Methyl oleate, methyl linoleate, methyl palmitate, methyl stearate and methyl erucate with total percentage of 56.30, 22.79, 8.28, 6.07, 6.55 respectively. methyl oleate (56.30%), a monounsaturated ester derived from oleic acid, which enhances biodiesel's oxidative stability and low-temperature fluidity. Following this is methyl linoleate (22.79%), a

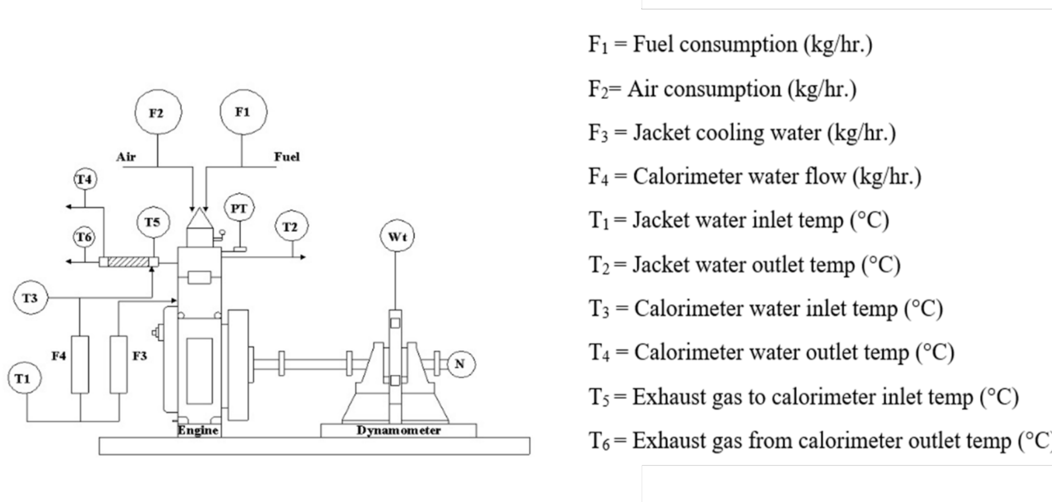


Figure 1: Schematic Diagram of VCR Engine [16]

Table 1: Specification of gas analyzer

Parameter	Resolution	Accuracy	Range
Carbon Monoxide (Infrared)	0.01%	+/- 5% of reading +/- 0.06% volume	0–10% Over-range: 20%
Carbon Dioxide (Infrared)	0.1%	+/- 5% of reading +/- 0.5% volume	0–16% Over-range: 25%
Nitric Oxide (fuel cell)	1 ppm	0–1500 ppm	0–1500 ppm Over-range: 5000 ppm

polyunsaturated ester from linoleic acid that improves fuel fluidity but may reduce oxidation resistance. Saturated esters like methyl palmitate (8.28%) and methyl stearate (6.07%) contribute to a higher cetane number, improving ignition quality, but their high melting points can negatively impact cold-flow properties, potentially causing fuel filter clogging in colder climates. The minor component methyl erucate (6.55%), a long-chain unsaturated ester, may influence combustion behavior due to its structural properties.

3.2. Performance characteristics

Figure 2a represents the relationship between Indicated Power and Brake Power. Indicated Power is the maximum energy generated inside the cylinder before any friction loss. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, Indicated Power goes on increasing except for 20 SBME. IP increases by 0.98%, 2.485%, 2.698% for 10 SBME, 30 SBME, 40 SBME, respectively, and decreases by 0.6606% for 20 SBME in comparison with diesel. This is due to the better oxygen content enhancing the fuel burning and reduces power on 20SBME due to the negative effect of higher viscosity and lower energy content.

