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Article

Exergy, energy and emissions analyses of biodiesel-diesel blends in a diesel engine

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Abstract: The aim of the research is to determine how well a single-cylinder, four-stroke (SCFS) diesel engine performs when combining Mahua oil methyl ester (MOME) with diesel. Utilizing B20 (a 4:1 ratio of diesel to MOME by volume), the analysis of energy, energy, and emissions was performed. According to research, diesel produced 5.99% and 10.87% more fuel energy intake and energy that was forcibly evacuated by exhaust gases than B20. The unanticipated losses in the diesel scenario were 9.25% higher than in the B20 scenario. Although the energy efficiency for diesel was 27.22%, the overall losses were 71.95%. B20's efficiency was 64.47% more than that of diesel. Diesel oil is 1.33% more readily available as an input than B20, according to the exergy research. Comparing diesel to B20, the former had 5.33 times more exhaust pollutants and 31.12% less braking power availability. Diesel's destruction rate is 0.96% lower than B20's. In terms of energy, energy expenditure, and emissions, B20 is found to be quite comparable to diesel.

Nomenclature

$\dot{E}_f$	Rate of fuel energy
$\dot{E}_x$	Rate of exergy transfer
$\dot{Q}_{ex}$	Energy consumption rate
$\dot{Q}_{lost}$	Rate of energy loss
H_u	Heating value
$\dot{Q}$	Rate of gross heat transfer
$\dot{W}$	Brake power
$\dot{m}$	Mass flow rate
h	Specific enthalpy

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s	Specific entropy
ϵ	Specific exergy
τ	Engine torque
ω	Angular velocity

Subscripts

dest	Destruction rate
ex	Exhaust gas
f	Fuel
in	Incoming
out	Outgoing

Abbreviation

C_{pw}	Specific heat of water
D_{engine}	Diesel engine
EBS	Energy balance sheet
KE	Kinetic energy
MOME	Mahua oil methyl ester
PE	Potential energy
SCFS	Single-cylinder, four-stroke
SOME	Methyl ester of soybean oil
YGME	Methyl ester of yellow grease

1. Introduction

Fossil fuels originating from non-renewable crude oil have been a major source of energy for the world's supply; it is estimated that 90% of these fuels are used for energy generation and transportation. Since fossil fuels' emissions are acknowledged to be the main contributors to global warming, several nations have enacted laws to mitigate their damaging effects on the environment as a result of the world's fastest-growing population. The industrial base and productivity of many developing nations are growing, but the demand for energy globally is only going to rise. At the current rate of consumption, known crude oil reserves could run out in less than 50 years. This circumstance sparked and maintained interest in finding sustainable raw materials for the production of liquid alternative fuels.

There was a lot of interest in using vegetable oils as fuel in the early days of the diesel engine, but as petroleum products became more widely available in the late 1950s, this desire began to wane. Nonetheless, a resurgence of interest in vegetable oil fuels occurred in the early 1970s due to oil stock. When it was discovered that the world's petroleum reserves were running low, interest in the subject changed. Vegetable oils can be used in diesel engines in three different ways generally speaking. These include transesterified vegetable oils, neat or pure vegetable oils, and mixtures of vegetable oils and diesel fuel. Because the fuel in the first and second forms is more viscous, there are issues with how well diesel engines operate over the long run. However, compared to pure or blended vegetable oil fuels, the esters of vegetable oils have far lower viscosities; as a result, viscosity-related issues like clogged engine parts like fuel injectors are dramatically decreased. Naturally, vegetable oils' esterification is one of their most promising uses as diesel fuels—both for edible and non-edible varieties. Vegetable oils are transesterified to yield methyl, ethyl, and butyl esters, which are commonly recognized. The most popular way to use biodiesel at the moment is to mix it with regular diesel fuel.

An energy-producing fuel that comes from biological carbon fixation is called a biofuel. Biofuels are fuels made from the transformation of biomass, as well as several types of biogases, fuels that are liquid, and biomass that is solid. Biofuels derived from sugar, starch, and vegetable oil are referred to as the initial-generation or conventional biofuels. Sustainable feedstock is used to manufacture biofuels classified as second generation. Numerous biofuels of the second generation, including wood diesel, mixed alcohols, biohydrogen diesel, bio methanol, cellulosic ethanol, algae fuel, and Fischer Tropsch diesel, are now in development. Since the indigenous supply of edible oil cannot keep up with demand, non-edible oil is the best option for use as a feedstock for biodiesel in India. A million tonnes or more of these oils are thought to be potentially available in India each year; the most common sources are neem, jatropha, mahua, and pogonamia oil, which is also referred to as Karanja oil.

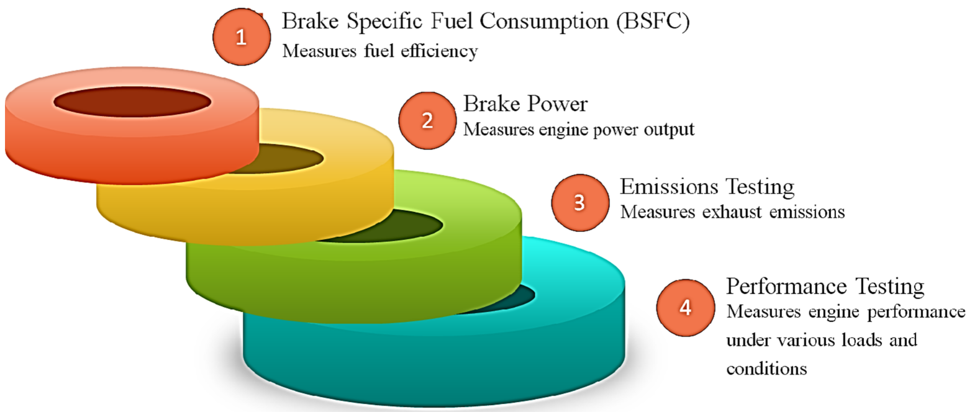

Figure 1. Standard measurement techniques for diesel engines.

