# Performance and Emission Optimization of a CI Engine Fueled with Juliflora Biodiesel Using Response Surface Methodology

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***Abstract.*** The objectives of the current study are to assess the performance and emission characteristics of a diesel engine running on Juliflora biodiesel-based blends at varying levels of brake power. These objectives were achieved through the implementation of a response surface methodology-based optimization technique to evaluate the combined effect of varying levels of brake power and biodiesel blend on engine parameters such as BTE, CO, HCs, NOx, and smoke. Contour plots were developed to evaluate the interaction effects between the variables. The accuracy of the developed model was validated through a test and forecast method. The most significant findings of the current study include the improvement in BTE with increasing levels of brake power. An improvement of 10-12% was achieved for Juliflora biodiesel-based blends compared to conventional diesel operation. Moreover, the levels of incomplete combustion emissions such as CO, HCs, and smoke were found to decrease substantially. Emissions of CO, HCs, and smoke were found to decrease by 55-60%, 30-35%, and 65-70%, respectively. However, NOx levels were found to increase by 35-40%. The developed model was found to have high accuracy in predicting the engine parameters, as the $R^2$ value was found to be greater than 0.95. The significance of the results lies in the demonstration of the fact that increased brake power along with a moderate level of Juliflora biodiesel blend ratio offers the optimum compromise between improved thermal efficiency and minimized incomplete combustion-related emissions. The results also reflect the viability of Juliflora biodiesel as a substitute fuel for diesel engines, which is beneficial for the cause of utilizing the energy in a more environmentally friendly manner.

***Keywords*****:** Juliflora biodiesel, response surface methodology, emissions, optimization.

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## Optimizarea performanței și a emisiilor unui motor cu compresie continuă alimentat cu biodiesel Juliflora utilizând metodologia suprafeței de răspuns

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***Rezumat.*** Scopul acestui studiu îl reprezintă evaluarea caracteristicilor operaționale și a emisiilor unui motor diesel alimentat cu amestecuri pe bază de biodiesel obținut la diferite niveluri ale puterii efective la frână. Aceste obiective au fost atinse prin aplicarea unei metode de optimizare bazate pe suprafața de răspuns (RSM – Response Surface Methodology), pentru evaluarea influenței combinate a diferitelor niveluri ale puterii efective la frână și ale amestecului de biodiesel asupra unor parametri ai motorului, precum randamentul, CO, HC (hidrocarburi nearse), NOx și fumigenitatea. Au fost construite grafice de contur pentru evaluarea efectelor de interacțiune dintre variabile. Acuratețea modelului dezvoltat a fost confirmată prin intermediul metodei de testare și predicție. Cele mai semnificative rezultate ale acestui studiu includ îmbunătățirea randamentului odată cu creșterea nivelului puterii efective la frână. Pentru amestecurile pe bază de biodiesel din Julliflora, s-a obținut o îmbunătățire de 10-12% comparativ cu funcționarea motorului diesel convențional. În plus, s-a constatat o reducere substanțială a emisiilor provenite din arderea incompletă, cum ar fi CO, HC și fumigenitatea. Emisiile de CO, HC și fumigenitatea s-au redus cu 55-60%, 30-35% și, respectiv, 65-70%. Cu toate acestea, s-a constatat o creștere a nivelului de NOx cu 35-40%. Modelul dezvoltat a demonstrat o acuratețe ridicată a predicției parametrilor motorului, valoarea $R^2$ fiind mai mare de 0,95. Semnificația rezultatelor constă în demonstrarea faptului că creșterea puterii efective la frână, combinată cu un conținut moderat de combustibil biodiesel Julliflora, asigură un compromis optim între creșterea randamentului termic și minimizarea emisiilor asociate arderii incomplete. Rezultatele confirmă, de asemenea, viabilitatea biodieselului din Julliflora ca și combustibil alternativ pentru motoarele diesel, fiind avantajos din perspectiva unei utilizări mai ecologice a energiei.

***Cuvinte-cheie*:** biodiesel Juliflora, metodologie a suprafeței de răspuns, emisii, optimizare.

## Оптимизация рабочих характеристик и выбросов дизельного двигателя, работающего на биодизельном топливе из Юлифлоры, с использованием метода поверхностного отклика

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***Аннотация.*** Целью данного исследования является оценка рабочих характеристик и выбросов дизельного двигателя, работающего на смесях на основе биодизеля из юлифлоры при различных уровнях тормозной мощности. Эти цели были достигнуты путем применения метода оптимизации на основе поверхности отклика для оценки комбинированного влияния различных уровней тормозной мощности и смеси биодизеля на такие параметры двигателя, как КПД, CO, УГС, NOx и дымность. Были построены контурные графики для оценки эффектов взаимодействия между переменными. Точность разработанной модели была подтверждена с помощью метода тестирования и прогнозирования. Наиболее значимые результаты данного исследования включают улучшение КПД с увеличением уровня тормозной мощности. Для смесей на основе биодизеля из юлифлоры было достигнуто улучшение на 10-12% по сравнению с работой обычного дизельного двигателя. Кроме того, было обнаружено существенное снижение уровня выбросов неполного сгорания, таких как CO, УГС и дымность. Выбросы CO, УГС и дымности снизились на 55-60%, 30-35% и 65-70% соответственно. Однако было обнаружено увеличение уровня NOx на 35-40%. Разработанная модель показала высокую точность прогнозирования параметров двигателя, поскольку значение $R^2$ оказалось больше 0,95. Значимость результатов заключается в демонстрации того факта, что увеличение тормозной мощности в сочетании с умеренным содержанием биодизельного топлива из юлифлоры обеспечивает оптимальный компромисс между повышением термического КПД и минимизацией выбросов, связанных с неполным сгоранием. Результаты также подтверждают жизнеспособность биодизельного топлива из юлифлоры в качестве альтернативного топлива для дизельных двигателей, что выгодно с точки зрения более экологичного использования энергии.

