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Research Article

Impact of additives on combustion behaviour and performance of a diesel engine powered by diesel-CIME blend: A comparative analysis

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ABSTRACT

This study evaluates the effects of blends containing diesel-Calophyllum Inophyllum Methyl Ester (CIME) with additives on the combustion and performance parameters of a diesel engine. In this investigation, the additives identified were propanol and Curcuma longa leaf oil. The engine characteristics were investigated by using 6%, 12%, and 18% (concentration by volume) of propanol and Curcuma longa leaf oil separately with a diesel-CIME blend (CI20). In comparison to diesel, propanol blends showed a lower heat release rate and a lower peak cylinder pressure. An increased proportion of propanol was found to cause significant engine knock at higher compression ratios, and the engine was unable to operate at higher loads while using CI20P18. The propanol blends reported comparable efficiencies compared to diesel. The average BTE of blend CI20P12 was 1.6% greater than that of diesel. The SFCs were seen to be higher for all blends when compared to diesel. 12.8% and 13.9% more average SFCs were recorded for the blends CI20P6 and CI20P12, respectively, than for diesel. In comparison to diesel and CI20, the Curcuma longa leaf oil blended modified blends had lower cylinder pressure, heat release rate, and mean gas temperature, while these modified blends had lower specific fuel consumption than the CI20 blend. The primary aim of this study is to investigate the potential for Calophyllum inophyllum oil, propanol and oil from the rising agricultural waste of Curcuma longa leaves. Experimental evaluation revealed that methyl ester, propanol, and Curcuma longa leaf oil could be effectively used as partial substitutes for diesel. The results of the artificial neural network (ANN) demonstrated a significant connection between the experimental and predicted values for the engine performance parameters.

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INTRODUCTION

Because of the global consumption of petroleum reserves, the importance of renewable alternative fuels in transportation, industry, electricity, and agriculture is steadily increasing [1]. Several researchers focused on producing unconventional fuels that are sustainable, economically viable, and simple to process due to the energy and environmental crises [2]. Biofuels are biodegradable, non-toxic, exhibit similar properties to petroleum fuels, and can be blended with petroleum fuels [3]. Adding biofuels to the fuel blend also has the significant advantage of reducing particulate matter emissions from diesel engines. [4]. Oil from several feedstocks has been used directly in diesel engines using techniques such as pyrolysis, dilution, and micro-emulsion. However, due to its highly viscous nature and low auto ignition quality, for short-term applications, these techniques work well as a partial substitute for diesel. The free fatty acid content can also cause numerous operational problems in diesel engines. These properties of oil can be improved by most commercial techniques of transesterification, converting it into biodiesel or methyl ester. The performance parameters of a diesel engine using methyl ester were examined in a number of studies. According to these studies, using straight methyl ester or diesel-methyl ester blends in diesel engines results in higher fuel usage. This is a result of methyl ester having higher densities and viscosities than regular diesel and having heating values that are relatively lower. Conversely, when methyl ester-diesel blends are used, diesel engine emissions usually become lower. Because methyl ester's inherent oxygen content improves combustion, resulting in lower emissions of CO, HC, and PM. Also, several studies have demonstrated that NOx emissions rise. The explanation for this rise is the inherent oxygen in methyl ester, which improves combustion and raises the temperature within the cylinder, allowing nitrogen to react with oxygen [5-6]. Research on methyl ester's impact on CO_2 emissions has yielded conflicting results. While some have concluded that methyl ester lowers emissions because of its low carbon-to-hydrogen ratio, others have concluded that because of its efficient combustion, emissions either increase or remain unchanged. However, taking into account the CO_2 life cycle circulation, methyl ester's CO_2 emissions are significantly lower [7]. Many studies have been conducted where the emphasis has been on diesel-methyl ester blends with specific additives. The various additives include lower-alcohol additives, higher-alcohol additives, and nanoadditives. Alcohol can potentially be combined with diesel and methyl ester more effectively as its carbon content rises [8]. Implementing alcohol as an additive to methyl ester blends is a promising process for increasing the use of both methyl ester and alcohol. However, many investigators found that low-carbon alcohols are not suitable due to their low heating value, poor antiknock qualities, and long ignition delay. H. Aydin et al. [9] studied the use of higher percentages of sunflower oil methyl ester with ethanol and reported higher torque at a lower average SFC with the methyl ester-ethanol blend. The CO_2 decrease with methyl ester-diesel was about 67%, while CO and SO2 were reduced with methyl ester-diesel and methyl ester-ethanol blends. This study also reported decreased NOx emissions with the methyl ester-diesel blend. B. Prabakaran et al. [10] investigated the engine characteristics with cottonseed oil methyl ester and anhydrous ethanol at 50%, 30%, and 10% (by volume). This study reported a thermal efficiency increase of about 8% with 50% ethanol. Also, the maximum pressure and heat release increased by 17% and 2.5 times with 50% ethanol. The HC, CO, and NOx emissions were 57%, 66%, and 29% less compared to diesel, respectively. L. Zhu et al. [11] investigated how diesel engine particulate emissions were affected by blends of methanol and methyl ester. The experimentation was carried out at different loads with diesel, methyl ester, and blends. Furthermore, increased mass fuel combustion was observed during the premixed combustion mode. The PM concentration decreased owing to the higher oxygen percent of the blends. N. Yilmaz et al. [12] studied the performance of the engine using 15% ethanol and 15% methanol separately with methyl ester. This study concluded that ethanol blending reduces the SFC as compared to methanol blending, as methanol has a greater heat of vaporization. Both the alcohols increased HC and CO emissions, but overall, methanol resulted in higher emissions. Lowered NOx emissions were reported with both alcohols, with no significant difference. Yilmaz N. et al. [13] used 5%, 10%, and 20% of pentanol in diesel-waste oil methyl ester. This study reported that pentanol can be safely used with diesel. With the use of pentanol, the SFC increased within the ranges of 5.27% and 8.61%, but the BTE decreased by a maximum of 5.33%. Also, the higher oxygen content showed higher exhaust temperatures. The latent heat of evaporation of pentanol caused a decrease in combustion efficiency as well as an increase in HC and CO. The maximum increase was 29.34% and 116.01% with 20% pentanol as compared to the diesel-methyl ester blend. The oxygen in pentanol increased NOx compared to diesel-methyl ester blends and regular diesel. While studying the emissions from n-pentanol/Fischer-Tropsch diesel fuelled diesel engine, with varying load and speed conditions, Ye L. et al. [14] reported lower HC, CO, NOX, and soot with this diesel than regular diesel. With n-pentanol, HC and CO increased, whereas NOX and soot decreased. Fischer–Tropsch diesel particles have a tighter arrangement than diesel particles. With the addition of n-pentanol, this effect becomes even more prominent. The maximum degree of graphitization is found in Fischer-Tropsch diesel, which decreases with the addition of n-pentanol. Rangabashiam D. et al. [15] looked into the effects of two oxygenated additives, dimethyl-carbonate and pentanol, on methyl ester/diesel blend ignition patterns in a diesel engine. At a 10% volume ratio, dimethyl-carbonate and pentanol were blended separately with blends of neem-methyl ester and diesel. Blending dimethyl carbonate and pentanol reduced SFC by 0.4 and 0.5 g/kW, respectively, while increasing BTE by 0.3 and 0.6%. At all loads, adding 10% volume of pentanol and dimethyl carbonate reduced CO emissions by 4.9% and 7.4%, respectively. HC emissions were also lowered by 3.1 and 4.7%, respectively. The peak pressure of the base fuel is enhanced by 2.3 and