In this research, there are following standard measurement techniques for diesel engines as shown in Figure 1. There are research gaps in the areas for energy and exergy analysis for diesel engines using mixtures of biodiesel and diesel: (a) Few optimization studies have used energy and exergy analysis to optimize engine design and operational characteristics. (b) Lack of study on real-time monitoring: To measure energy and exercise performance, more studies on real-time monitoring devices are required. (c) Limited comparison to conventional fuels: Additional research is required to assess the energy and exergy performance of mixes of biodiesel and conventional fossil fuels. The novelty of this research is (a) Exergy analysis applied to mixtures of biodiesel and diesel, offering a more thorough comprehension of engine efficiency. (b) A comparison of classic fossil fuels and their energy and energy performance.

The following factors restricting the biodiesel concentration to 40% (B40) in diesel fuel blends is based on several factors:

- **Engine Compatibility**: Elevated biodiesel concentrations may lead to problems with the materials used in engines, including deterioration, corrosion, and damage to the fuel system.
- **Fuel Properties**: Compared to diesel, biodiesel has a larger water content, a lower energy density, and a higher viscosity. Increased concentrations may have an impact on engine performance, combustion, and fuel flow.
- **Cold Flow Performance**: Compared to diesel, biodiesel has a greater pour and cloud points, which makes it more prone to gelling and waxing in cold weather. Increased concentrations may make cold flow less effective.
- **Oxidation Stability**: Diesel is less prone to oxidation than biodiesel, which can cause deposit development and fuel degradation. The likelihood of oxidation-related problems can rise with higher concentrations.

- **Emissions and Particulates**: The concentration of biodiesel can lead to an increase in particulate matter (PM) and nitrogen oxides (NOx) emissions, which could have an adverse effect on the quality of the air.
- **Fuel Storage and Handling**: To avoid contamination, degradation, and damage to fuel systems, higher concentrations of biodiesel call for specific storage and handling practices.
- **Standardization and Regulation**: The 40% cap complies with current industry rules, standards, and laws, guaranteeing uniformity and reducing interruptions to the fuel supply chain.

2. Literature review

Demand for energy rises as industrialization and human population grow worldwide [1,2]. To increase the effectiveness of equipment and systems for converting energy by lowering hazardous emissions that happened during the generation of intended energy, experts have been looking for alternative sources of energy during in the past few decades [3–6]. Due to their excellent fuel efficiency, durability, and stability, diesel engines (D_{engine}) play a key part in industrial operations today for the generation of electricity [7]. However, due to environmental issues and severe emission regulations implemented by governments, the possibility of diesel engines being abandoned recently surfaced in several countries [8,9]. The problems can be resolved while still allowing the use of diesel engines by substituting alternative fuel for regular diesel fuel. Biodiesel fuels are among the most widely used alternative fuels for use in diesel engines because they are renewable, biodegradable, and easy to manufacture using a straightforward process [10,11]. Since biodiesel oil from numerous sources or fuel additives to diesel oil are commonly used to fuel diesel engines, studies well about combustion, operation, and exhaust emission aspects of these engines are frequently published in the *scientific* literature [12–17].

The impact of various diesel engine research circumstances on exergy analysis has been the subject of numerous research in the *literature*. Studies on this subject have been conducted since the middle of the 20th century [18]. A thorough computer analysis of energy and exergy performance, confirmed experimentally, was performed by Rakopoulos on D_{engine} functioning with sporadic load circumstances [19]. In another investigation, Giakoumis [20] compared once more energy and exergy analysis by way of a transitory D_{engine} operation using a computational model. At lower temperature combustion D_{engine}, Zheng and Caton presented energy and exergy dispersion for eight operational circumstances made up of four various recirculation rates of exhaust gases and two distinct injector times [18]. In analytical research founded on the second rule of thermodynamics, Caton et al. examined the exergy destruction that occurs throughout the combustion mechanism [21]. Energy and exergy assessments for D_{engine} running on two distinct biodiesels manufactured from methyl ester of soybean oil (SOME) and methyl ester of yellow grease (YGME), as well as blends containing 1:2 by ratio of cetane ingredient by weight with SOME, were examined by Tat [22]. Cetane number and ignition delay were also taken into consideration. In order to investigate the impact of cylinder wall insulating for a turbocharged D_{engine} running under transitory load conditions, as insulators, Giakoumis employed plasma spray zirconia and silicon nitride [23]. According to energy analysis assessments, combustion of a fossil fuel results in the thermal efficiency of one-third of its energy [24]. An engine powered by POME may account about 26% of the energy contained in oil [25]. Similar energy performance values were also obtained from alternative and petroleum diesel fuel [26]. Diesel fuel burned in diesel engines emits more particulate matter than B50 biofuels and pure biodiesel, as shown in previous research [27].

Mohanraju et al. [28] research aims to improve the performance of diesel engines that use common rail direct injection (CRDI) by using industrial leather waste fat biodiesel (ILWFB) instead of industrial diesel waste oil. This is achieved by combining graphene oxide nanoplates (GONPs) and aluminium nitrate (Al (NO3)3) nanoparticles in a ratio of 50 ppm (parts per million) as catalysts to improve the ignition process.