***Ключевые слова:*** биодизельное топливо из юлифлоры, методология поверхностного отклика, выбросы оптимизация.

## I. INTRODUCTION

The rapid depletion of fossil fuels and the increasing rate of environmental pollution have enhanced the need for obtaining feasible, sustainable, and renewable fuels that could be effectively used in CI engines soon [1]. Diesel engines, despite having a high efficiency rate and a longer lifespan, are major contributors of some critical pollutants, such as CO, HC, NOx, and PM, in the transportation, agricultural, and power plant sectors of a country. Therefore, significant research has been conducted towards obtaining renewable fuels that could be safely utilized in diesel engines with minor modifications in its existing structure while obtaining enhanced efficiency from its operation.

Biodiesel has emerged as one of the most promising options available to conventional petroleum diesel on account of its renewable nature, biodegradability, and less emission footprint. It is produced by the transesterification of vegetable oils, animal fats, or non-edible feedstocks and can be used in any proportion in blends with diesel. Various non-edible feedstocks have been investigated and among them, Juliflora or Prosopis juliflora has gained increasing importance due to its high oil yield, adaptability in arid and semi-arid regions, and capability to grow on marginal lands unsuitable for food crops. The use of Juliflora as a feedstock for biodiesel falls under non-food competing feedstock and provides socio-economic benefits through land reclamation and rural employment generation [2].

The operating parameters, like brake power and fuel blend ratio, have a strong influence on engine performance and emission characteristics. It is impossible to capture the interaction effects among these variables with conventional one-factor-at-a-time experimental approaches. Response surface methodology presents an effective statistical and optimization tool in this context to analyze the combined influence of multiple parameters, visualize response behavior through contour and three-dimensional surface plots, and determine optimal operating regions with reduced experimental effort [3].

The field of predictive modeling, in recent years, has helped to improve engine performance analysis significantly as data-driven models have become more advanced. Regression models based on machine learning algorithms like Extreme Gradient Boosting (XGBoost) have proved to be quite accurate in predicting nonlinear relationships between engine inputs and outputs. The combination of engine performance analysis based on RSM and predictive validation by test vs. forecast analysis is quite effective [4].

With the foregoing in mind, the current study concentrates on the performance and emission enhancement of a compression ignition engine fuelled with Juliflora biodiesel-diesel blends for different brake power values. The combined influence of brake power and Juliflora biodiesel-diesel blend proportions on BTE, CO, HC, NOx, and smoke emissions has been examined with the aid of contour plots and three-dimensional response surface graphs. Additionally, the predictive validity of the models has been assessed through comparison analyses between predicted and experimental results. The results of this research should contribute to the definition of an optimal region where enhanced efficiency with low emissions can be attained, thereby validating the usability of Juliflora biodiesel as a promising alternative fuel for CI engines [5].

### *A. Novelty and Contribution of the Present Study*

The novelty of the present work is the experimental-statistical combined evaluation of Juliflora biodiesel blends under different brake power conditions using a RSM optimization approach. In contrast with conventional experimental studies where the performance and emission trends are presented individually, the present work focuses on the combined effect analysis of brake power and Juliflora biodiesel blends on engine parameters such as BTE, CO, HCs, NOx, and smoke using contour plot analysis.

Another significant contribution of the present work is the formulation and validation of a highly accurate prediction model with $R^2$ values > 0.95 using a test and forecast approach.

From the present work, it is clearly evident that the increase in brake power with a Juliflora biodiesel blend offers a balanced improvement in brake thermal efficiency (10-12% improvement) along with significant reductions in the rates of incomplete combustion products such as CO, HCs, and smoke (55-70%), despite a moderate increase in NOx (35-40%).

Therefore, this work contributes to the field by showing a statistical optimization of the operating strategy and validating the feasibility of Juliflora biodiesel as an environmentally friendly alternative fuel for diesel engines.

## II. MATERIALS AND METHODS

### *A. Fuel Preparation & Properties*

The oil extracted from Juliflora (Prosopis juliflora) was the raw material to produce biodiesel, owing to its inedible property, which makes it suitable for growing on marginal lands. The raw oil derived from Juliflora was then converted into biodiesel through a common transesterification process using methanol and an alkaline catalyst. The biodiesel was then purified by washing, drying, and filtration to remove any contaminant or reactants. The blends of biodiesel with diesel were prepared using a volumetric mixture of Juliflora biodiesel with normal diesel fuel.

The important physico-chemical characteristics of biodiesel such as density, viscosity, calorific values, cetane number of Juliflora biodiesel were found to be in acceptable ranges for fueling a diesel engine. The presence of in-built oxygen content along with a higher cetane number in Juliflora biodiesel is expected to improve the combustion efficiency along with affect the formation of emissions [6].

### *B. Engine Test Setup and Instrumentation*

Experiments were conducted on a diesel engine operated at a constant rated speed. The engine was coupled with a hydraulic load dynamometer to apply variable load conditions. Brake power was varied systematically while maintaining all other operating parameters constant to isolate its effect on performance and emissions. Fuel consumption was measured using a burette and stopwatch method, while air flow was monitored through an air box fitted with an orifice meter and manometer [7]. A calibrated AVL DI gas analyzer was used to measure exhaust gas emissions, including CO, HC, and NOx. An AVL smoke meter was used to record smoke opacity. To guarantee measurement accuracy and reproducibility, all instruments were calibrated prior to experimentation [8]. Figure 1 depicted the research setup.