3.1 bar, respectively, by adding dimethyl carbonate and pentanol. Due to its increased qualities, HRR was also improved. The effect of ethanol and isopropanol additions (15%) in diesel was investigated by Alptekin E. [16]. According to the findings, adding ethanol and isopropanol increased the SFC by 6.2% and 5.7%, respectively. Also, the cylinder pressure was higher with additives. The addition of alcohol increased both HC and CO emissions by 6% and 4.6%, respectively. Alcohol was also found to increase NOx levels by 7.1 and 9.4%, respectively. De Poures M.V. et al. [17] conducted a similar study using 1-hexanol at 10%, 20%, and 30% with diesel. Injection timings were set at 21o, 23o, and 25o CA bTDC, with EGR of 10%, 20%, and 30%, respectively. The results show that adding 1-hexanol improves premixed combustion and increases the ignition delay. It was the longest with the 30% 1-hexanol injection at 25o CA bTDC with 30% EGR. This condition also helped to lower smoke density by 35.9%; however, it also increased NOx and HC levels. S. Sivalakshmi et al. [18] used diethyl ether (5%, 10%, and 15% by volume) with methyl ester to investigate the effects on diesel engine characteristics. Better peak pressure with the improved BTE and SFC was noted with the 5% additive. With a reduction in CO, increased NOx was reported with a 5% additive. HC emissions were found to be increased for all blends compared to neat methyl ester. This study suggested a 5% addition of diethyl ether to methyl ester. With EGR (0%, 10%, and 20%) and ethyl hexyl nitrate additive (1% by volume) in diesel-methyl ester blends. Venkateswarlu K. et al. [19] worked on NOx reduction. The EGR increased BTE with a decrease in SFC and EGT. CO and HC emissions were found to be increased with EGR, with a decrease in NOx. This study reported that 20% EGR and methyl ester blend B40 with ethyl hexyl nitrate were the preferred combinations for a greater reduction in NOx. Imdadul H.K. et al. [20] worked with the 2-ethylhexyl nitrate additive in diesel-palm methyl ester-pentanol blends. The methyl ester was used in 10% and 20% concentrations, with 5% and 10% pentanol. The additive was used at a proportion of 1000 ppm and 2000 ppm. In addition to evaluating the thermal stability of the blends, performance and emission analyses were also carried out. As ethyl hexyl nitrate is a cetane improver, the blends resulted in an increased cetane number by 6.06% and 14.67% with 1000 ppm and 2000 ppm in the blends, respectively. The alcohol-methyl ester blends were found to be more thermally stable than methyl ester. With ethyl hexyl nitrate, the BTE and SFC were found to be improved. Also, the ternary blends resulted in improved NOx emissions with an increase in CO and HC emissions. A potentially helpful approach for enhancing engine characteristics is the use of nanoparticles in fuel blends. Different kinds of nanoparticles, which are added to fuel mixes, include metal-based, metal oxide-based, and carbonaceous-based particles. Adding metal oxide-based nanoparticles to methyl ester improves the properties of the fuel. There is only one drawback to adding nanoparticles to methyl ester: viscosity rises. Methyl ester burns cleaner when metal oxide nanoparticles are added because the metal oxides enrich the nanoparticles with oxygen atoms [21].