This study discovered that, when Al (NO3)3 nanoparticles and GONPs 50 ppm were added to the ILWFB blend, the pressure within the cylinder rose by 0.463% and 1.5%, and the heat release rate (HRR) improved by 4.19% and 12.04% when compared to the ILWFB blend and diesel under maximum load conditions [28]. In order to create biodiesel for use as fuel in common rail direct injection (CRDI) diesel engines, researcher Ravikumar Jeyabal [29] looked into the transesterification method. Furthermore, Di-tert-butyl peroxide (DTBP) is employed as an ignition booster in order to reduce emissions from exhaust gases. According to the study's findings, CR 19 and IP 500 psi reduced HC and CO emissions by 21.73% and 28.49%, respectively, compared to pure diesel [29]. The research investigation attempts to explore the characteristics of a diesel engine with a dual fuel mode that works on a blend of sapota seed biodiesel (SB) and hydrogen gas. According to this study, introducing hydrogen to SSB resulted in higher BTE, lower emissions, and somewhat higher NOx emissions [30]. Temperature, interaction duration, the ratio of methanol to oil, and catalyst concentration are among the process parameters that are optimized by the outcome surface technique method's central composite rotatable design, or CCRD. The CCRD optimization strategy yielded superior outcomes. The ultimate, optimized outcomes are as follows: 96.69% coconut oil methyl ester ratio, 55°C temperature, 59.2-minute duration, 0.7 catalyst concentration, and 6.4 molar ratio were all recorded [31]. More NOx emissions were lowered by the biodiesel blends than by the Bio-Si nanoparticle mixes. Additionally, while comparing the B50Bio-Si100 mix to plain diesel, the smoke opacity diminished by 31.87%, the hydrocarbon (HC) emissions were reduced by 34.14%, the carbon monoxide (CO) emissions were dropped by 43.97%, and the oxides of nitrogen (NOx) emissions were marginally raised by 4.45%. With the exception of a slight rise in NOx emissions, all of the emissions were found to be lower in all combinations than in neat diesel. Consequently, the ILWFB mix including Bio-Si nanoparticles proved to be a practical substitute for diesel fuel in diesel engines [32].

In order to reduce emissions and improve performance, Vellaiyan et al. [33] suggest a unique method of mixing water and 2-Ethylhexyl nitrate (2-EHN) into Bauhinia racemosa biodiesel (BRD). The optimization findings show that 20.33 percent, 10.26 percent, and 2.05%, respectively, are the ideal concentrations of BRD, water, and 2-EHN in CRD. Comparing WPO to CDF, the emissions differences are 19.2%, 3.7%, and 12.0% greater for NOx, HC, and CO, respectively. Nevertheless, the addition of water results in significant drops in these emissions; for WPO10W, the computed drops are 21.2%, 9.8%, and 22.2% [34]. Significant improvements in efficiency of energy and decreases in emissions were seen through testing with an aqueous ammonia emulsion and a ZnS/Cu nanocomposite in a diesel-biodiesel blend. After thorough examinations of the qualities of the fuel and nanocomposite materials, the best mix compositions were identified [35]. When compared to standard diesel fuel, the fuel combination under investigation shows the potential to reduce the use of fossil fuels by about 37%. It can also reduce the levels of hydrocarbons, carbon monoxide, and nitrogen oxides by 8.1%, 20.2%, and 8.3%, respectively [36].

Blends of biodiesel and diesel have been thoroughly investigated as a potential substitute fuel. Researchers Canakci and Van Gerpen (2001) investigated the process of turning oils and fats high in free fatty acids into biodiesel [37]. Graboski and McCormick (1998) looked into how fuels made from fat and vegetable oil burned in diesel engines [38]. Knothe (2005) investigated how the structure of fatty acid alkyl esters affects the qualities of biodiesel fuel [39]. Antioxidants were optimised by Senthil et al. (2017) for mixtures of biodiesel and diesel. The effects of biodiesel-diesel mixes on engine performance as well as emissions were investigated by Sharma and Singh (2009).

3. Experimental Setup and uncertainty analysis

With the assistance of MOME, tests on SCFS diesel engine were carried out in Engine Research Lab at IET Lucknow, India. Investigations were conducted into the characteristics related to output and emissions. SCFS diesel engine was connected to AC alternator of 230V. Diesel was used to start the engine, and corresponding readings were recorded. Next, several MOME blends were used, and finally, the engine was run on gasoline. Figure 2 displays SCFS diesel engine for an experimental setup. Table 1 provides information on the engine's specifications. SCFS diesel engine of 3.5 Kw was used in this research for testing. The experiment has been conducted at Institute of engineering and technology, Lucknow. Diesel was used to start the engine, then several MOME blends were used to power it. Investigations were conducted into the emission and performance traits. By running the aforementioned engine at full load with diesel oil and B20, the different losses are calculated using energy analysis and the first law of thermodynamics. The available work of D_{engine} is calculated using B20 and diesel as part of an exergy analysis, which also applies the second law of thermodynamics.

Figure 2. An experimental setup.

This study's primary novelty was elucidating the relative impact of each fuel blend on the energy and exergy components. This study adds to our understanding of the sustainability index, energy-exergy analyses, and how test fuels' chemical and physical characteristics impact them. The present study is anticipated to make a significant contribution to the field of internal combustion engines about the impacts of blending Mahua oil methyl ester. Based on that, these results might offer credence to the environmentally sound and sustainable idea of mixing Mahua oil methyl ester fuel for the future widespread usage of diesel engines.

