INTERNATIONAL JOURNAL OF AUTOMOTIVE SCIENCE AND TECHNOLOGY

2025, VOL. 9, NO:1, 40-47 www.ijastech.org e-ISSN: 2587-0963

Determination of the Sesame Oil Biodiesel (SOB) Ratio Providing the Lowest Emissions by Multi-Purpose RSM Optimization

Samet Uslu[1*]

[1.] *Mechanical Engineering Department, Faculty of Engineering, Karabuk University, Karabuk, 78050, Turkey.*

Research Article

Abstract

Emissions from internal combustion engine vehicles have a major impact on environmental pollution and global warming, which are among the world's biggest problems. The use of alternative fuels is quite popular to reduce the emission values originating from diesel engines, which are preferred due to their high efficiency. Another issue that has become popular in recent years is optimization studies for alternative fuels. In this study, to determine the most suitable sesame oil biodiesel (SOB) in terms of emissions in a single cylinder diesel engine using SOB as an alternative fuel, firstly engine experiments were performed, and response surface methodology (RSM) optimization was performed using experimental data. In the optimization design, SOB percentage and engine load were determined as factors, while carbon monoxide (CO), hydrocarbon (HC), carbon dioxide (CO_2), and nitrogen oxide (NO_x) were determined as responses affected by the factors. The optimum variable levels offered by the optimization study are 15% SOB and 850 W engine load. The emission levels designed as responses under these conditions are 0.0680% CO, 7.1858 ppm HC, 4.0887% CO_2, and 316.4166 ppm NO_x. When compared with the test results, it was concluded that the RSM results and the test results converged in the 0.71%-2.34% error range and accordingly the RSM optimization was successfully performed.

Keywords: Optimization; biodiesel; sesame oil; emission reduction; diesel engine.

History
Received 04.11.2024
Revised 10.12.2024
Accepted 13.01.2025

Contact
* Corresponding author
Samet Uslu
sametuslu@karabuk.edu.tr
Address: Mechanical Engineering Department, Faculty of Engineering, Karabük University, Karabük, Turkey

To cite this paper: Uslu, S.,Determination of the Sesame Oil Biodiesel (SOB) Ratio Providing the Lowest Emissions by Multi-Purpose RSM Optimization International Journal of Automotive Science and Technology. 2025; 9 (1): 40-47. http://dx.doi.org/10.30939/ijastech..1579371

1. Introduction

It is projected that the use of alternative energy sources will increase more as the demand for energy keeps growing [1,2] and the environmental impact of carbon fuels becomes more apparent [3,4]. It will be essential to keep funding research and development, enact rules and regulations that encourage the use of renewable energy sources, and work to lower consumption and increase energy efficiency to meet the world's long-term energy needs [5–7]. The search for novel and varied energy sources, including biofuels, has become increasingly important [8]. The power sector will probably use a combination of fossil fuels and renewable energy sources to meet the growing demand for electricity while addressing environmental issues [9]. Despite being believed to be more sustainable and environmentally beneficial than fossil fuels, renewable energy sources have their own issues and drawbacks. Resources and land are needed to produce biofuels (especially first generation), which could negatively impact ecosystems and food supply [10]. Some, like pyrolysis, require significant investments in technology and equipment and can be quite energy intensive. Finding sustainable and renewable energy sources is a challenging and ongoing task that will probably require a variety of strategies and technological advancements.

Utilizing biofuels could address several issues, such as lowering air pollution, improving engine performance and providing an inexpensive fuel substitute, and lowering overall fuel costs [11,12]. To reduce their CO_2 emissions, biofuels can also be used with fossil fuels to further improve their sustainability and environmental impact. One of the biggest sources of carbon emissions worldwide is the transportation sector [13,14]; using biofuels can help lower these emissions [15]. To address the global climate issue and guarantee the sustainability of our energy future, this is imperative.

Vegetable oils and the biodiesels made from them are now a viable substitute for fuels derived from petroleum [16]. By combining them with regular diesel fuel, they can be used in diesel engines without any changes. Vegetable oils are a renewable energy source because they are made from renewable vegetables, emit heat at a rate like that of diesel, have low emissions (CO, HC, and PM), and contain little sulfur. Vegetable oils have been the subject of extensive research and development due to these significant benefits. Studies have also been carried out on sesame oil, a type of vegetable oil, based on its use in diesel engines. Widely cultivated sesame, a seed crop, is among the top producers of oilseed worldwide [17]. Sesame, which contains of a very great oil content of almost 44-58%, is valuable in unsaturated fatty acids [18]. Under ideal storage conditions, sesame oil is much more resistant to oxidative deterioration than other vegetable oils, and it does not break down as quickly in hotter regions [19]. Based on these properties, sesame oil is considered a potential source of vegetable oil for biodiesel production and some studies are being carried out in this regard. In one of these studies, Santos et al. [20] experimentally investigated the effects of SOB use in diesel engines. The study's findings led the authors to the conclusion that SOB use raised CO and NO_x emissions. On the other hand, the authors reported that specific fuel consumption decreased with increasing SOB ratio. For these reasons, it was concluded that SOB use up to 20% mixture ratio could be an alternative to fossil diesel fuel. In an another investigation, John et al. [21] tested the impacts of SOB on compression ignition engine reactions at different compression ratios. The authors confirm the fact that SOB can be utilized as an alternative fuel source for diesel, in line with the conclusion stated in literature sources. Many studies similar to these have been conducted in the past [22,23].