Figure 2b represents the relation between Specific fuel consumption to Brake Power. Specific Fuel Consumption is the amount of fuel consumed per unit of power output per unit of time. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, Specific fuel consumption goes on decreasing. On the average when comparing with diesel, SFC for 10, 20, 30 and 40 SBME decreases by 4.72%, 7.94%, 6.01% and 4.17%, this is primarily due to the higher cetane number of sesame biodiesel results in shorter ignition delay which increases the fuel efficiency. The variation in SFC among biodiesel–diesel blends is more distinct at lower Brake Power, whereas the differences tend to reduce with increasing engine load. This behaviour can be attributed to the elevated in-cylinder temperatures at higher Brake Power, which reduce the influence of fuel viscosity and promote improved atomization and vaporization of all the fuels thereby leading to more efficient and uniform combustion. As a result, the SFC values for biodiesel–diesel blends converge towards those of pure diesel at higher loads.

Figure 2c represents the relation with Brake Thermal Efficiency to the Brake Power. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, Brake Thermal Efficiency increases for all the blends. It increases by 3.58%, 9.57%, 7.138% and 4.056% for 10, 20, 30 and 40 SBME respectively. Brake Thermal Efficiency increases with increasing BP due to oxygen

Table 2: Fuel Property of Various Blends of Biodiesel

Sample	Density (kg/m^3) ASTM D1298	Viscosity (cSt) ASTM D445	Flash Point (°C) ASTM D975	Calorific Value (MJ/kg)	Cetane Index ASTM D4737
0SBME	842.4	2.87	63	42.5	46
10SBME	834.5	2.81	70	41.56	49
20SBME	843.7	2.97	72	41.32	51.23
30SBME	851.3	3.02	76	39.42	51.98
40SBME	855.1	3.28	79	38.59	52.36

Table 3: GCMS Composition of Biodiesel

S.N.	FAME component	Common name	Retention time	Area (%)
1	9-Octadecenoic acid methyl ester	Methyl oleate	40.764	56.30
2	9,12-Octadecadienoic acid methyl ester	Methyl linoleate	40.570	22.79
3	Hexadecanoic acid methyl ester	Methyl palmitate	37.366	8.28
4	Octadecanoic methyl ester	Methyl stearate	41.131	6.07
5	13-Docosenoic acid methyl ester	Methyl erucate	48.090	6.55

content on biodiesel resulting in better energy conversion and reducing energy losses.

Figure 2d represents the relation with Mechanical Efficiency to the Brake Power. Mechanical Efficiency is the ratio of Brake Power to the indicated Power. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, Mechanical Efficiency goes on decreasing except for 20 SBME. Mechanical Efficiency increases for 20 BMEP by 0.618% and decreases by 10, 30 and 40 SBME 1.83%, 2.25% and 1.807% respectively. Mechanical Efficiency decreases with increasing BP due to the high viscosity of sesame oil and its lower calorific value causing poor atomization and increased friction, which shows less amount of Indicated Power was converted into useful Brake Power.

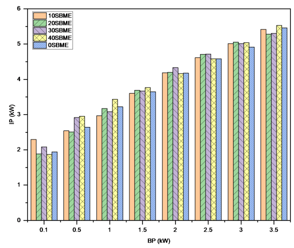
The figure 2e represents the relation of Exhaust gas temperature with Brake Power. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, EGT increases for 20 and 40 SBME while it decreases for 10 and 30 SBME. On average when comparing with diesel, the EGT of 20, 40 SBME increases by 2.865%, 0.49%, respectively and decreases on 10, 30 SBME by 2.38%, 0.163% respectively. Sesame has lower calorific value which results in more amount of fuel to be injected into the cylinder to generate same Brake Power, due to which EGT increases.

3.3. Combustion characteristics

Figure 3a represents the relation between Cylinder Pressure Maximum to the Brake Power. CPM is the highest pressure reached inside the cylinder during the combustion process. The value of CPM at low and high load varies from (51.36-69.06) bar, (50.27-68.48) bar, (49.80-67.90) bar, (51.85-67.77) bar and (51.36-67.94) bar. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, CPM increases for 20 and 30 SBME while it decreases for 10 and 40 SBME. CPM increases with increase in BP due to higher energy density, shorter ignition delay and higher compression ratio.