The literature stated mostly focuses on examining different methyl esters, either with or without additives, to observe how they affect the performance and emission characteristics of diesel engines. But investigating the impact on the combustion parameters is also essential. Therefore, this study compares the effects of diesel-methyl ester-additive blends mainly on the combustion behaviour and performance characteristics of a diesel engine. The additives selected for this investigation were comparatively less researched; the first additive was propanol, and the second additive was the oil derived from the increasing agricultural waste of Curcuma longa leaves. The primary goal of this investigation was to explore the potential for propanol, Calophyllum inophyllum oil, and oil derived from Curcuma longa leaves. This study has particular relevance to the region of India, where potential exists for both Calophyllum inophyllum oil and Curcuma longa leaf oil. Thus, this study investigates the suitability of Calophyllum inophyllum methyl ester and Curcuma longa leaf oil as renewable and green fuels for diesel engines in order to increase the variety of alternative fuels.

MATERIALS AND METHODS

Infrared (IR) Spectroscopy of Curcuma Longa Leaf Oil

The technique of infrared spectroscopy (IR) detects energy in the electromagnetic radiation spectrum at wavelengths shorter than radio waves but longer than visible light. Mid-IR contributes significantly to the structure information of functional groups [22].

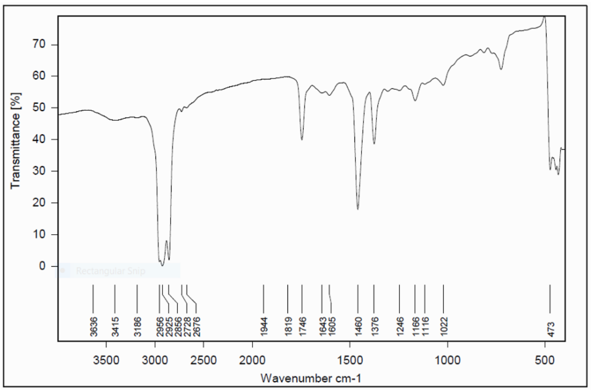

Figure 1. IR spectrum of Curcuma longa leaf oil

For the current study, the IR for Curcuma longa leaf oil was done. The graph of transmittance versus the wave number is presented in Fig. 1. It clearly shows the ester and carbonyl groups between wave numbers 1746 cm-1 and 1819 cm-1.

Fuel Sample Preparation and Characterization

The oil extracted from Calophyllum inophyllum was transesterified to yield methyl ester. To minimize the amount of free fatty acid in the raw oil, acid esterification was used in the first stage. The ideal reaction conditions were methanol (13 wt%), sulfuric acid (0.7 wt%), 90 minutes, 57 °C, and 650 rpm. This oil was used in a next stage base-catalyzed transesterification with ideal conditions of methanol (13 wt%), potassium hydroxide (0.7wt %), 90 min., 65 oC, and

500 rpm. After a 10-hour settling time, the impure methyl ester was collected and washed in hot distilled water before being dehydrated. The methyl ester was then mixed with diesel, propanol, and Curcuma longa leaf oil. The methyl ester percentage in the diesel was fixed with the Taguchi optimization and Taguchi-Grey relational optimization studies prior to this study. Also, as per ASTM D7467, methyl esters can be blended with diesel in amounts ranging from 6% to 20%, providing a good balance of cost, efficiency, and emissions [23]. The additive percentage was decided by studying the available literature. The concentration below 20% of the additives is recommended by most of the studies [24-25]. The blends were made by varying the volume proportions of propanol and Curcuma longa leaf oil (6%, 12%, and 18%) and methyl ester (20%) in diesel, designated as CI20P6, CI20P12, CI20P18, CI20CL6, CI20CL12, and CI20CL18.

Engine Tests

A single-cylinder, four-stroke diesel engine was used for the tests. The setup was equipped with an eddy current dynamometer. For the exhaust temperature measurement, K-type thermocouples were used. Table 1 shows engine specifications in detail, while Fig. 2 shows the schematic of the experimental set-up. Experiments were carried out at 1500 rpm, and the injection timing was 23 obTDC. The compression ratios were 14:1, 16:1, and 18:1, and the engine was loaded at intervals of 25%. In the initial testing, inophyllum methyl ester blends were used. CI05, CI10, CI15, CI20, CI25, and CI30 were the blends that were used. CI20 was shown to be the most feasible blend. Further research added 6%, 12%, and 18% (by volume) of propanol and Curcuma longa leaf oil to CI20, resulting in CI20P6, CI20P12, CI20P18, CI20CL6, CI-20CL12, and CI20CL18.