We used root-mean-square (RMS) analysis to do an uncertainty analysis of the outcome measures [40–42].

$$RMS = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}, \tag{1}$$

whereas the standard deviation of the mean was used for the emission parameter uncertainty analysis [40–42].

Table 1. Features of diesel engine.

S.No	Parameters	Features
1	Number of cylinders	Single
2	Manufacturer	Kirloskar
3	Speed	1500 r.p.m
4	Compression ratio	16.5 to 1
5	Cooling medium	Water
6	Bore (D) × stroke (L) (mm)	80 × 110
7	Lubrication	20W40

$$\text{Uncertainty} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}}, \tag{2}$$

where, $n =$ total number of trials, $x =$ observed data, $\bar{x}$mean value of the observed data.

The following formula was used to calculate the overall uncertainty (OU) of the experimental data [40–42]:

$$OU = \sqrt{\text{uncertainty of } \left[\text{BTE}^2 + \text{HC}^2 + \text{BSFC}^2 + \text{NO}_x^2 + \text{CO}^2 + \text{Smoke}^2\right]}. \tag{3}$$

The performance parameters (BTE and BSFC) have an uncertainty of ± 0.85. For HC and NOx, the uncertainty is ± 0.1, whereas the CO value is determined to be ± 0.04.

4. Energy Analysis

To make the computations easier, the following presumptions must be made before using it with the test engine:

- The engine is operating in steady-state conditions.
- The benchmark state is described as $T_0 = 300K$ and $P_0 = 1$Patm and it is presumed that the system is open.
- Ideal gas mixes exist between the combustion air and exhaust gases.
- Incoming and outgoing fluid stream impacts on potential energy (PE) and kinetic energy (KE) are disregarded [22].

The mass balance again for Control volume can be described as:

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}. \tag{4}$$

Equation (5), in a general sense, gives the energy balance equation under conditions of steady state while neglecting KE and PE:

$$\dot{Q} + \dot{W} = \sum \dot{m}_{out} h_{out} - \sum \dot{m}_{in} h_{in}. \tag{5}$$

Equation (6) can be used to express the improved energy balance for the test engine if combustion heat is transported to the atmosphere and the engine produces braking power:

$$\dot{E}_f = \dot{W} + \dot{Q}_{ex} + \dot{Q}_{lost}. \tag{6}$$

The brake power can be described as:

$$\dot{W} = \omega\tau. \tag{7}$$

The combustion air's energy can be disregarded because it is in the same condition as the normative benchmark condition, which is specified as $T_0 = 300K$ and $P_0 = 1$Patm, and as a result, the rate of heat uptake to the control volume is expressed only by using the chemical energy of the fuel.

Fuel energy rate can be represented as:

$$\dot{E}_f = \dot{m}_f H_u. \tag{8}$$

Exhaust energy rate can be represented as:

$$\dot{Q}_{ex} = \dot{m}_{ex} \Delta h. \tag{9}$$

The thermal efficiency is measured as:

$$\eta = \frac{\dot{W}}{\dot{E}_f}. \tag{10}$$

The brake specific fuel consumption can be represented as:

$$BSFC = \frac{\dot{m}_f}{\dot{W}}. \tag{11}$$

4.1. Importances of energy analysis

There are the following importances of energy analysis as shown in Figure 3:

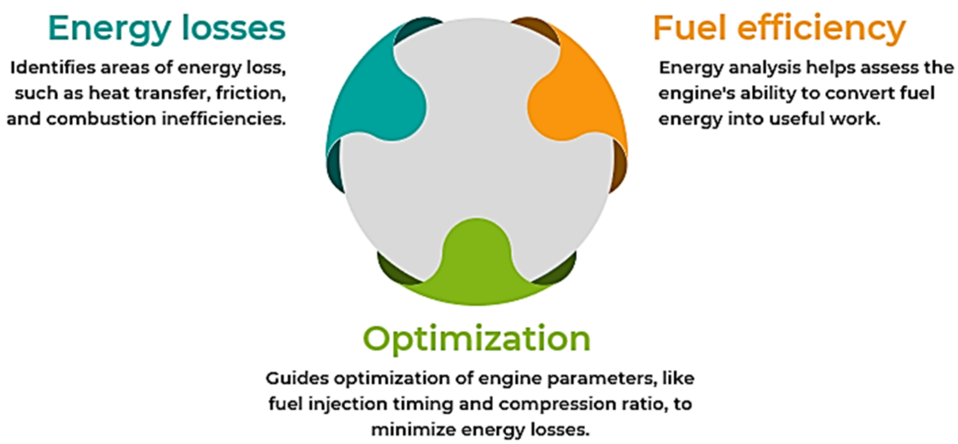

Figure 3. Importances of energy analysis.

5. Exergy Analysis

Exergy has been defined in a wide variety of ways by scientists. Baehr gave the initial definition of it as the portion of energy that is transformed into other forms of energy. Bosnjakovic's definition of exergy, which is more precise and thorough, can be summed up as the most work that can be produced via a process that can be undone, when *system* is in balance with its environment. Exergy is lost due to irreversible processes like combustion, transmission of heat via a restricted temperature differential, fuel/air blending, regulating, resistance, etc. This contrasts with energy, which is retained during all processes.