Even if using biodiesel as an alternative fuel reduces emissions from diesel engines, there will be losses in produced fuel, money, and time if the ideal combination ratio is exceeded or not identified. It is crucial to ascertain the ideal combination ratio because of this. However, it can take a lot more experiments to reach this conclusion through experimental research. Furthermore, even with a lot of experiments, an accurate analysis might not be achievable. Optimization applications, which may mimic a big number of trials with high success rates with a small number of experiments instead of executing many tests, are the way that will eliminate all these negatives [24]. RSM is a popular application in numerous industries and professions since it has demonstrated its dependability and effectiveness among these applications [25,26]. A few studies have also been conducted on the optimization of SOB usage with RSM in diesel engines to save time and experiment costs [27–29].

In the current research, RSM optimization was conducted to define the optimum SOB ratio and obtain the lowest emissions. There are different studies in the literature related to SOB/diesel blends. However, there are limited studies in which SOB usage is optimized with RSM. Moreover, no study was found on the optimization of SOB obtained from waste sesame oil. The most important point that distinguishes this study from other studies is the optimization of the usage of SOB obtained from waste sesame oil in diesel engines with RSM. This caused this study to emerge as a new and different study.

2. Materials and Methods

2.1. Biodiesel production and Test procedure

Biodiesel from sesame oil was produced using the transesterification process. Figure 1 shows a schematic illustration of the process used to produce biodiesel from sesame oil. 100 mL of sesame oil was put in a water bath bottle set at 65°C and allowed to cool to 63°C. To make methoxide, put 2 g of powdered NaOH (catalyst) and 25 mL of methanol in a container. Use a mechanical mixer to agitate the mixture for 20 minutes. After adding the methoxide, the heated sesame oil is stirred for 25 minutes. To separate the glycerin, the resultant mixture is placed in a separating funnel and left for 15 hours. Following the separation of the glycerin, the valve at the end of the funnel is used to separate the glycerin from the sesame methyl ester. Following the synthesis of the sesame methyl ester, it is cleaned in hot water and the biodiesel is dried for four hours at 100 °C to eliminate any remaining water. The final output is acquired after filtering is completed. The assets of manufactured SOB and diesel are tabulated in Table 1.

Table 1. Some main assets of test fuels.

Item	Diesel	SOB
Density at 15°C (g/cm^3)	0.830	0.922
Lower thermal value (MJ/kg)	43.000	38.075
Kinematic viscosity (mm^2/s)	2.86	5.8
Cetane number	56	52

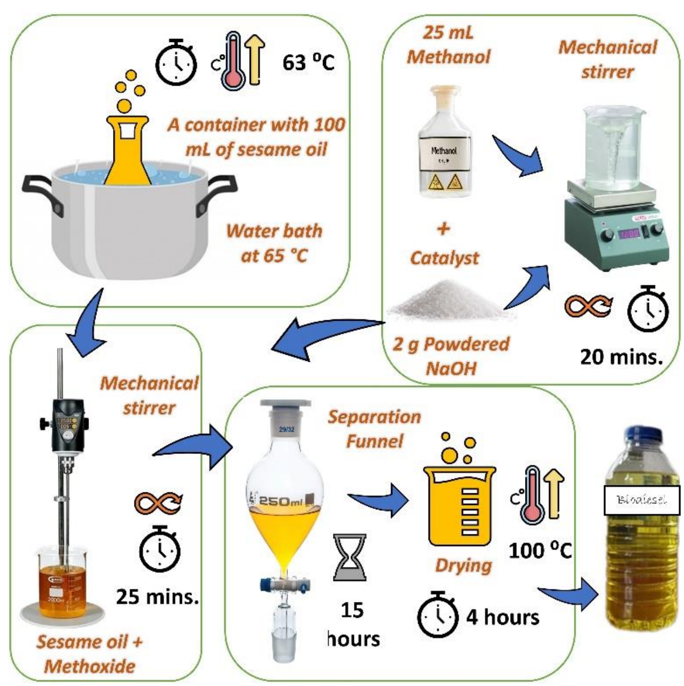

Figure 1. Schematic illustration of the biodiesel production

After SOB production, test fuels were created using four different SOB ratios (from 10% to 40% with 10% changes). Experiments were carried out at 6 different engine loads (from 500 W to 3000 W with 500 W changes) at 3000 rpm continuous engine speed using the created test fuels and pure diesel, and emission changes were examined. The representation inspect of the experimental setup is presented in Figure 2, and the basic characteristics of the engine are presented in Table 2.