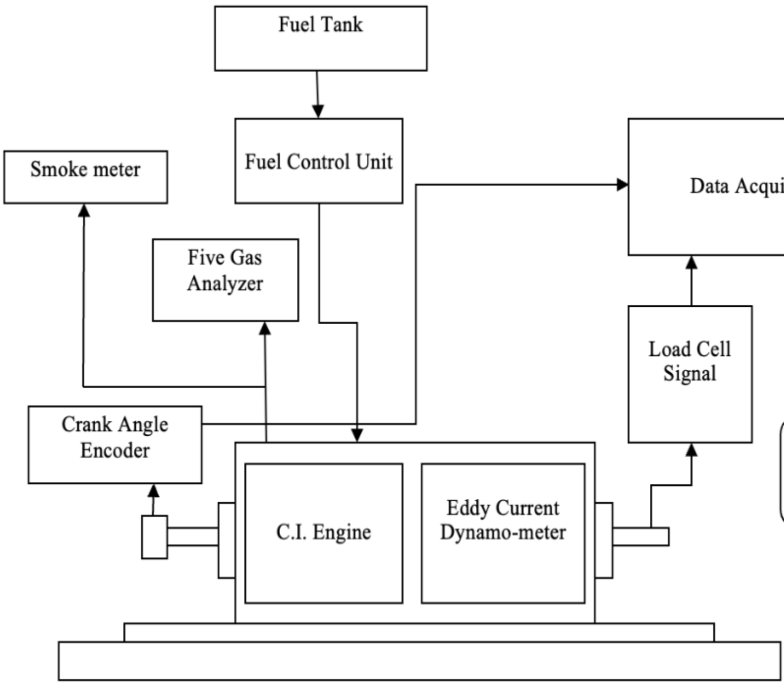

Figure 2. Schematic of experimental engine set up

Table 1. Engine specifications

Name of the Description	Details
Name	Kirloskar oil engine
Model	240PE, Single cylinder Four stroke Research Engine
Bore	87.5 mm
Stroke	110 mm
Swept Volume	661cm3
r/min	1500
Brake Horse Power	3.5 kW
Compression Ratio	12:1 – 18:1
Injection Variation	0-25 deg bTDC
Nozzle Operating Pressure	230 bar

Experiments were first performed with diesel to produce the baseline results. After recording these results, tests were carried out using CI20, CI20P6, CI20P12, CI20P18, CI20CL6, CI20CL12, and CI20CL18 blends. All the tests were conducted in steady-state settings to assure accuracy. Each test was done three times, and the average results at CR 18 and for the maximum loading condition are discussed for the combustion parameters, while the performance parameters are compared for the varying loading condition.

RESULTS AND DİSCUSSİON

Combustion Parameters

Cylinder Pressure: A clearer understanding of combustion activity is provided by the variation in gas pressure, which is dependent upon the fuel present during the uncontrolled combustion stage. [26-27]. The delayed combustion of diesel compared to methyl ester is due to the lower cetane number. The high cetane number of methyl ester accelerates the formation of ignition points [28]. From Fig. 3, it is noted that the cylinder pressure peaked between 6-9o aTDC for all test fuels. CI20 had the highest cylinder pressure of 62.50 bar at 7o aTDC, whereas diesel had 63.2 bar at 6o aTDC. In comparison to diesel, the high atomic weight species of CIME resulted in weak atomization, which reduced the mass of fuel combusted in the premixed combustion process and lower cylinder pressure. The pressure was reduced when propanol was added to CI20. At 8o aTDC, 6% propanol blending produced a peak pressure of 60.7 bar, whereas 12% blending produced a peak pressure of 57.7 bar. With the Curcuma longa leaf oil additive, it has been observed that premixed combustion takes most of the vaporized fuel.

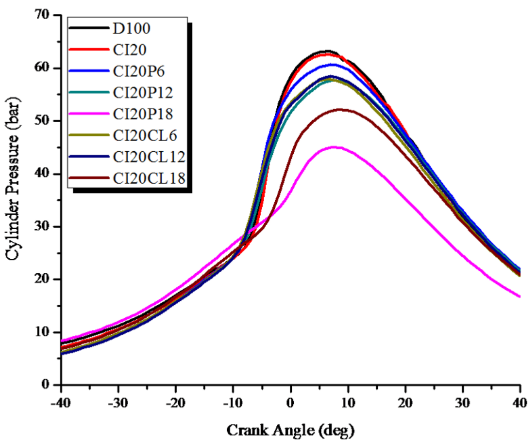

Figure 3. Cylinder pressure values related to crank angle

The variation in peak pressure was the same as diesel for all other blends, with an increasing additive percentage. 52.11 bar, 58.04 bar, and 57.92 bar were the pressures for CI20CL6, CI20CL12, and CI20CL18, respectively. Some studies reported higher in-cylinder pressures for methyl ester blends with high blending ratios owing to the higher cetane number of methyl ester, as the higher cetane number reduces ignition delay and gives an earlier start of combustion.