For exergy analysis, the same presumptions that were made for energy analysis apply. On the basis of these hypotheses, Equation (12) can provide the exergy balance equation in a broad perspective as:

$$\dot{E}_{xQ} + \dot{E}_{xW} - \sum \dot{m}_{out} h_{out} + \sum \dot{m}_{in} h_{in} - \dot{E}_{xdest} = 0. \tag{12}$$

The specific chemical exergy of fuel can be represented as:

$$\varepsilon_f^{ch} = H_u \varphi. \tag{13}$$

Equation (14) can be used to compute the liquid fuel's chemical exergy factor,

$$\varphi = 1.0401 + 0.1728\frac{h}{c} + 0.2169\frac{\alpha}{c}\left[1 - 2.0628\frac{h}{c}\right] + 0.0432\frac{o}{c}. \tag{14}$$

The total work for such engine is equivalent to the exergy transfer rate corresponding to work:

$$\dot{E}_{xW} = \dot{W}. \tag{15}$$

Equation (16) can be used to represent the exhaust exergy that makes up the engine's mass transfer exergy production rates:

$$\dot{E}_{xexh} = \dot{m}_{exh} \times \varepsilon. \tag{16}$$

The following formula represents exhaust exergy per unit mass:

$$\varepsilon = \varepsilon^{tm} + \varepsilon^{ch}, \tag{17}$$

where,

$$\varepsilon^{ch} = \bar{R} T_a \sum_{i=1}^{n} a_i \ln \frac{y_i}{y_i^e}, \tag{18}$$

and

$$\varepsilon^{tm} = \sum_{i=1}^{n} a_i \left[(\bar{h}_i - \bar{h}_{0i}) - T_a(\bar{S}_i - \bar{S}_{0i}) \right]. \tag{19}$$

Equation (20) can be used to calculate the rate at which energy is transferred in relation to heat transfer.

$$\dot{E}_{xQ} = \sum \left(1 - \frac{T_0}{T_{cw}}\right) \dot{Q}_{lost}. \tag{20}$$

The exergy efficiency represented as

$$\eta_{ex} = \frac{\dot{E}_{xW}}{\dot{E}_{xf}}. \tag{21}$$

5.1. Importances of exergy analysis

There are the following importances of exergy analysis as shown in Figure 4:

It is calculated that B_{20} has the following molecular formula. Eighty percent diesel ($C_{12}H_{26}S_{0.0024}$) and twenty percent Mahua biodiesel ($C_{18.63}H_{35.87}O_2$) are used to calculate the number of C, H, O, and S atoms. Table 2 shows fuel properties. Molecular formula for B_{20} is assessed and displayed in Table 3. The mass fraction ratio of diesel and B_{20}'s H, C, and O is determined and displayed in Table 4.

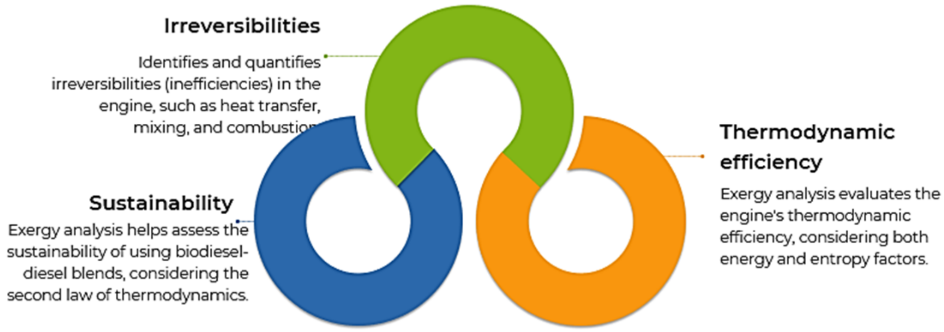

Figure 4. Importances of exergy analysis.

Table 2. Properties of fuel.

S.No	Properties	Unit	Diesel	Mahua oil	MOME
1	Specific gravity	–	0.842	0.904	0.880
2	Carbon residue	%	0.034	0.42	0.2
3	Calorific value	MJ/Kg	45.34	38.86	37.0
4	Flash point	°C	63.0	238	208

Table 3. Molecular formula of B_{20} and diesel.

S.No.	Fuel	Molecular formula
1	B_{20}	$C_{13.32}H_{27.37}O_{0.4}S_{0.00192}$
2	Diesel	$C_{12}H_{26}S_{0.0024}$

Table 4. Mass fraction ratio for B_{20} and diesel.

S.No	Elements	B_{20}	Diesel
1	S/C	0.003	0.00047
2	O/C	0.03	—–
3	H/C	0.17	0.182

6. Exergy Analysis

A driveshaft reciprocating engine's fuel efficiency is measured by BSFC. It is calculated by dividing the amount of fuel consumed every hour by the amount of power generated. The comparative graph of BSFC for various biodiesel blends at various loads is shown in Figure 5. According to the graph, BSFC rises as the amount of biodiesel in blends rises. At minimum load and maximum load, BSFC for B_{20} is raised by 23.21% and 5.52%, respectively. Poor fuel alienation, a reduced calorific value, and increased viscosity are the causes of this rise. As a result, the B_{20} strategy and the diesel are extremely similar at greater loads.

Figure 6 depicts the variation in BTE when using different blends and fuel. Greater viscosity, poor alienation, and poor calorific value were the causes of the decline in BTE with biodiesel blends at high loading. The BTE for B_{20} and B_{30} blends rises with increased load. Among the mixes, B_{20} has the highest maximal microbial thermal efficiency at increasing loading.