Figure 3b represents the relation between Cumulative Heat Release (CHR) to the Brake Power CHR is the total amount of heat released in the combustion chamber as a function of crank angle. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, CHR decreases for all the blend. The value of CHR at low and high load varies from (0.59-1.2) kJ, (0.57-0.99) kJ, (0.56-0.97) kJ, (0.64-0.96) kJ and (0.63-1) kJ. On increasing BP, CHR decreases due to the lower calorific value of blends of Biodiesel compared to diesel. It was found that with the rise of the blending ratio from 10 SBME to 40 SBME, NHR increases on 20 and 30 SBME and decreases on 10 and 40 SBME. The value of NHR at low and high load varies from (23.24-53.48) J/deg, (19.82-52.97) J/deg, (22.90-50.86) J/deg, (24.39-52.00) J/deg and (21.64-51.90) J/deg.

Figure 3c represents the relation between Net Heat Release (NHR) to the Brake Power. NHR increases on increasing BP due to lower energy density as more fuel is injected into cylinder to meet the power requirement. Also, cylinder temperature and pressure increase when BP is increased which can increase heat losses reducing



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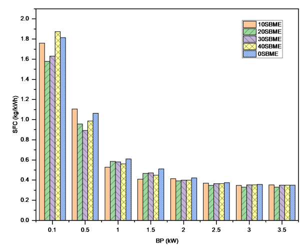

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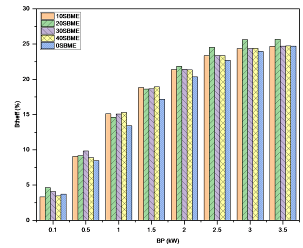

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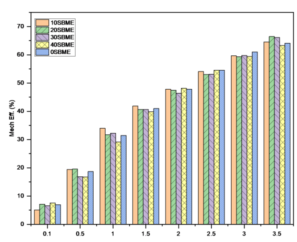

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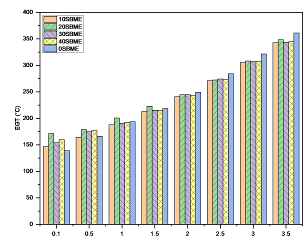
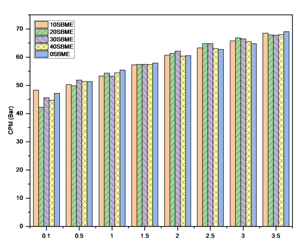


(e)

Figure 2: (a) Relation of Indicated Power with Brake Power. (b–e) Relation of Specific Fuel Consumption (SFC), Brake Thermal Efficiency, Mechanical Efficiency, and Exhaust Gas Temperature (EGT) with Brake Power, respectively.



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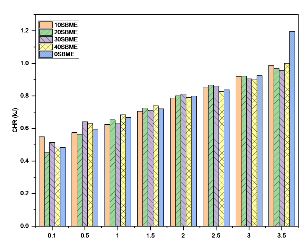

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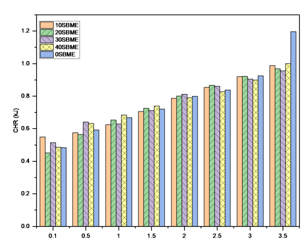


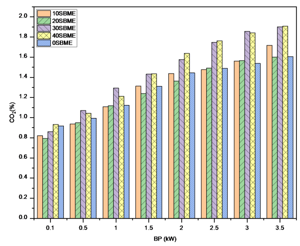
(c)

Figure 3: (a–c) Relation of Cylinder Pressure Maximum (CPM), Cumulative Heat Release (CHR), and Net Heat Release (NHR) with Brake Power, respectively.

NHR.