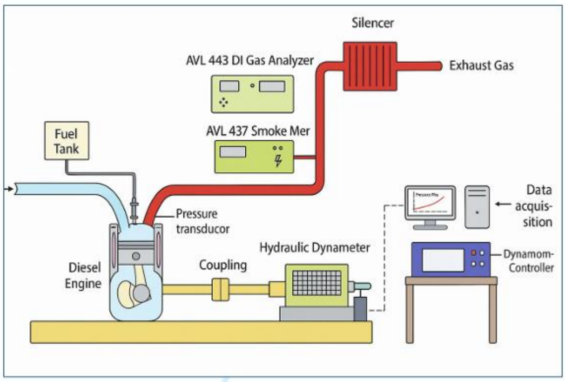


**Fig. 1. Research Setup.**

### *C. Experimental Procedure*

To establish baseline performance and emission parameters, the engine was mainly run on neat diesel fuel. Additionally, tests were conducted at different load conditions utilizing mixes of Juliflora biodiesel. The engine was given time to establish steady-state conditions at each operating point before the data was recorded [9].

### *D.* Response Surface Methodology

The combined impacts of braking power and biodiesel mix ratio on engine performance and emission characteristics were analyzed and optimized using RSM. To alter the input parameters within their respective ranges in a scientific manner, an appropriate experimental design was created. To determine the connections between the independent and response variables, regression models were developed.

To see interaction effects and pinpoint ideal operating regions, contour plots and 3D response surface maps were created. These visual aids made it easier to understand reaction patterns and to weigh the trade-off between lower emissions and higher efficiency [10].

### *E. Predictive Modeling and Validation*

A test/forecasted analysis was done to evaluate the created models' predictive power. Training and testing datasets were created from the experimental data. Based on the input parameters, an Extreme Gradient Boosting (XGBoost) regression model was used to forecast engine reactions. Experiments were used to verify the accuracy of the results. The performance of the predictive model was evaluated using statistical measures, such as the coefficient of determination ($R^2$) [11]. The robustness and dependability of the suggested modeling and optimization approach are confirmed by a strong agreement between test and predicted values.

### *F. Data Analysis*

Following the processing of all experimental and forecasted data using Python-based computational tools, several graphical representations, including contour maps, three-dimensional surface plots, and test vs forecasted plots, were created to aid in the analysis and interpretation. This made sure that the thorough evaluation of the engine behavior under shifting operating conditions would go hand in hand with both predictive modeling and statistical optimization approaches applied to the engine operating data [12].

## III. RESULTS AND DISCUSSION

The performance, combustion, and emissions behavior of the compression ignition engine using biodiesel blends from Juliflora has been examined using contour, surface, and model prediction graphs. The interactive effects of brake power and biodiesel blend levels on brake thermal efficiency, hydrocarbon emissions, carbon monoxide emissions, oxides of nitrogen, and smoke opacity had been considered to determine optimal conditions. Model prediction techniques using response surface methods had been used to model the nonlinear interactions among engine variables and to compare experimental observations with prediction outcomes. The obtained outcomes offer significant information regarding efficiency improvement and emission suppression under the use of biodiesel derived from Juliflora, which can be considered adequate to suitably use in the CI engine.

### *A. Brake Thermal Efficiency*

Figure 2 illustrates the contour map, three-dimensional surface response, and test versus forecasted comparison of brake thermal efficiency as a function of brake power and Juliflora biodiesel blend ratio. A consistent increase in BTE is observed with increasing brake power for all blend proportions [13]. At lower brake power, the BTE remains minimal due to incomplete combustion, increased heat losses, and lower in-cylinder temperatures. As BP increases, improved air–fuel mixing and higher combustion temperatures enhance fuel utilization, leading to a noteworthy rise in thermal efficiency [14].

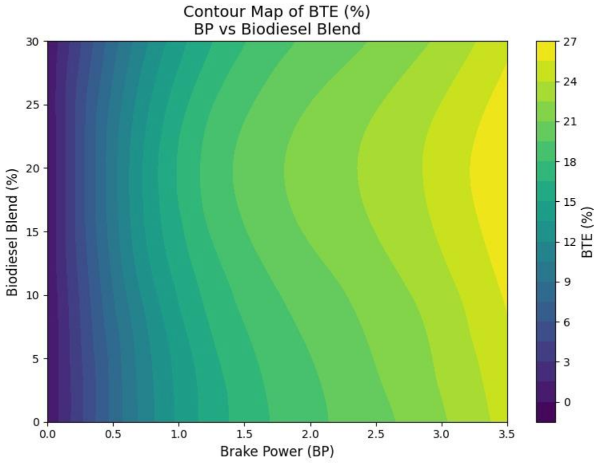
The contour and surface plots reveal that biodiesel blends exhibit slightly higher BTE compared to neat diesel at higher brake power. This enhancement, approximately 10–12% at max load conditions, is assigned to the higher oxygen content and cetane number of Juliflora biodiesel, which promote faster ignition and more complete combustion. However, at very high blend ratios and low loads, insignificant reductions in BTE are observed due to increased fuel viscosity and lower calorific value of biodiesel [15].