Figure 7 illustrates how CO_2 varies in relation to brake power for various MOME blends. Compared to different MOME blends, diesel has a higher carbon dioxide component. As load grows, the CO_2 emission

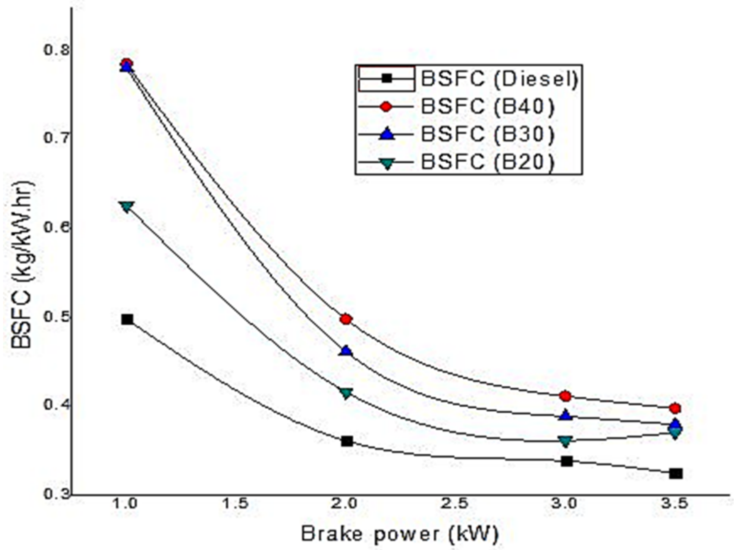

Figure 5. Comparative graph of BSFC for various biodiesel blends at various loads.

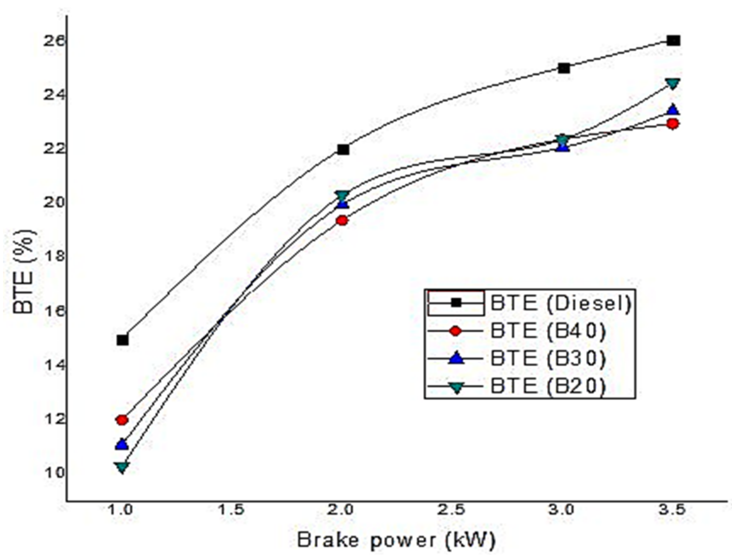

Figure 6. Variation in BTE, using different blends and fuel.

trend is on the rise. This upward tendency can be brought on by increased fuel use as load rises. The blends' emissions are found to be lower than those of diesel.

Figure 8 shows how NOx concentration varies with engine load for different MOME blends. The mixes display an increasing tendency with regard to load when related to diesel. The composition of NOx increases when exhaust gas temperature rises under increasing loads.

For different MOME blends, Figure 9 shows how the concentration of hydrocarbons varies with engine load. The graph shows that diesel has a lower hydrocarbon emission rate than fuel based on Mahua ester. The emission of HC falls off as the blends get stronger. This proves that all of the fuel has been completely burned. Perhaps more oxygen is present in the fuel, which would explain this.

Carbon Monoxide Emission: Carbon monoxide levels as a function of brake force are depicted in Figure 10. According to observations, emissions rise together with the load. All mixes emit carbon

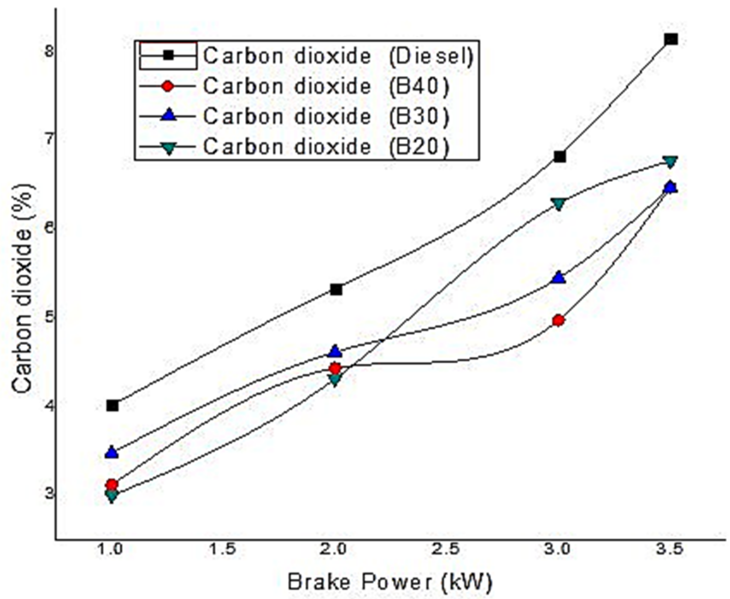

Figure 7. Variation in CO2 with various MOME blends.