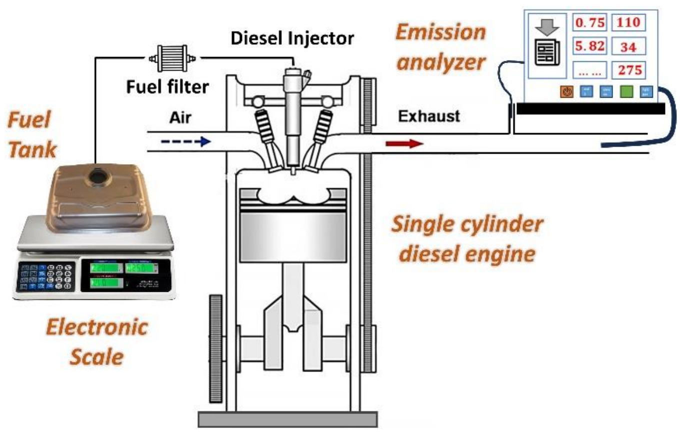

Figure 2. Schematic illustration of the experimental setup

Table 2. Requirements of the test engine.

Engine Qualifications	
Brand/Model	Lutian LT 178F
Type	Air cooled, 4-strokes diesel engine
Cylinder number and volume	single and 296 cm^3
Maximum output power	3.2 kW
Engine power	7 Hp

2.2. RSM design

Among optimization techniques, RSM stands out for its excellent accuracy and ease of use. It is commonly used in engineering applications to model and optimize test variables and output factors [30,31]. In contrast to other optimization methods, RSM is a strategy that reduces time by decreasing the number of tests and constructing the suitable matrix for those tests [32,33]. It is common practice to employ a quadratic polynomial, as shown in Eq. (1) below, when modeling complicated systems with RSM. The RSM model is constructed by estimating the coefficients denoted by β, derived using least squares regression.

$$y = \beta_0 + \sum_{i}^{k} \beta_i x_i + \sum_{i=1}^{k} \sum_{j \geq i}^{k} \beta_{ij} x_i x_j + \mathcal{E} \quad (1)$$

In this case, the coefficients are represented by β, the independent variables by x, the model's anticipated response by y, its rank by k, and the random error by ε.

In this RSM study; SOB ratio and engine load were selected as factors affecting diesel engine emissions, while CO, HC, CO_2, and NO_x were evaluated as emissions. As identifying the ideal SOB ratio to produce the lowest emissions was the main goal of the study, experiments were carried out until 40% SOB ratio and 3000 W engine load, at which point emissions and combustion efficiency began to decline based on the experimental findings. Increasing the engine load and SOB ratio was not required. As a result, Table 3 displays the levels of these factors that were chosen for the RSM design. Furthermore, Table 4 displays the experiment matrix utilized for the RSM. Considering the levels of the chosen criteria, the experiments displayed in the table were chosen at random. For RSM optimization, firstly, a 'Central composite' design was created using the experimental data shown in Table 4. Then, analysis was performed under 'full quadratic' conditions and at 95% confidence level. Then, optimization was performed by selecting 'Minimize' objective for all responses with 'Response Optimizer'.

Table 3. Levels of factors used on the RSM design

Factors	Levels					
SOB (%)	0	10	20	30	40	-
Engine Load (W)	500	1000	1500	2000	2500	3000

Table 4. Table of experiments for RSM

Factors		Responses			
SOB (%)	Engine Load (W)	CO (%)	HC (%)	CO_2 (%)	NO_x (ppm)
0	500	0.105	18.00	2.70	180.67
0	1000	0.091	27.67	3.16	217.33
0	3000	0.081	81.33	6.78	545.50
10	500	0.109	23.33	2.60	183.00
10	1500	0.068	32.67	3.90	278.00
10	3000	0.055	77.67	7.15	568.00
20	1500	0.061	25.33	5.22	420.33
20	3000	0.053	58.33	8.26	787.00
30	500	0.076	7.00	3.72	271.33
30	1000	0.058	17.33	4.48	311.67
30	3000	0.057	48.67	8.65	780.67
40	500	0.127	43.67	2.32	134.67
40	1500	0.092	66.00	3.32	217.33
40	3000	0.119	128.00	5.75	476.50

3. Results and Discussion

For each response, the model's equations are displayed below from Eq. (2) to Eq. (5). Regarding the actual factors, the reaction for specific levels of each element can be predicted using the equation.