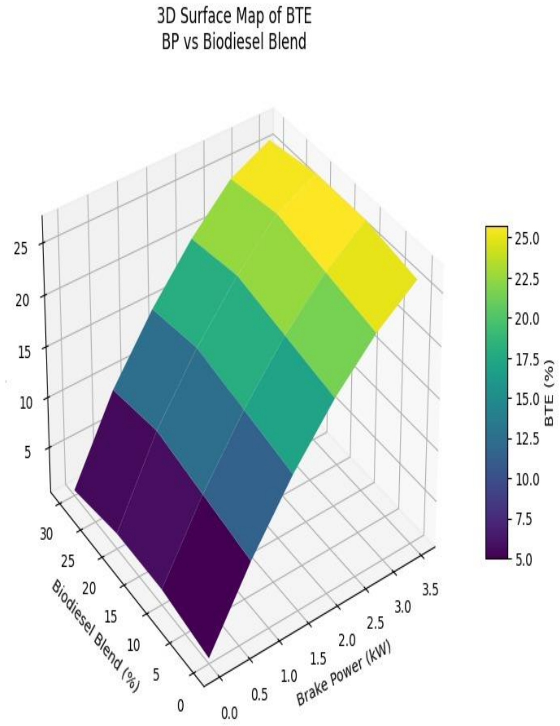
From the test vs. forecasted BTE plot in figure above, an excellent correlation can be seen between the experimental data and the corresponding calculated data. This confirms how good this predictive equation was in optimizing the performance of the machine.

### *B. HC Emissions*

Figure 3 present the HC emission response with respect to brake power and biodiesel blend ratio. HC emissions decrease significantly with increasing brake power for all blends, which is evident from both contour and surface plots. At low brake power, incomplete combustion and flame quenching near the cylinder walls result in higher HC emissions. As BP increases, improved combustion efficiency reduces unburned hydrocarbons [16].

An overall decrease of almost 30–35% in HC emissions is observed for biodiesel blends compared to diesel at higher BP. The reduction is more pronounced for higher biodiesel blends due to the inherent oxygenated nature of Juliflora biodiesel, which enhances oxidation of unburned fuel particles [17].





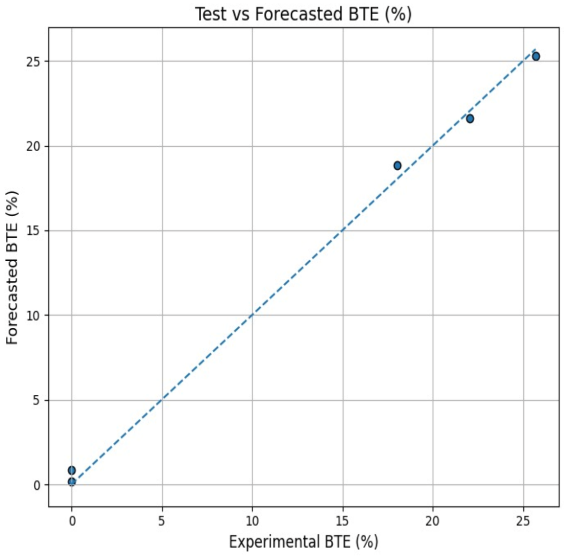


**Fig. 2. Contour, surface, and experimental–predicted BTE versus BP.**

Additionally, the higher cetane number reduces ignition delay, limiting fuel accumulation during the premixed combustion phase and thereby decreasing HC formation [18].

The test versus forecasted HC emissions plot demonstrates a close correlation between measured and predicted values, validating the accuracy of the developed response surface model.