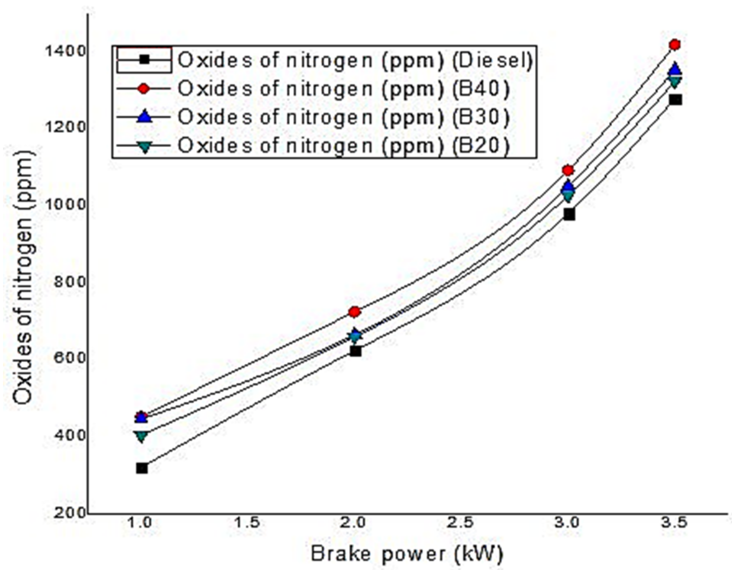

Figure 8. Variation in NOx with various MOME blends.

monoxide in a range that is relatively similar at low and medium loads. In comparison to diesel, blends emit more pollution as the load increases.

It has been determined that B_{20} is the gasoline that I.C. engines respond best to in terms of performance and emission profile. Many researchers proposed that mixtures of biodiesel and conventional diesel oil combined up to 20% be utilized in practically every diesel machine and be acceptable with the preponderance of distribution and storage equipment. In consideration of that one, we think of moving on to the energetic and exergetic study for B_{20} blends and comparing the outcomes with diesel oil.

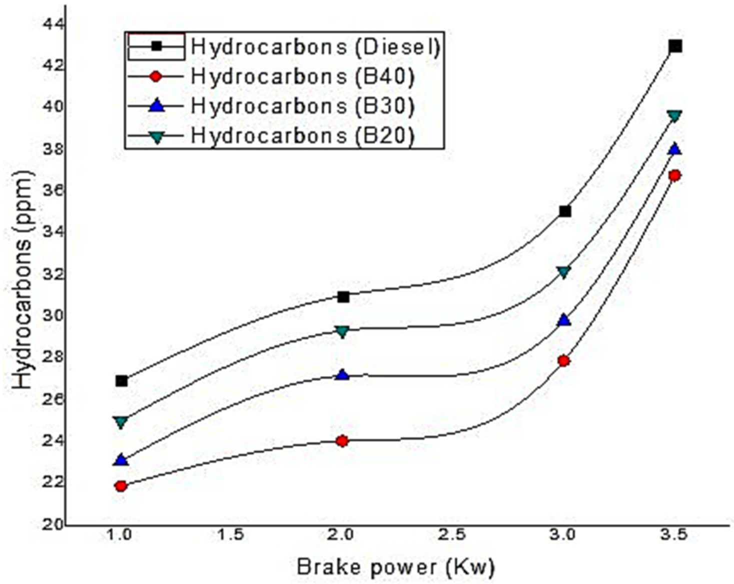

Figure 9. Variation in hydrocarbon emission with various MOME blends.

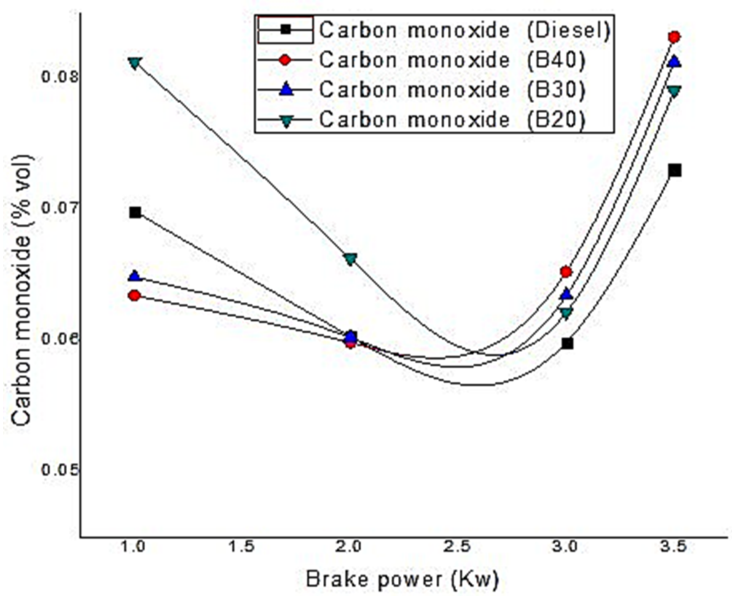

Figure 10. Variation in carbon monoxide emission with various MOME blends.

Table 5. EBS for B_{20} and diesel.