$$CO = 0.132852 - 0.00311 * SOB - 0.000046 * Load + 0.00000000345359 * SOB * Load + 0.000079 * SOB^2 + 0.00000000946433 * Load^2 \quad (2)$$

$$HC = 5.53733 - 1.68745 * SO + 0.029390 * Load - 0.000356 * SOB * Load + 0.059512 * SOB^2 - 0.000000718330 * Load^2 \quad (3)$$

$$CO_2 = 2.41904 - 0.110345 * SOB - 0.000075 * Load + 0.000013 * SOB * Load - 0.002941 * SOB^2 + 0.000000476254 * Load^2 \quad (4)$$

$$NO_x = 196.9886 + 10.58552 * SOB - 0.085941 * Load + 0.002454 * SOB * Load - 0.317394 * SOB^2 + 0.000064 * Load^2 \quad (5)$$

3.1. Surface Plot of Responses

Incomplete combustion may occur due to many reasons in the combustion process, and in this case the probability of emissions such as CO and HC to occur increases. The changes in CO and HC emissions resulting from incomplete combustion depending on SOB and engine load are shown in Figure 3 and Figure 4. The impact of the alteration in SOB ratio is analogous for both categories of emissions. While the increase in SOB from 0% to 15%-20% reduces CO and HC emissions, both emissions started to increase after 20% SOB ratio. The oxygen content of biodiesel improved combustion and reduced incomplete combustion emissions. However, the relatively high viscosity of SOB (as shown in Table 1) caused the viscosity of the fuel mixture to increase after 15%-20% mixing ratio. Since the pumping difficulty and atomization problem brought about by high viscosity negatively affected the quality of combustion, CO and HC emissions started to increase again.

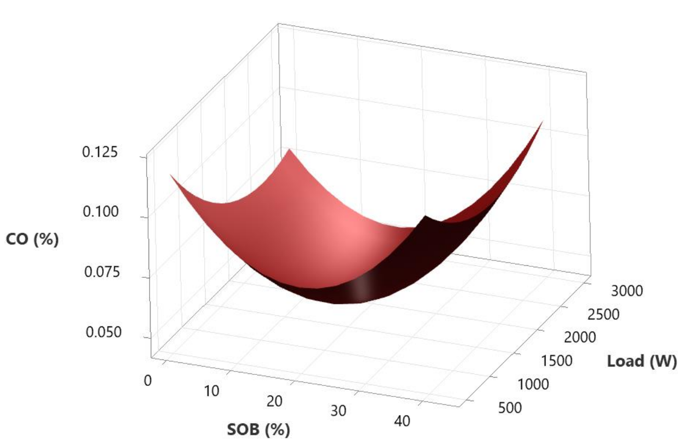

Figure 3. Surface graph of CO emission changes depending on SOB and load.

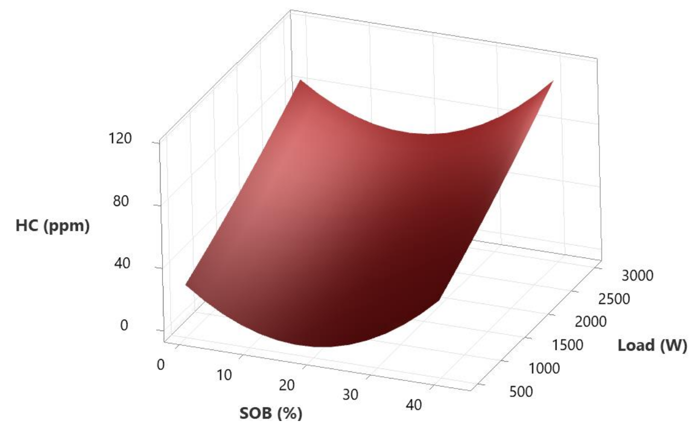

Figure 4. Surface graph of HC emission changes depending on SOB and load.

CO_2 emission is one of the emission types that occur in complete combustion where combustion quality is high. As the complete combustion rate in the cylinder increases, it is likely that CO_2 emission will increase. On the other hand, because the in-cylinder temperature will rise as the cylinder's complete combustion rate rises, NO_x is the pollutant most impacted by this circumstance [34]. The changes in CO_2 and NO_x emissions depending on SOB and engine load are shown with the surface graphs in Figure 5 and Figure 6. As can be clearly seen from both graphs, increasing engine load caused both emissions to increase. This situation occurred because the increase in in-cylinder temperature with increasing load caused more combustion. On the other hand, increasing SOB ratio caused emissions to increase up to 15%-20% mixture ratio and then decrease. As stated in CO and HC emissions, as the SOB ratio in the fuel mixture increases, the viscosity of the mixture increases, and the combustion deteriorates, which leads to a decrease in CO_2 emissions. In addition, the decrease in the in-cylinder temperature together with the deteriorated combustion also leads to a decrease in NO_x.