3.4. Emission characteristics

Figure 4a represents relation between CO_2 emission and BP. With the rise of the blending ratio from 10 SBME to 40 SBME, CO_2 emission increases for 30 and 40 SBME while decreases for 10 and 20 SBME. CO_2 emission increases by 11.41%, 11.77% on 30 and 40 SBME respectively while it decreases by 1.31% ,3.502% on 10 and 20 SBME. For lower biodiesel blends such as 10 and 20 SBME, the uncertain reduction in CO_2 emissions can be attributed due to the lower carbon-to-hydrogen ratio and higher inherent oxygen content of the methyl esters, which promote more complete combustion and slightly reduce the total carbon oxidation compared with pure diesel. Similar findings have been reported by Dwivedi et al. [17] and Tejesh et al. [18], who observed that lower biodiesel blends tend to produce marginally lower CO_2 emissions due to improved combustion efficiency and reduced carbon intensity, whereas higher blend ratios may show increased CO_2 formation because of higher viscosity and poorer atomization, leading to incomplete mixing and less efficient combustion.



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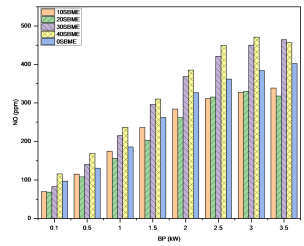

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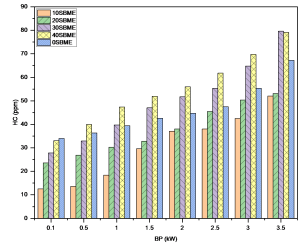

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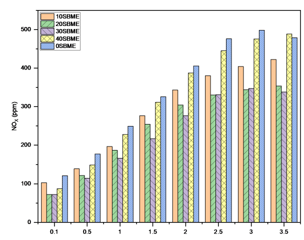

(d)

Figure 4: (a–d) Relation of CO_2, NO, HC, and NO_x emissions with Brake Power, respectively.

Figure 4b represents the relationship of NO emission and BP. With the rise of the blending ratio from 10 SBME to 40 SBME, NO emission increases for 30 and 40 SBME while decreases for 10 and 20 SBME. NO emission increases by 10.41% ,21.65% on 30 and 40 SBME respectively while it decreases by 15.804% ,19.175% on 10 and 20 SBME. Lower blends have less cetane number as compared to higher blends which lead to lower cylinder temperature resulting in less NO emission but as the blend increases NO emission also increases. Higher oxygen content in SBME increases combustion temperature increasing cylinder temperature which supports the formation of NO. Also, shorter ignition delay which results in earlier combustion allows sufficient time for NO formation during peak temperature.

Figure 4c represents the relationship of HC emission and BP. With the rise of the blending ratio from 10 SBME to 40 SBME, HC emission increases for 30 and 40 SBME while decreases for 10 and 20 SBME. HC emission increases by 6.42% ,18.51% on 30 and 40 SBME respectively while it decreases by 36.55% ,18.97% on 10 and 20 SBME. Biodiesel has higher viscosity than diesel but in lower blends this property is slightly reduced resulting in lower HC. HC emission increases as the blend increases because of high viscosity of SBME which causes poor atomization. Incomplete combustion also leads to higher HC emission.

Figure 4d represents the relationship of NO_x emission with BP. With the rise of the blending ratio from 10 SBME to 40 SBME, NO_x emission increases for 30 and 40 SBME while decreases for 10 and 20 SBME. NO_x emission increases by 10.35% ,21.27% on 30 and 40 SBME respectively while it decreases by 13.9003% ,18.93% on 10 and 20 SBME. The lower blends have lower NO_x emission due to lower cetane number of biodiesel which lead to lower cylinder temperature.

SBME has higher oxygen content which promotes complete combustion increasing the combustion temperature. Thus, higher temperature favors the formation of NO_x. Lower ignition delay due to the higher cetane number of SBME leads to the more heat release during combustion contributing to NO_x formation.