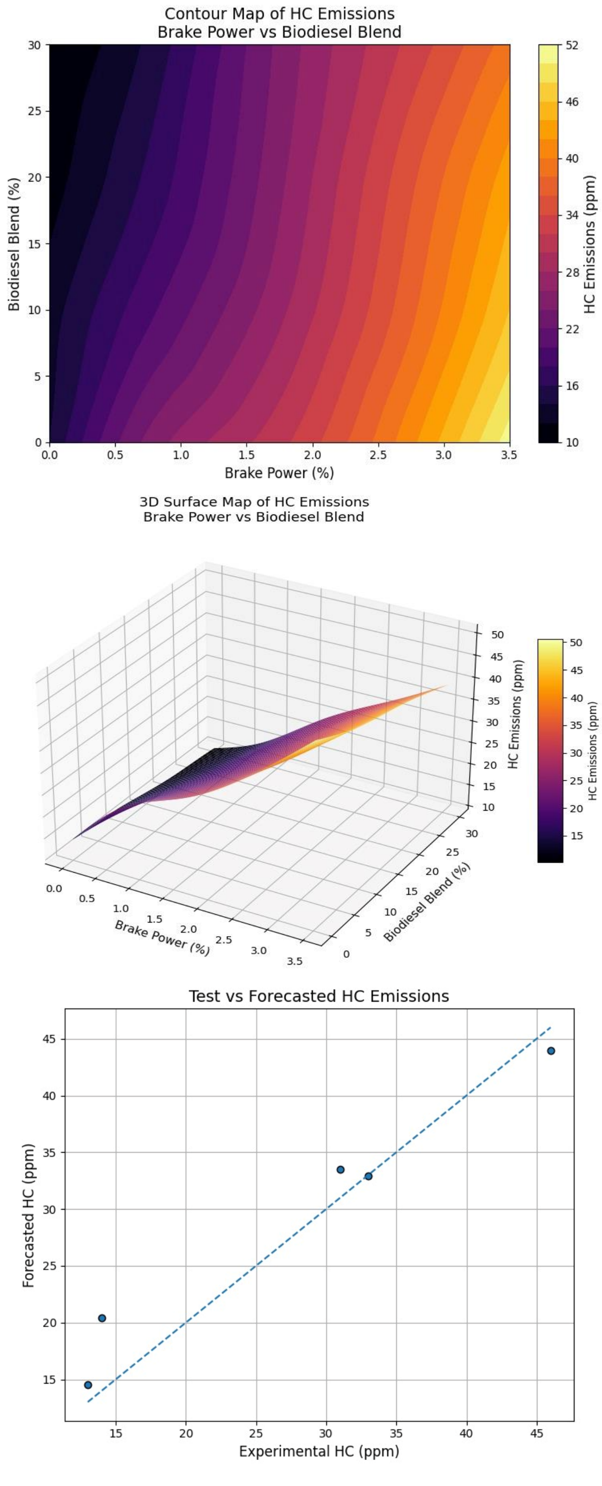


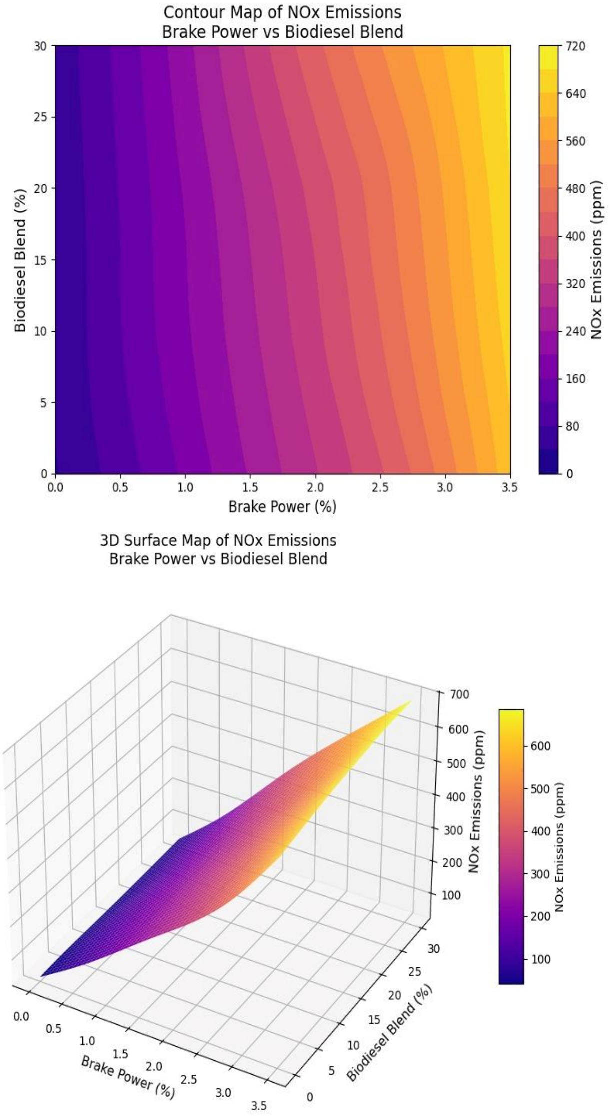
**Fig. 3. Contour, surface, and experimental–predicted HC emissions versus BP.**

### *C. Nitrogen Oxides (NOx) Emissions*

Figure 4 depict the NOx emission behavior as a function of brake power and biodiesel blend ratio. Unlike HC emissions, NOx emissions increase consistently with brake power for all fuel blends. This trend is clearly visible in both contour and surface response plots.

The increase in NOx is mainly associated with elevated in-cylinder temperatures and extended residence time of combustion gases at higher loads [19]. Compared to diesel, Juliflora biodiesel blends show a noticeable increase in NOx emissions, with an increment of approximately 35–40% at higher BP and blend ratios. This behavior is assigned to the higher oxygen content and advanced combustion phasing caused by the higher cetane number of biodiesels, which intensifies thermal NOx formation. Also, the ignition delay is lowered, thus increasing the peak combustion temperatures [20].

The test values plotted against the predicted values of NOx show a strong correlation in the data, thus validating the accuracy of the response surface method in predicting the trends of NOx emission.



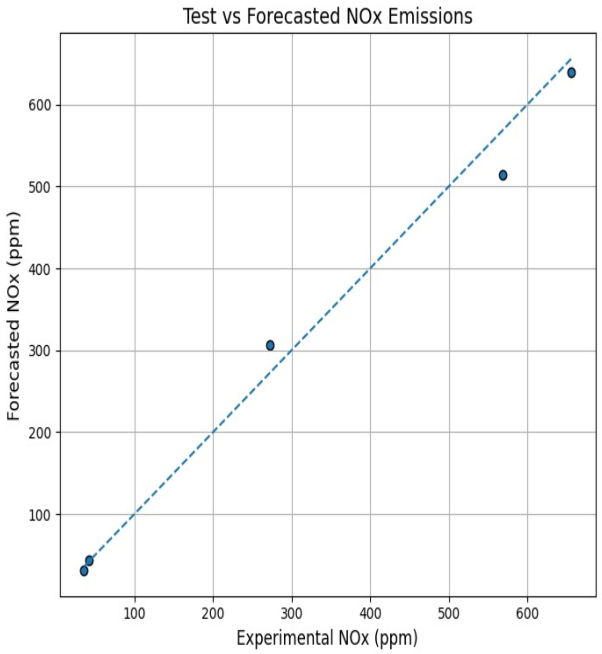


**Fig. 4. Contour, surface, and experimental–predicted $NO_X$ emissions versus BP.**

### *D. Carbon Monoxide (CO) Emissions*

The contour and surface plots for CO emissions in figure 5 clearly show a decreasing trend with increasing biodiesel blend ratio, while CO increases slightly with brake power due to increased fuel input.