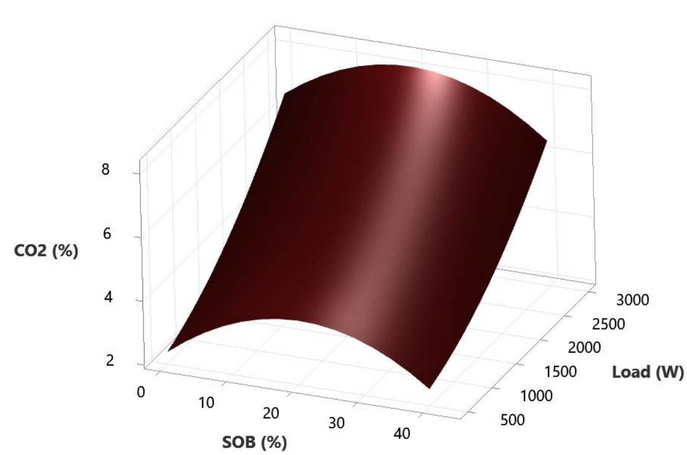

Figure 5. Surface graph of CO_2 emission changes depending

on SOB and load.

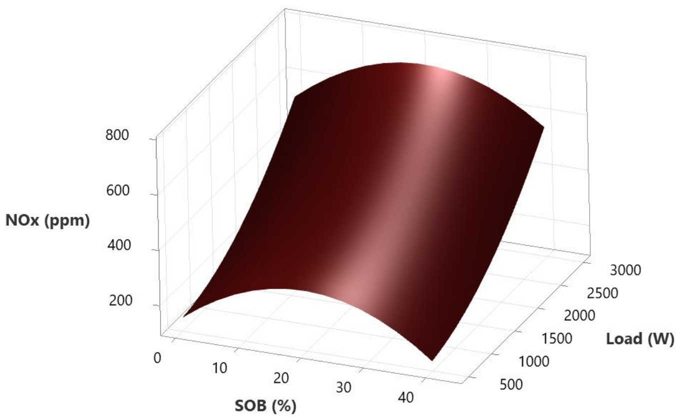

Figure 6. Surface graph of NO_x emission changes depending on SOB and load.

3.2. Optimization and Confirmation

The main purpose of this study is to define the ideal SOB percentage to achieve low emission concentrations in diesel engines operating with SOB/diesel mixtures. For this purpose, RSM optimization was used. In the optimization, SOB ratio and engine load were defined as input variables, while CO, HC, CO_2, and NO_x emissions were defined as responses. As optimization objectives, a minimum level was targeted for all responses. The parameters used for optimization are shown in Table 5.

Table 5. Parameters of optimization

Response	Goal	Lower	Target	Upper	Weight	Importance
NO_x	Min	134.667	134.667	787.000	1	1
CO_2	Min	2.318	2.318	8.648	1	1
HC	Min	7.000	7.000	128.000	1	1
CO	Min	0.053	0.053	0.127	1	1

The optimum operating conditions and responses resulting from these are shown in Figure 7. 15% SOB and 850 W load were found to be optimum variable levels, while 0.0680% CO, 7.1858 ppm HC, 4.0887% CO_2, and 316.4166 ppm NO_x were determined as the lowest responses. According to the verification study conducted to measure the level of peace of the optimization, the error rates between the test results and RSM results were found to be in the range of 0.71%-2.34% and within reliable limits as shown in Table 6.

In one of the few studies that have been done on the optimization of sesame oil biodiesel, Kumar et al. [26] found that 20% was the ideal biodiesel ratio. In a second study, Uday and Simhadri [35] claimed that the best outcomes came from a 20% biodiesel ratio. John et al. [36] also claimed that the ideal biodiesel ratio was 20% in another study. Variability in the optimal biodiesel ratio may result from the inclusion of several components alongside biodiesel in all experiments. It may be concluded that the study's optimal 15% SOB ratio is mostly in line with previous research.