Heat Release Rate: The heat released in premixed combustion is determined by the heating value, ignition delay, and rate of air-fuel mixing [29]. The heat release analysis also reveals the design of the cylinder, fuel, injection system, and operating conditions, as well as their impact on combustion [30]. The experimentation was done with 23o bTDC injection timing. The heat release rate was negative past the commencement of premixed combustion in all of the samples, which followed the same pattern. This is the result of the absorption of latent heat from the surroundings. The spontaneous ignition of fuel increases the heat release rapidly. The change from a negative to a positive sign on the heat release rate occurs later in the case of diesel than in the case of methyl ester blend and additive blends. When compared to CI20 and other fuel samples, it has been observed from Fig. 4 that diesel combustion gives more heat release due to its higher heating value and longer ignition delay, which was found to be 56.66 J/deg. Due to its greater cetane number, CI20 began to burn slightly earlier. Because of the higher latent heat of vaporisation of propanol, the in-cylinder temperature was reduced during atomization, and combustion took place in a lower temperature environment. Therefore, the propanol-added blends had significantly lowered HRR.

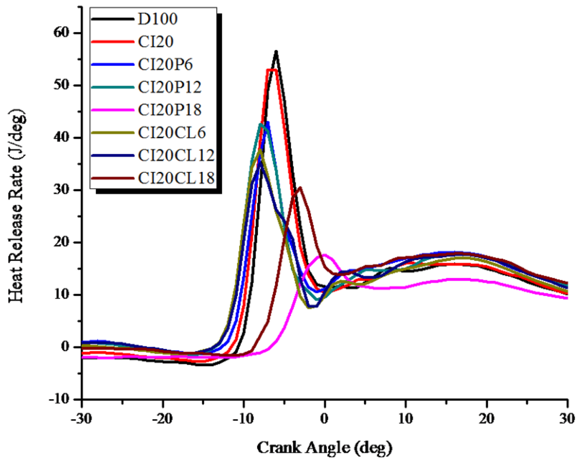

Figure 4. Heat release rate values related to crank angle

Owing to its good antiknock qualities, the methyl ester fuel starts combustion earlier than diesel. The addition of Curcuma longa leaf oil to diesel-methyl ester blends resulted in a comparatively lower heat release due to its lower heating value.

Cumulative Heat Release Rate and Mean Gas Temperature: It is the integration of the heat release rate that represents the total released combustion energy. Because of the higher heat of evaporation, the cumulative heat release rate of CI20 was more negative in stage one, as per Fig. 5. In the second and third stages, because of the higher burning rate aided by oxygen, CI20 surpasses D100. Even with the additives, the same trend has been observed. Since D100 has a higher heating value than all other blends, it has a higher total amount of released energy. The mean gas temperature shows the effectiveness of the combustion.

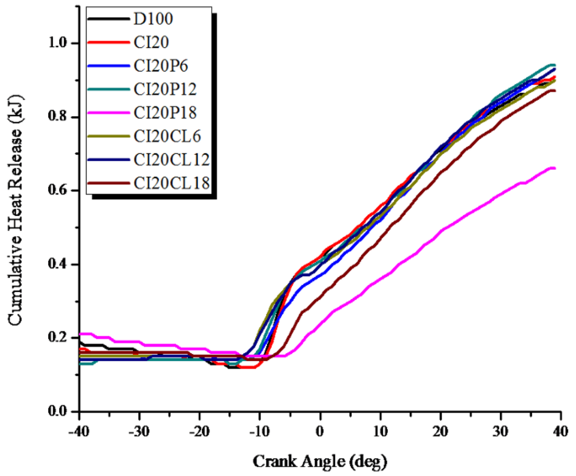

Figure 5. Ccumulative heat release values related to crank angle

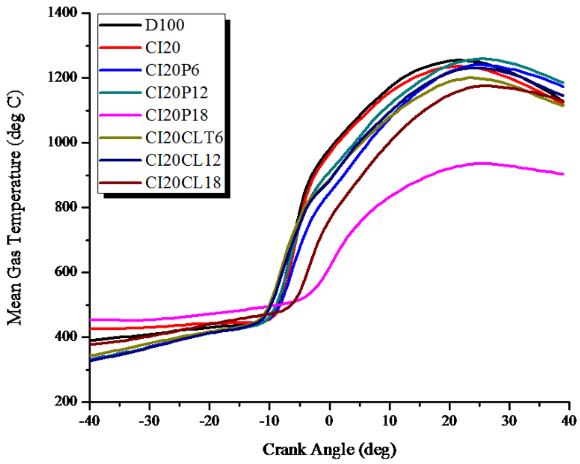

Figure 6. Mean gas temperature values related to crank angle

Cylinder temperatures against crank angle are depicted in Fig. 6. One can observe that for the CI20 and more so for the propanol and Curcuma longa leaf oil blends with respect to diesel, the temperatures were lower up to around their maximum values and appeared delayed, while later on during expansion, they seemed to recover. The maximum value of this temperature was achieved with methyl ester and additives at different crank angles. The highest temperature observed with D100 was 1254.5 oC at 22o aTDC, while with CI20 it was 1236 oC. The CI20P6 and CI20P12 blends reported 1241 oC and 1258 oC at 25o aTDC, respectively, but with 18% propanol, knocking was observed and the engine could not run at higher load conditions. The Curcuma longa leaf oil decreased this temperature, and the lowest temperature noted with an 18% addition was 1175 oC.