At lower brake power, CO emissions are higher due to incomplete oxidation caused by insufficient combustion temperature [21].

It has been observed that Juliflora biodiesel blends reduce the CO emissions by 55–60% compared to diesel at higher loads.

This is mainly due to the increased percentage of oxygen contents available with biodiesel, which further enhances the combustion kinetics to produce more $CO_2$ [22].

The minimum CO emission areas are found in the moderate to higher biodiesel blends (20–30%) and higher BP, as indicated by the contour plots.

The test versus forecasted CO emissions plot proves high prediction accuracy, with most data points thoroughly following the accurate prediction line [23].

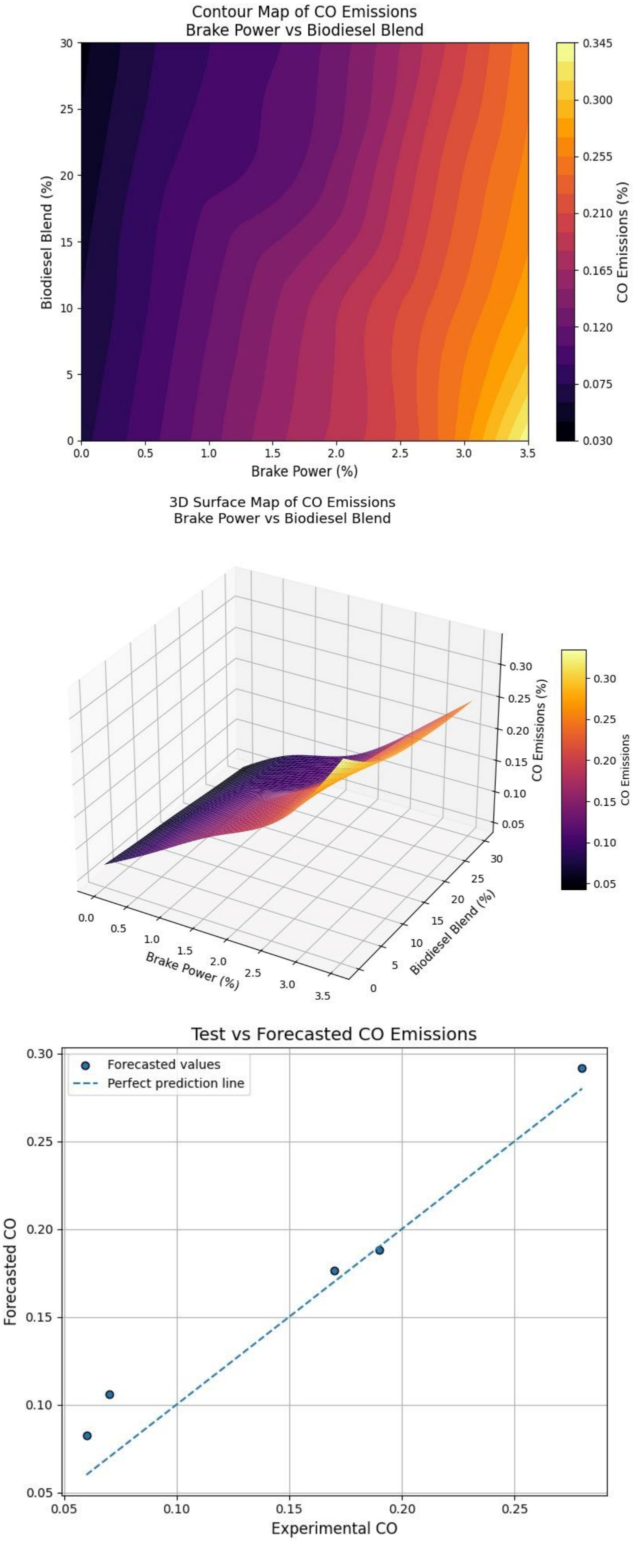


**Fig. 5. Contour, surface, and experimental–predicted CO emissions versus BP.**

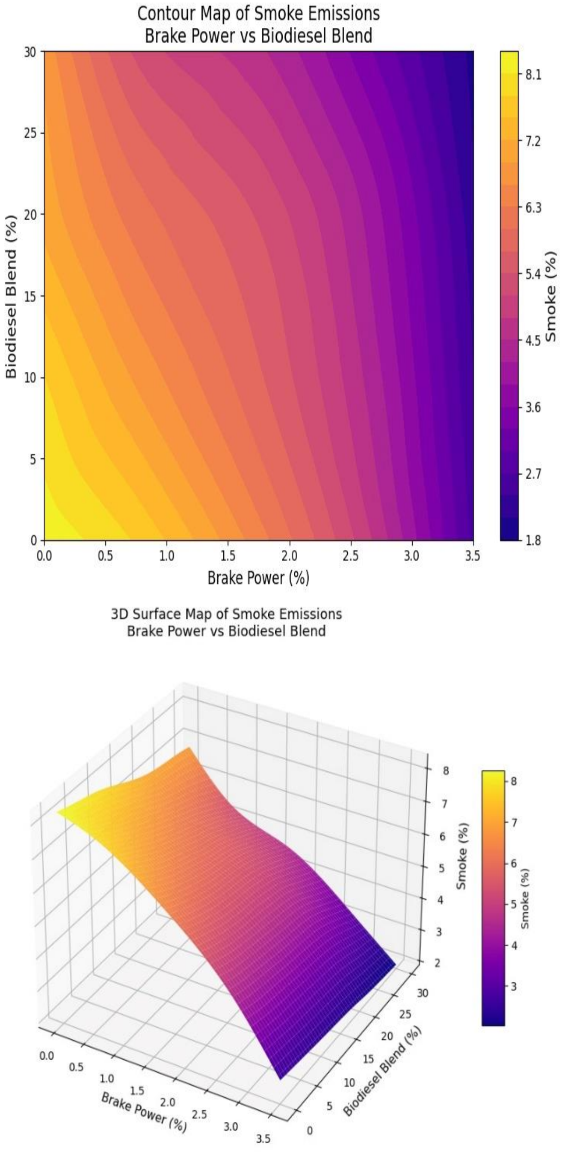
### *E. Smoke Emissions*

Smoke emission contours and surface plots in figure 6 demonstrate an obvious reduction with increasing biodiesel blend ratio and BP. Diesel operation exhibits higher smoke opacity, particularly at low and medium loads, due to fuel-rich zones and soot precursor formation [24].

The addition of Juliflora biodiesel shows that there is a considerable decrease in the percentage of smoke emitted by about 65-70%.

This can be explained by the absence of sulfur and aromatic compounds along with the presence of oxygen within the biodiesel, enhancing the soot oxidation during the combustion process [25].

The contour plots show that the lowest smoke levels occur at higher BP and higher biodiesel blend ratios, indicating diminished emissions. The strong correlation between experimental and forecasted smoke values further proves the effectiveness of the response surface–based modeling approach.



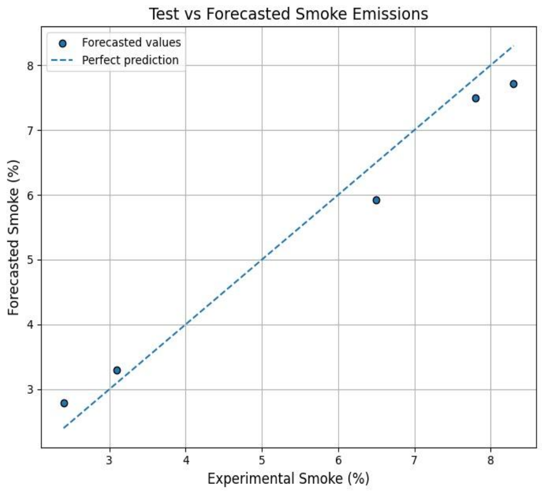


**Fig. 6. Contour, surface, and experimental–predicted Smoke Opacity versus BP**

## IV. CONCLUSION

This paper analyses the performance, emission, and characteristics of a compression ignition engine running on Juliflora biodiesel fuel blends using brake power variables, employing response surface methodology techniques. Based on the outcome, it was observed that the brake thermal efficiency was augmented along with the brake power for all fuel types. Upon comparison between diesel fuel and the Juliflora biodiesel fuel blends, it was observed that the performance was almost identical, with B20 having the best trade-off. At higher loads, the B20 mixture revealed a 4-7% augmentation in BTE.