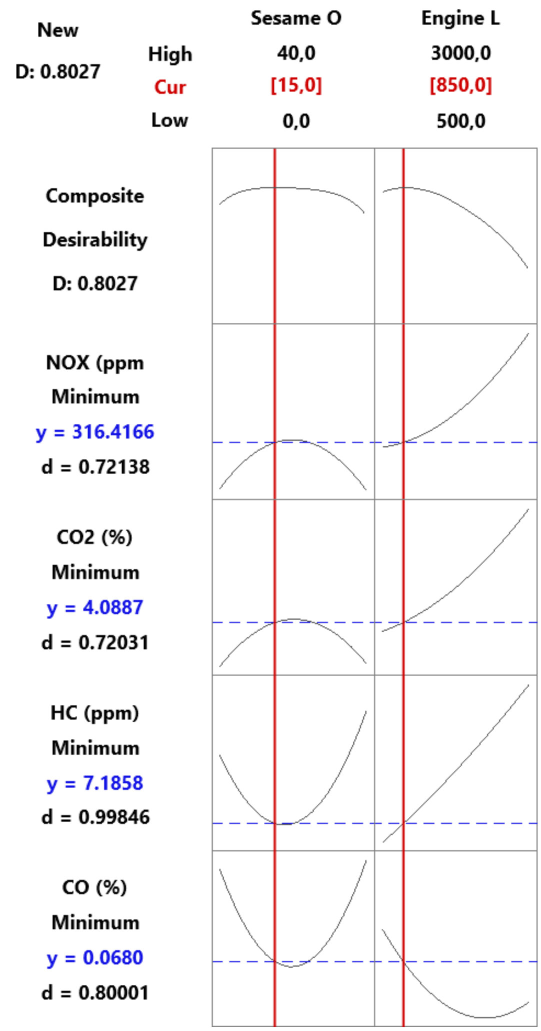

Figure 7. Optimization plot

Table 6. Confirmation

SOB (%)	Load (W)		CO (%)	HC (ppm)	CO_2 (%)	NO_x (ppm)
15	850	RSM	0.068	7.1858	4.0887	316.4166
		Test	0.067	7.300	4.06	324.00
Error (%)			**1.49**	**1.56**	**0.71**	**2.34**

4. Conclusions

In current research, RSM optimization was utilized to define the appropriate conditions in a diesel engine operated with SOB/diesel fuel mixtures. First, experimental studies were carried out at different engine loads and mixture ratios and RSM optimization was performed with the experimental data. The results obtained;

- Experimental studies reveal that the lowest CO and HC are obtained in the range of 10%-20%.
- The SOB ratio being greater than 10-20% worsened the viscosity and caused emissions to be negatively affected.
- 15% SOB and 850 W load were found to be optimum variable levels, while 0.0680% CO, 7.1858 ppm HC, 4.0887% CO2, and 316.4166 ppm NOx were determined as the optimum responses.
- The error rates between test and RSM findings were determined to be within reliable bounds, ranging from 0.71% to 2.34%, based on the verification research that was carried out to gauge the optimization's degree of peace.

Finally, it was concluded that SOB can be successfully utilized by combining with diesel in specific ratios, and RSM can also be successfully employed to optimize diesel engine responses and operating conditions.

Nomenclature

CO	:	carbon monoxide
CO_2	:	carbon dioxide
HC	:	hydrocarbon
NaOH	:	sodium hydroxide
NO_x	:	nitrogen oxide
RSM	:	response surface methodology
SOB	:	sesame oil biodiesel

Conflict of Interest Statement

I declare that I have not received any financial interest or advantage from any direct implementation of my research.

References

[1] Alzubaidi, MIA., Altawwash, ASA., Abbas, WN. Study on the performance and emissions of compression ignition engine powered by diesel and biodiesel blends. Int J Thermofluids. 2024;24:100869. https://doi.org/10.1016/j.ijft.2024.100869

[2] Uslu, S., Maki, DF., Al-Gburi ASK. Investigation of nanoparticle (Fe3O4) addition to 3rd generation biodiesel (spirulina microalgae)/diesel mixture as an innovative fuel according to different engine variables: An RSM optimization. Energy Convers Manag. 2024;310:118481. https://doi.org/10.1016/j.enconman.2024.118481

[3] Kheiralipour, K., Khoobbakht, M., Karimi, M. Effect of biodiesel on environmental impacts of diesel mechanical power generation by life cycle assessment. Energy. 2024;289:129948. https://doi.org/10.1016/j.energy.2023.129948

[4] Simsek, S., Uslu, S. Evaluation of the Possible Effects of Varying the Volumetric Ratio of Lpg on the Spark Ignition Engine's Performance, Emissions, and Combustion. Int J Automot Sci Technol. 2024;8(3):273–8. https://doi.org/10.30939/ijastech..1491371

[5] Erdoğan, S., Aydın, S., Balki, MK., Sayin, C. Operational evaluation of thermal barrier coated diesel engine fueled with biodiesel/diesel blend by using MCDM method base on engine performance, emission and combustion characteristics. Renew Energy. 2020;151:698–706. https://doi.org/10.1016/j.renene.2019.11.075

[6] Jagtap, SP., Pawar, AN., Lahane S. Improving the usability of biodiesel blend in low heat rejection diesel engine through combustion, performance and emission analysis. Renew Energy. 2020;155:628–44. https://doi.org/10.1016/j.renene.2020.03.115

[7] Celik, M. and Uslu, S. Experimental investigation of diesel engine running on diesel fuel supplemented with CeO2 metal nanoparticles. Energy Sources, Part A Recover Util Environ Eff. 2023;45(1):246–262. https://doi.org/10.1080/15567036.2023.2168093

[8] Jain, A., Bora, BJ., Kumar, R., Sharma, P., Deepanraj, B., Irshad, K., Ravikiran, C. Application of hybrid Taguchi L16 and desirability for model prediction and optimization in assessment of the performance of a novel Water Hyacinth biodiesel run diesel engine. Fuel. 2023;339:127377.https://doi.org/10.1016/j.fuel.2022.127377