Energy of fuel supplied	Energy expenditure	B_{20} (kW)	Diesel (kW)
B_{20}	Cooling water's ability to carry energy	2.73	2.73
Diesel	Energy used for braking	2.65	2.80
9.10 kW	Inexplicable energy loss	1.37	1.51
9.50 kW	Energy emitted in exhaust gases	2.36	2.64

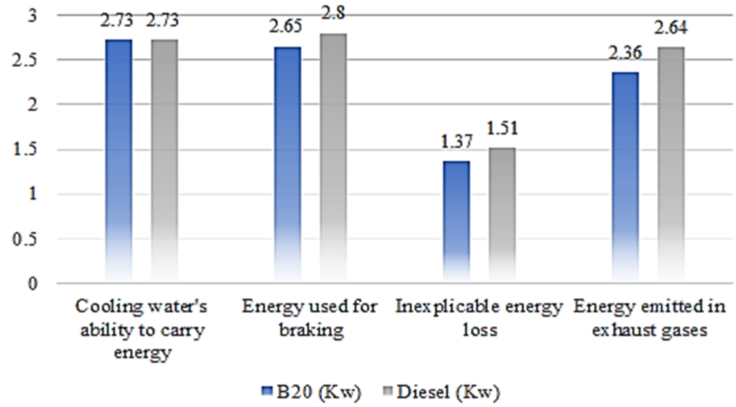

Figure 11. Energy expenditure for B_{20} (9.10 kW) and diesel (9.50 kW).

Energy Analysis

The energy is transmitted and consumed by utilizing diesel and B_{20} is detailed in an energy balance sheet (EBS), which is displayed in Table 5. In order to simplify the analysis, the C_{pw} is assumed to be 4.18 kJ/kg·K, and the specific heat of engine emission is dependent on the heat wasted by exhaust, which is equivalent to the heat obtained by flowing water. Figure 11 depicts the graphical energy dispersion of B_{20} and diesel, respectively.

Exergy Analysis

Table 6 presents distributions of exergy with respect to unit time for B_{20} and diesel, based on the exergy analysis formulas. Figure 12 depicts the graphical exergy dispersion of B_{20} and diesel, respectively.

Table 6. EBS for B_{20} and diesel.

Exergy of fuel supplied	Energy expenditure	B_{20} (kW)	Diesel (kW)
B_{20}	Cooling water's ability to carry exergy	0.06	0.05
Diesel	Exergy used for braking	2.65	2.80
10.10 kW	Destructed exergy	7.26	7.19
10.50 kW	Exergy emitted in exhaust gases	0.25	0.33

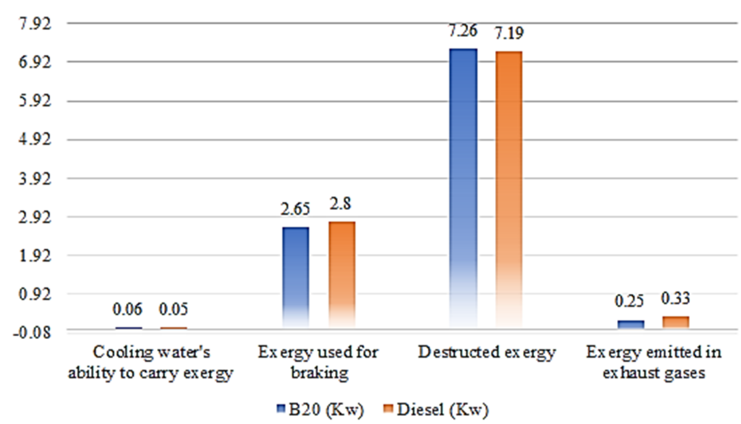

Figure 12. Energy expenditure for B_{20} (10.10 kW) and diesel (10.50 kW).

7. Future research

Potential avenues for future investigation concerning energy and exergy analysis in diesel engines using blends of biodiesel and diesel:

- *Advanced fuel characterisation*: Examine how the chemical makeup and physical characteristics of biodiesel affect energy and performance efficiency.
- *Multi-dimensional modelling*: Create detailed models that take into account variables like heat transmission, combustion, and fuel spray in order to replicate the energy and exhaust fluxes in diesel engines.
- *Optimisation of engine parameters*: Engine design and operating factors, such as fuel injection time, compression ratio, and piston bowl shape, can be improved by using energy and exergy analysis.
- *Alternative biodiesel sources*: Examine the energy and physical capabilities of diesel engines that run on biodiesel derived from unconventional sources, such as algae or farm waste.
- *Hybrid energy systems*: Examine the environmental and energy advantages of combining diesel engines with electric or solar-powered motors and other alternative energy sources.
- *Exergy-based emissions analysis*: Build techniques based on exergy to evaluate and reduce emissions from diesel engines that run on mixtures of biodiesel and diesel.
- *Applications of machine learning*: Utilise machine learning algorithms to maximise the energy and exhaust efficiency of diesel engines by taking into account the fuel's characteristics and the operating environment.

8. Conclusion

According to energy analysis, diesel had a higher fuel intake of energy than B_{20}, as well as higher energy for BP, energy flowing through exhaust emissions, and unaccounted wastage. Diesel had an energy efficiency of 27.22%, but it also had total losses of 71.95%. Compared to diesel, B_{20} demonstrated greater efficiency and fewer losses. Because diesel has a higher heating value than B_{20}, its fuel energy intake is 5.99% higher. Diesel and B_{20} have respective energy efficiencies of 30.37% and 29.12%.

The following conclusions have been reached as a result of this observation:

- At greater loads, the emission rate for B_{20} is equivalent to that produced by diesel.
- B_{20} fuel exhibits nearly identical *exergetic* and energetic calculated results to diesel.
- Diesel and B_{20} had energy efficiencies of 30.37% and 29.12%, respectively.
- Diesel has a 27.22% energy efficiency rating while overall losses reached 71.95%.
- In comparison to diesel, the BSFC for B_{20} is somewhat higher at maximum load, increasing by 5.52%.
- The blend B_{20} has been found to possess the highest BTE at higher loads when compared to blends that are similar to diesel.

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