Mass Fraction Burned: How much energy is transformed throughout the combustion cycle at a certain crank angle is indicated by the mass fraction burnt. It is affected by the engine geometry, air-fuel ratio, ignition angle, residual mass, and so on. Also, the concentration of methyl ester affects the combustion rate and therefore the mean gas temperature, owing to poor atomization and poor spray characteristics. At a lower compression ratio, combustion began closer to the top dead centre. For higher compression ratios, it began a few degrees earlier. This could be due to an increased cylinder temperature.

From Fig. 7, it can be observed that the start of combustion for all blends was between 7o and 12o bTDC. For D100 and CI20, the maximum mass fraction burned was observed at 27o aTDC. With propanol addition, the maximum value of mass fraction burned was noted at 35o aTDC, particularly with the CI20P12 blend, while with CI20CL18 it was at 40 oaTDC. The combustion duration with additive blends was longer than diesel due to the higher volume of fuel supplied. Another factor is the decreased heating value and somewhat higher viscosity of the fuel, which could have resulted in poor mixture formation when compared to diesel.

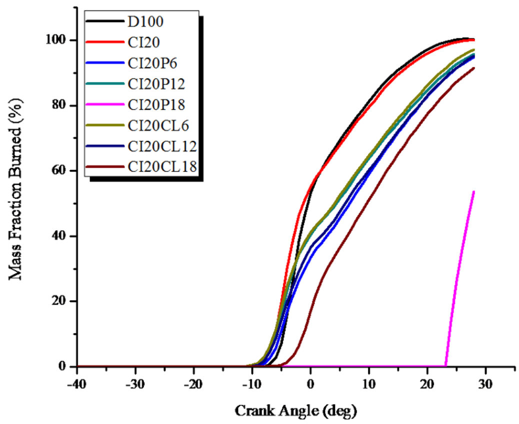

Figure 7. Mass fraction burned values related to crank angle

Performance Parameters

Brake Thermal Efficiency (BTE): BTE is affected by the viscosity, heating value, cetane number, and oxygen content of the fuel. It is the amount of energy recovered from burned fuel at the output [31]. Fig. 8 depicts the effect of various blends on BTE. Methyl ester in a higher percentage in the blends results in decreased efficiency as compared to diesel. It is due to poor volatility, poor atomization, and poor spray characteristics. The BTE of diesel was better compared with the CI20 blend.

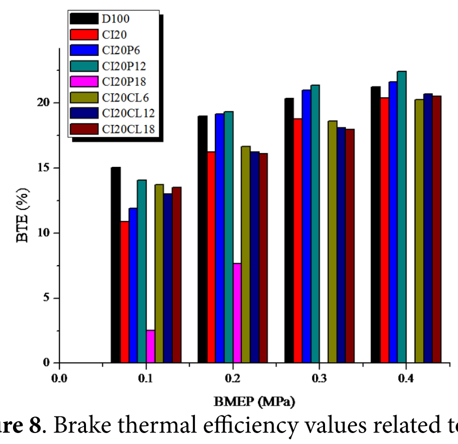

Figure 8. Brake thermal efficiency values related to BMEP

The modified blends with propanol resulted in lower BTE than base fuel at higher compression ratios and lower load conditions, but at higher loads, the CI20P6 and CI20P12 reported slightly higher BTE. At full load condition on the engine, D100 gave 21.5%, while CI20P12 reported 22.4% BTE. While analyzing engine characteristics with diesel-methyl ester-higher alcohol, Ramakrishnan et al. [32] reported a similar trend. Additionally, according to the research by S. Ravi et al. [33], the addition of propanol to waste plastic oil increased BTE because the fuel blend's density was reduced, which enhanced the fuel atomization properties. Among ternary blends of Curcuma longa leaf oil, the BTE values were very close to each other and lower than those of diesel. At full load, the blends CI20CL6, CI20CL12, and CI20CL18 had 20.24%, 20.7%, and 20.52% BTE, respectively.

Specific Fuel Consumption (SFC): The SFC results relative to engine loads are depicted in Fig. 9. At all CRs, SFC decreased with increasing load for all tested blends. One potential reason for this reduction is that brake power increases at a higher percentage with load than fuel consumption.