4. Discussion

This study systematically evaluates the performance, combustion, and emission characteristics of sesame biodiesel methyl ester (SBME) blends, identifying 20% SBME as the optimal formulation. The blend achieves a 9.57% increase in Brake Thermal Efficiency (BTE) and a 7.94% reduction in specific fuel consumption (SFC) compared to diesel, driven by its oxygen-rich molecular structure. This oxygen content enhances fuel-air mixing and combustion completeness, reducing unburned hydrocarbon residues. The obtained result is in close agreement with the reason reported by Kshatriya et al. and Canakci et al. [19], [20]. However, higher blends (30–40 SBME) exhibit diminished Mechanical Efficiency due to increased viscosity (3.02–3.28 cSt), which delays atomization and amplifies friction losses. Notably, 20 SBME maintains a marginal 0.618% improvement in mechanical efficiency, leveraging sesame oil's inherent lubricity to offset energy-density limitations (39.32 MJ/kg vs. diesel's 42.5 MJ/kg). A similar result was observed in this study, which is in agreement with the findings cited in Zetra et al. [21].

Combustion dynamics reveal that 20 SBME achieves peak cylinder pressure (50.27–68.48 bar) and Net Heat Release (19.82–52.97 J/deg), attributed to its high cetane index (47.19) and dominant fatty acid esters, such as methyl oleate (56.30%) and linoleate (22.79%). These esters shorten ignition delay, enabling rapid premixed combustion phases [22]. Despite this, Cumulative Heat Release decreases across all blends (0.56–1.2 kJ), reflecting SBME's lower energy density—a trade-off inherent to oxygenated biodiesels.

Emission profiles highlight the dual role of sesame's antioxidants and oxygen content. The 20 SBME blend reduces CO_2 (Negative 3.5%), NO (Negative 19.18%), and HC (Negative 36.55%) emissions, as sesamin and sesaminol lignans stabilize combustion and suppress incomplete oxidation [17][18]. Conversely, higher blends (30–40 SBME) increase NO_x emissions (Positive 10.41 to Negative 21.65%) due to elevated adiabatic flame temperatures, which accelerate thermal NO_x formation [19]. This underscores the importance of blend optimization to balance emission reductions and combustion efficiency.

5. Conclusion

The experimental investigation into the performance, combustion, and emission characteristics of sesame biodiesel methyl ester (SBME) blends in a single-cylinder diesel engine demonstrates the viability of sesame biodiesel as a sustainable alternative to conventional diesel. Through systematic evaluation of blends ranging from 10% to 40% SBME, the 20% blend (20 SBME) emerged as the optimal formulation, offering a balanced improvement in engine efficiency, combustion dynamics, and environmental impact. Key findings are summarized as follows:

- The 20 SBME blend exhibited a 9.57% increase in Brake Thermal Efficiency and a 7.94% reduction in specific fuel consumption compared to pure diesel, attributed to its higher cetane number and oxygen content, which enhance combustion efficiency.
- Mechanical Efficiency improved marginally (0.618%) for 20 SBME, whereas higher blends (30–40 SBME) showed declines due to increased viscosity and reduced calorific value affecting atomization and friction losses.
- Enhanced combustion efficiency was observed for 20 SBME, with higher Cylinder Pressure Maximum (CPM) and Net Heat Release (NHR) compared to diesel. However, Cumulative Heat Release (CHR) decreased across all blends, indicating efficient energy utilization during peak combustion phases.
- Lower blends (10–20 SBME) significantly reduced emissions: CO_2 decreased by up to 3.5%, NO by 19.18%, and HC by 36.55%, owing to improved oxidation stability and complete combustion facilitated by sesame biodiesel's inherent antioxidants and oxygen content.
- Higher blends (30–40 SBME) led to increased NO_x and HC emissions due to incomplete combustion and elevated combustion temperatures.

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Conflict of interest

The authors declare that they have no conflict of interest.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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