[9] Hossain, AK., Sharma, V., Ahmad, G., Awotwe, T. Energy outputs and emissions of biodiesels as a function of coolant temperature and composition. Renew Energy. 2023;215:119008. https://doi.org/10.1016/j.renene.2023.119008

[10] Lin, D., Mao, Z., Feng, X., Zhou, X., Yan, H., Zhu, H., Liu, Y., Chen, X., Tuo, Y., Peng, C., Chen, D., Yang, C. Kinetic insights into deoxygenation of vegetable oils to produce second-generation biodiesel. Fuel. 2023;333(Part 2):126416. https://doi.org/10.1016/j.fuel.2022.126416

[11] Abati, S.M., Bamisaye, A., Adaramaja, AA., Ige, AR., Adegoke, KA., Ogunbiyi, EO., Idowu, MA., Olabintan, AB., Saleh, TA. Biodiesel production from spent vegetable oil with Al2O3 and Fe2O3-biobased heterogenous nanocatalysts: Comparative and optimization studies. Fuel. 2024;364:130847. https://doi.org/10.1016/j.fuel.2023.130847

[12] Uslu, S., Maki, DF., Al-Gburi, ASK. Synthesis of spirulina microalgae biodiesel, and experimental research of its effects on compression ignition engine responses with iron II-III oxide (Fe3O4) nanoparticle supplementation. Energy Convers Manag. 2023;293:117457. https://doi.org/10.1016/j.enconman.2023.117457

[13] Aminzadegan, S., Shahriari, M., Mehranfar, F., Abramovic, B. Factors affecting the emission of pollutants in different types of transportation: A literature review. Energy Reports. 2022;8:2508–29. https://doi.org/10.1016/j.egyr.2022.01.161

[14] Javanmard, ME., Tang, Y., Wang, Z., Tontiwachwuthikul, P. Forecast energy demand, CO2 emissions and energy resource impacts for the transportation sector. Appl Energy. 2023;338:120830. https://doi.org/10.1016/j.apenergy.2023.120830

[15] Oloyede, CT., Itabiyi, OE., Popoola, OA., Jekayinfa, SO., Olaniyan, MA., Adebayo, AO., Ogunkunle, O., Zamri, MFMA., Fattah, IMR. Navigating prospects and challenges for green fuels for achieving economical, environmental and ecological resilience: a scientific review. Biofuels. 2023;15(7):929–41. https://doi.org/10.1080/17597269.2023.2299090

[16] Musthafa, B., Saravanan, B., Asokan, MA., Devendiran, S., Venkatesan, K. Effect of ethanol, propanol and butanol on karanja biodiesel with vegetable oil fuelled in a single cylinder diesel engine. Egypt J Pet. 2023;32(2):35–40. https://doi.org/10.1016/j.ejpe.2023.05.001

[17] Gebremeskel, AF., Ngoda, PN., Kamau-Mbuthia, EW., Mahungu, SM. The Sesame (Sesamum indicum L.) Value Chain and Microbiological Quality of Crude Sesame Oil, a Case Study in Western Tigray, Ethiopia. Food Nutr Sci. 2021;12(12):1306–25. https://doi.org/10.4236/fns.2021.1212096

[18] Bded, AS., Ahmad, MA. Enhancing Heavy Crude Oil Flowability Using Vegetable Sesame Oil Extract as Bio-additives. Arab J Sci Eng. 2024;49:8459–74. https://doi.org/10.1007/s13369-024-08953-3

[19] Chizoo, E., Okechukwu, MF., Dominic, OO., Kingsley, AA., Chimamkpam, AS., Mariagorretti, MC., Chinonso, EP. Renewable diesel synthesis from sesame indicum (bene) seed oil using novel heterogeneous biocatalyst derived from the Chrysophyllum albidium seed coat. Heliyon. 2023;9(11):22006. https://doi.org/10.1016/j.heliyon.2023.e22006

[20] Santos, TK., Siqueira, JAC., Santos, RF., Bassegio, D., de Souza SNM. Performance And Emission Characteristics Of Sesame Biodiesel Blends In Diesel Engine. Eng Agrícola. 2023;43(5). https://doi.org/10.1590/1809-4430 Eng.Agric.v43n5e20220229/2023

[21] John, JG., Hariram, V., Sooryanarayanan, S., Subramaniam, GS., Osborn, JRB., Christo, AC., Seralathan, S. Impact of varying the compression ratio on the combustion phenomenon of the diesel engine when fuelled with sesame biodiesel. Mater Today Proc. 2020;33(7):3715–21. https://doi.org/10.1016/j.matpr.2020.06.133

[22] Tejesh, P., Kotebavi, V., Shyam, P., Prasad PSD. Performance and Emission Characteristics of a CI Engine Fuelled with Palm and Sesame Oil Blended Diesel. Int J Veh Struct Syst. 2018;10(5):342–6. https://doi.org/10.4273/ijvss.10.5.07