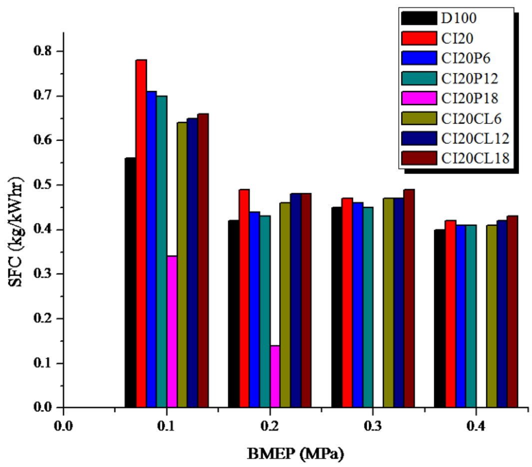

Figure 9. Sspecific fuel consumption values related to BMEP

As the percentage of additives in the blends was kept very close to each other, the variation in the specific fuel consumption has shown very little variation at all compression ratios. The CI20 blend has an average 17.27% higher SFC than diesel. The increase in SFC with CI20P6 and CI20P18 when compared to diesel was 12.8% and 13.9%, respectively. Since the blends have a lower heating value, their fuel consumption was higher than diesel. The Curcuma longa leaf oil also increased the SFC, and this increase in SFC of CI20CL6, CI20CL12, and CI20CL18 compared to diesel was 3% to 5% on average. The SFC may have increased compared to CI20 owing to a slight reduction in the calorific value of the modified blends, but the better atomization and improved density and viscosity helped to decrease it. Yoshimoto et al. [34] reported similar outcomes for butyl alcohol and biodiesel.

Artificial Neural Networks (ANN) Modeling for Performance Parameters

The data obtained from the investigation with the diesel-methyl ester-propanol and diesel-methyl ester-Curcuma longa leaf oil additives was used to create the neural network model for predicting only the performance parameters of the engine. Figs. 10 and 11 show the closeness between the input and target values using the regression coefficient metric of BTE and SFC.

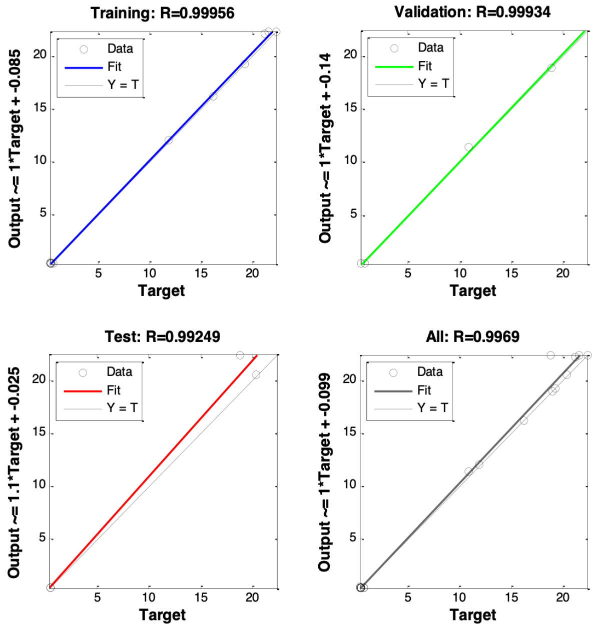

Figure 10. Closeness measure between the input and target values using the regression coefficient metric of BTE and SFC for the diesel-CIME-propanol blend

The ANN modeling was performed using the MATLAB environment. Out of many types, for creating the network, the feed-forward-back propagation method was selected. As per the literature survey, it produces better results. The training function used was TRAINGDM, i.e., gradient descent with momentum weight and biased function [35-36]. The performance function used was the mean squared error. The number of layers used was 2, with the number of neurons being 10. The transfer function used was a tangent sigmoidal function, which provides better results. While training the network, initially in the training parameters, the 1000 epochs were considered with a maximum failure of 6, and if the straight line is not fitted, the maximum failure is changed to value 1000. The learning rate and the momentum coefficient are taken as 0.01 and 0.9, respectively. It is understood from the figures that one can predict engine performance with correlation coefficients of 0.9969 for the propanol additive and 0.99042 for the Curcuma longa leaf oil additive, respectively. It is evident that the model was successful in predicting engine performance since there is a clear correlation between the measured values obtained from the experimental testing and the projected values made by the ANN model.

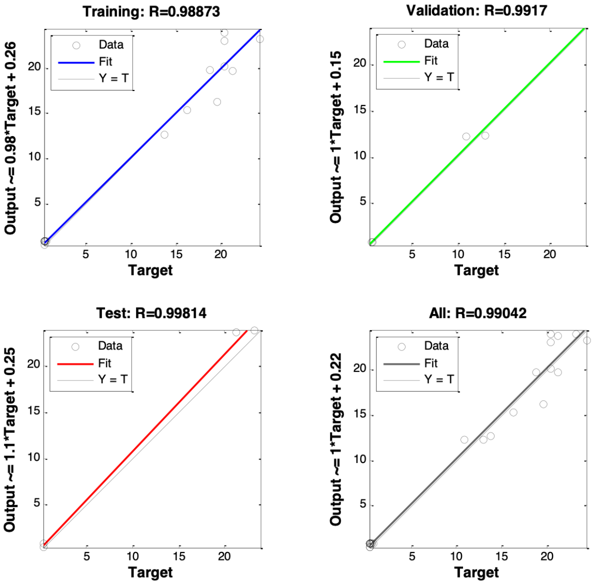

Figure 11. Closeness measure between the input and target values using the regression coefficient metric of BTE and SFC for the diesel-CIME-Curcuma longa leaf oil blend