Emission analysis shows that a considerable decrease in regulated emissions is occurring along with an increase in the ratio of biodiesel. Compared to diesel fuel, CO emissions decreased by 20–30% and smoke opacity decreased by 25–35%. This is thought to be because Juliflora biodiesels have improved carbonaceous material oxidation and no aromatics. Increased cylinder temperatures and better oxygen availability are responsible for a little increase in NOx emissions of roughly 3–8%.

A clear understanding of how brake power and blend ratio together may impact engine performance was provided via contour plots and 3D surface plots. When compared to experimental findings, the predictive correlations demonstrated a high degree of accuracy, with a minimum range of error beginning at ±5%. Response surface optimization technique showed that the blend ratio that would give efficiency gains with substantially reduced emissions is in the range of 15 to 25% biodiesel fuel and brake powers belonging to the medium to high range. Juliflora biodiesel could be considered as a feasible substitute fuel in CI engines without any modifications.

## References

[1] Srinivasan SA, Musthafa B, Naidu BV, Kumar MS. Optimization and experimental investigation on CI engine characteristics fuelled with low carbon alcohols and juliflora biodiesel blends: A RSM approach. Fuel. 2025 May 15; 388:134542.

[2] Gopidesi RK, Uttamrao KN, Hadi AA, Kumar KS, Khan TY, Shaik AS, Alamiery AA. Optimization of compression ratio in LHR engine fueled with nano Al 2 O 3-emulsified biodiesel using RSM and machine learning. RSC advances. 2025;15(59):51178-97.

[3] Jayapalan S, Muthuswamy P, Chandrasekharan T, Michael S, Sekar P, Kuppuswami S. Optimization of performance and emission characteristics of a CRDI engine fuelled with waste plastic oil biodiesel blend using response surface methodology. InAIP Conference Proceedings 2024 Mar 12 (Vol. 3042, No. 1, p. 020034). AIP Publishing LLC.

[4] Gopidesi RK, Sr P, Dhana Raju V. Mitigation of harmful exhaust pollutants of DI diesel engine using emulsified fuel and hythane gas in a dual-fuel mode. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2025 Dec 31;47(1):3987-4009.

[5] Musthafa B, Asokan MA. Numerical and experimental investigation of performance and emission characteristics of hydrogen enrichment with prosopis juliflora biodiesel in CI engine using RSM and ANN optimization. International Journal of Hydrogen Energy. 2024 May 13;66:326-36.