[23] Yilmaz, A., Dede, G., Ozcanlı, M., Serin, H. Thermodynamic analysis of a diesel engine fueled with diesel and sesame oil biodiesel. J Biotechnol. 2016;231:47. https://doi.org/10.1016/j.jbiotec.2016.05.180

[24] Paneerselvam, P., Panithasan, MS., Venkadesan, G. RSM optimization of ultrasound-assisted melia dubia oil extraction with green solvents and their suitability for diesel engine applications. Renew Energy. 2024;222:119925. https://doi.org/10.1016/j.renene.2023.119925

[25] Yesilyurt, MK., Uslu, S., Yaman H. Modeling of a port fuel injection spark-ignition engine with different compression ratios using methanol blends with the response surface methodology. Proc Inst Mech Eng Part E J Process Mech Eng. 2023;237(3):936–44. https://doi.org/10.1177/095440892211123

[26] Simsek S, Uslu S, Simsek H, Uslu G. Improving the combustion process by determining the optimum percentage of liquefied petroleum gas (LPG) via response surface methodology (RSM) in a spark ignition (SI) engine running on gasoline-LPG blends. Fuel Processing Technology 2021;221:106947. https://doi.org/10.1016/j.fuproc.2021.106947

[27] Kumar, M., Gautam, R., Ansari, NA. Performance characteristics optimization of CRDI engine fuelled with a blend of sesame oil methyl ester and diesel fuel using response surface methodology approach. Front Mech Eng. 2023;9. https://doi.org/10.3389/fmech.2023.1049571

[28] Simsek, S., Uslu, S., Simsek H. Response surface methodology-based parameter optimization of single-cylinder diesel engine fueled with graphene oxide dosed sesame oil/diesel fuel blend. Energy AI. 2022;10:100200. https://doi.org/10.1016/j.egyai.2022.100200

[29] Bajwa, W., Ikram, A., Malik, MAI., Razzaq, L., Khan, AR., Latif, A., Hussain, F., Qazi, A. Optimization of biodiesel yield from waste cooking oil and sesame oil using RSM and ANN techniques. Heliyon. 2024;10(15):34804. https://doi.org/10.1016/j.heliyon.2024.e34804

[30] Ghanbari, M., Mozafari-Vanani, L., Dehghani-Soufi, M., Jahanbakhshi, A. Effect of alumina nanoparticles as additive with diesel–biodiesel blends on performance and emission characteristic of a six-cylinder diesel engine using response surface methodology (RSM). Energy Convers Manag X. 2021;11:100091. https://doi.org/10.1016/j.ecmx.2021.100091

[31] Pali, HS., Sharma, A., Kumar, M., Annakodi, VA., Nguyen, VN., Singh, NK., Singh, Y., Balasubramabian, D., Deepanraj, B., Truong, T.H., Nguyen, P.Q.P. Enhancement of combustion characteristics of waste cooking oil biodiesel using TiO2 nanofluid blends through RSM. Fuel. 2023;331(Part 1):125681. https://doi.org/10.1016/j.fuel.2022.125681

[32] Çalhan, R., Ergani, SK., Uslu S., Synthesis of Fe–Ni–TiO2/activated carbon nanoparticles and evaluation of catalytic activity in a palm oil/diesel fuel blended diesel engine and optimization with RSM. Sci Technol Energy Transit. 2023;78(16). https://doi.org/10.2516/stet/2023013

[33] Yaman, H, Yesilyurt, MK, Uslu, S., Simultaneous optimization of multiple engine parameters of a 1-heptanol / gasoline fuel blends operated a port-fuel injection spark-ignition engine using response surface methodology approach. Energy. 2022;238(Part C):122019. https://doi.org/10.1016/j.energy.2021.122019

[34] Simsek, S., Uslu, S., Simsek, H., Uslu, G. Multi-objective-optimization of process parameters of diesel engine fueled with biodiesel/2-ethylhexyl nitrate by using Taguchi method. Energy. 2021;231:120866. https://doi.org/10.1016/j.energy.2021.120866
[35] Uday, RSS. and Simhadri, K., Performance and Emission Characteristics of Four Stroke Diesel Engine Using Sesame Biodiesel Blends with Addition of TiO2 Nano-Particles. IOP Conference Series: Materials Science and Engineering. 2020;954:012032. https://doi.org/10.1088/1757-899X/954/1/012032
[36] John, JG., Hariram, V., Sooryanarayanan, S., Subramaniam, GS., Osborn, JRB., Christo, AC., Seralathan, S., Impact of varying the compression ratio on the combustion phenomenon of the diesel engine when fuelled with sesame biodiesel. Materials Today: Proceedings.2020;33(7):3715-3721. https://doi.org/10.1016/j.matpr.2020.06.133