The results of this investigation showed that while the lower calorific value of methyl ester and additives prevents improvement of the BSFC, it is possible to enhance the combustion characteristics. It is recommended to combine appropriate additives to improve the cetane number in order to optimize the overall engine performance. A few of the characteristics of Curcuma longa leaf oil, the second addition employed in this study, were examined. It is necessary to examine properties such as latent heat of vaporization, cetane number, cold filter plugging point, oxidation stability, and storage stability. The analysis of carbon deposits on pistons, valves, and injectors, as well as the examination of crankcase lubricating oil to determine any degradation or contamination brought on by blow-by leakage, can all be explored in future research.

CONCLUSION

The experimentation resulted in following conclusions.

1. Diesel had a maximum cylinder pressure of 63.2 bar, whereas diesel-methyl ester-propanol blends had a maximum cylinder pressure of 60.7 bar. With Curcuma longa leaf oil blended modified blends, there was a reduction in peak cylinder pressure. The cylinder pressure with diesel was the highest among all.

2. With diesel, the maximum heat release rate was 56.66 J/deg. All modified blends resulted in less heat release. The peak rates reported for CI20P6 and CI20P12 were 43.08 J/deg and 42.62 J/deg, respectively, while Curcuma longa leaf oil blends reported a peak heat release of 38 J/deg.

3. Modified blends with propanol provide higher combustion efficiency. The average BTE with the CI20P12 blend was the highest at CR 18, which was 1.6 % higher than diesel BTE. But with an increase in the percentage of Curcuma longa leaf oil in the diesel-methyl ester blend, BTE decreased.

4. With modified blends of propanol, SFC remained higher than diesel but decreased when compared to the CI20 blend. This increase was 12.8% and 13.9% with CI20P6 and CI20P18, respectively. With Curcuma longa leaf oil, there was a marginal increase in SFC. The SFC value of the modified fuel blends was lower than that of the CI20 fuel blend as well. Among the modified blends, the CI20CL6 blend reported the lowest SFC value.

5. The outcome demonstrated that the feed-forward-back propagation training method was appropriate for forecasting the brake thermal efficiency along with specific fuel consumption for various fuel blend ratios. Additionally, it was noted that for these parameters, R values were close to 1.

6. Analysis of the experimental data by the ANN showed that there was a good correlation between the measured data and the predicted data resulted from the ANN.

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DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

USE OF AI FOR WRITING ASSISTANCE

Not declared.

ETHICS

There are no ethical issues with the publication of this manuscript.

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NOMENCLATURE

ANN	Artificial Neural Network	CO	Carbon Monoxide
ASTM	American Society for Testing and Materials	CO_2	Carbon Dioxide
aTDC	After Top Dead Centre	CIME	Calophyllum Inophyllum Methyl Ester
bTDC	Before Top Dead Centre	CR	Compression Ratio
BTE	Brake Thermal Efficiency	D100	Diesel 100%
CA	Crank Angle	EGR	Exhaust Gas Recirculation
CI05	Diesel 95% + Calophyllum Inophyllum Methyl Ester 5%	EGT	Exhaust Gas Temperature
CI10	Diesel 90% + Calophyllum Inophyllum Methyl Ester 10%	HC	Hydrocarbons
CI15	Diesel 85% + Calophyllum Inophyllum Methyl Ester 15%	HRR	Heat Release Rate
CI20	Diesel 80% + Calophyllum Inophyllum Methyl Ester 20%	IR	Infrared Spectroscopy
CI25	Diesel 75% + Calophyllum Inophyllum Methyl Ester 25%	MATLAB	Matrix Laboratory
CI30	Diesel 70% + Calophyllum Inophyllum Methyl Ester 30%	NOx	Nitrogen Oxides
CI20P6	Diesel 74% + Calophyllum Inophyllum Methyl Ester 20% + Propanol 6%	NO	Nitric Oxide
CI20P12	Diesel 68% + Calophyllum Inophyllum Methyl Ester 20% + Propanol 12%	ppm	Parts Per Million
CI20P18	Diesel 62% + Calophyllum Inophyllum Methyl Ester 20% + Propanol 18%	PM	Particulate Matter
CI20CL6	Diesel 74% + Calophyllum Inophyllum Methyl Ester 20% + Curcuma longa leaf oil 6%	rpm	Revolution per minute
CI20CL12	Diesel 68% + Calophyllum Inophyllum Methyl Ester 20% + Curcuma longa leaf oil 12%	SFC	Specific Fuel Consumption
CI20CL18	Diesel 62% + Calophyllum Inophyllum Methyl Ester 20% + Curcuma longa leaf oil 18%	SO2	Sulfur Dioxide