[6] Rambabu R, Sridevi G, Kruthiventi SS, Masthanvali PS, Borigorla V, Kalyanamanohar V. Effects of Compression Ratio on a Diesel Engine Powered by Tamarind Seed Biodiesel Blend. International Journal of Vehicle Structures & Systems. 2023;15(6):793-6.

[7] Bala Prasad K, Dhana Raju V, Ahamad Shaik A, Gopidesi RK, Sreekara Reddy MB, Soudagar ME, Mujtaba MA. Impact of injection timings and exhaust gas recirculation rates on the characteristics of diesel engine operated with neat tamarind biodiesel. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 2025 Dec 31;47(1):7767-85.

[8] Kaur G, Singh N, Rajor A. RSM-CCD optimized Prosopis juliflora activated carbon for the Adsorptive uptake of Ofloxacin and disposal studies. Environmental Technology & Innovation. 2022 Feb 1;25:102176.

[9] Reddy SV, Premkartikkumar SR, Gopidesi RK, Kautkar NU. A Review on nano coatings for IC engine applications. International Journal of Mechanical Engineering and Technology. 2017;8(9):70-6.

[10] Musthafa B, Prabhahar M. Experimental and Numerical Analysis of Performance, and Emission Characteristics of CI Engine Using Juliflora-Gulmohar Biodiesel/Blends and ANN Prediction using MATLAB. Case Studies in Thermal Engineering. 2025 May 13:106338.

[11] Gopidesi RK, Valeti SV, Kumma N, Mutluri A, Venu B. Evaluation dual fuel engine fuelled with hydrogen and biogas as secondary fuel. Int. J. Recent Technol. Eng. 2019;8(2):1902-5.

[12] Ramachandran M, Subramanyan N. Study and Optimization of Ethanol (LRF) Juliflora Biodiesel (HRF) Fuelled RCCI Engine with and without EGR System. Tehnički vjesnik. 2024 Apr 23;31(3):784-91.

[13] Rao PM, Dhoria SH, Patro SG, Gopidesi RK, Alkahtani MQ, Islam S, Vijaya M, Jayanthi JL, Khan MA, Razak A, Kumar R. Artificial intelligence-based modelling and hybrid optimization of linseed oil biodiesel with graphene nanoparticles to stringent biomedical safety and environmental standards. Case Studies in Thermal Engineering. 2023 Nov 1; 51:103554.

[14] Naik GG, Dharmadhikari HM, More SA, Sarris IE. The optimization of a ternary blend using grey relation analysis with the Taguchi method for the improved performance and reduction of exhaust emissions. Fire. 2025 Feb 19;8(2):83.

[15] Gopidesi RK, Gangolu NR. Assessment of diesel engine characteristics fuelled by Jatropha with tamarind seed oil biodiesel. INCAS Bulletin. 2020;12(1):51-7.

[16] Swamy LR, Banapurmath NR, Harari PA, Chandrashekar TK, Keerthi BL, Naveen SS, Katti BB, Kulkarni PS. Diesel engine performance fuelled with manifold injection of ethanol and water-in-diesel emulsion blends. Materials Today: Proceedings. 2022 Jan 1; 66:1914-9.

[17] Gopidesi RK, Premkartikkumar SR. Abating environmental pollutants of a diesel engine by using emulsified fuel. International Journal of Ambient Energy. 2021 Nov 18;42(15):1708-11.

[18] Ukande MD, Shaikh S, Murthy K, Shete R. Review on pharmacological potentials of Prosopis juliflora. Journal of Drug Delivery and Therapeutics. 2019 Jul 2;9(4–s):755-60.

[19] Asokan MA, Prabu SS, Bade PK, Nekkanti VM, Gutta SS. Performance, combustion and emission characteristics of juliflora biodiesel fuelled DI diesel engine. Energy. 2019 Apr 15; 173:883-92.

[20] Rambabu R, Kruthiventi SS, Rajesh M, Yadla B, Sai TM, Poluraju D, Varun B, Kumar GN. Environmental Implications of Novel Biodiesel: A

Comprehensive Experimental Investigation. International Journal of Vehicle Structures & Systems (IJVSS). 2025 Jun 1;17(4).

[21] Ahmad A, Khan KA, Ahmad VU, Qazi S. Antibacterial activity of juliflorine isolated from Prosopis juliflora. Planta medica. 1986 Aug;52(04):285-8.

[22] Gopidesi RK, Kakunuri GK, Manideep JY, Kalyan C, Rambabu R. Production of waste plastic oil and its impact on a diesel engine used as a fuel. InAIP Conference Proceedings 2020 Dec 7 (Vol. 2311, No. 1, p. 020043). AIP Publishing LLC.

[23] Venu H, Raju VD, Nair JN, Algburi S, Anqi AE, Rajhi AA, Kareemullah M. Exergy and Energy-Based Sustainability Evaluation of Diesel-Biodiesel-Ethanol Blends with Emission Forecasting using Advanced Machine Learning Models. Case Studies in Thermal Engineering. 2025 Jun 17:106516.

[24] Nair JN, Nagadurga T, Raju VD, Venu H, Algburi S, Kamangar S, Arabi AI, Razak A, Marakala N. Impact of fuel additives on the performance, combustion and emission characteristics of diesel engine charged by waste plastic bio-diesel. Case Studies in Thermal Engineering. 2025 Mar 1;67:105755.

[25] Rambabu R, Kruthiventi SS, Vali PM, Rajesh M, Khageswar V, Chowdari GK. Experimental Analysis of Palmyra Biodiesel Performance in a Diesel Engine with Varied Injection Timing. International Journal of Vehicle Structures & Systems. 2025 Apr 1;17(2):224-7.

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