MULTIDISCIPLINARY SCIENCE JOURNAL

RESEARCH ARTICLE
Published Online: March 29, 2023
https://doi.org/10.31893/multiscience.2023015

Influential study of oxygenated additives in waste cooking biodiesel blends on diesel engine performance

S. Padmanabhan[a] | M. Selvamuthukumar[b] | S. Mahalingam[c] | K. Giridharan[d] | S. Ganesan[e]

[a]School of Mechanical and Construction, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India.
[b]Department of Applied Engineering, Vignan's Foundation for Science, Technology and Research, Vadlamudi, Andhra Pradesh, India.
[c]Department of Mechanical Engineering, Sona College of Technology, Salem, India.
[d]Department of Mechanical Engineering, Easwari Engineering College, Chennai, India.
[e]School of Mechanical Engineering, Sathyabama Institute of Science and Technology, Chennai, India.

Abstract The rapid increase in energy demand brought on by the global population boom has led to a surge in the popularity of recycling waste materials into usable energy sources. That is to say, turning trash into usable energy will soon be a hot topic. More and more people are becoming aware of the benefits of biodiesel as a way to lessen their environmental impact by replacing their regular diesel fuel with a cleaner alternative. Usually, biodiesel is produced by mixing vegetable oils with animal-based oils. Because of its low production cost and low environmental impact, waste cooking oil (WCO) is suitable for biodiesel research. Using oxygenated fuels appears to be a practical strategy for lowering engine pollution. The purpose of this study is to examine the effects of varying ratio of diethyl ether (DEE) additives and waste cooking oil biodiesel on the efficiency and emissions of a diesel engine. Emission parameters were evaluated in comparison to those of pure diesel, and results were optimized for various load conditions and mixtures of oxygenated additives. The engine efficiency of WCO and DEE blends of 20% was found to be around 5.2% greater than that of standard diesel, while fuel consumption was reduced by 15%. Additionally, additives lowered CO emissions by 7-9% and HC emissions by 9%. The data were subsequently evaluated using the design of experiment tool, "Full Factorial Design" to establish the most optimal running condition with fuel consumption of 0.2720 kg/kWh, hydrocarbon of 50 ppm and carbon monoxide 0.277% at maximum load circumstances by the 20% fuel mixes.

Keywords: waste to energy, waste cooking oil, biodiesel, diesel engine, emission, optimization

1. Introduction

The lack of renewable energy and the consequences of global warming are the two biggest problems facing humanity in the twenty-first century. Increases in both population and per capita income have resulted in a dramatic increase in the global demand for energy. Effective utilization of energy resources is fundamental to human progress because of its profound impact on improving people's standard of living. Access to sufficient energy sources is crucial to economic development in any country. All sectors of society, including farming, manufacturing, shipping, shopping, and households, require some type of energy (Panwar et al 2011). The rising usage of fossil fuels to meet the high energy needs of industrialized countries and the residential sector has resulted in new environmental contamination issues. The generation of electricity from fossil fuels has a number of concerns for human health and the environment and may have long-term implications for global climate change (Degfie et al 2019). Since there has been a rise in environmental concerns, scientists are actively investigating renewable energy options. Some examples of renewable energy are wind, hydropower, solar electricity, biomass, and biofuels. Biodiesel is one potential solution to the problem of how to meet economic and environmental demands (Li et al 2014).

Alternatives to fossil fuels and the damage they cause to the environment are being researched, and biodiesel and diesel fuel blends are one of the possibilities being looked into. Transesterification of plant or animal lipids yields biodiesel, which can be used as a diesel fuel substitute. Waste cooking oil is seen as a competitive alternative to vegetable oil in the biodiesel industry due to its lower production costs (Venkatesh et al 2021). As an added bonus, turning WCO into a fuel source helps prevent the pollution that would result from dumping it. Because it uses recycled cooking oil and generates less pollution than alternative methods, WCO's biodiesel manufacturing is good for the environment. It's useful since it lessens the demand for importing petrochemical oil and minimizes the expense of treating garbage. Economics, ecology, and resource conservation are the three routes to biodiesel production from spent cooking oil (Phan and Phan 2008). The biodiesel from waste cooking oil and blended it with fossil fuel at varied ratios, then tested the performance and emissions of a diesel engine using this fuel. While utilizing a B30 gasoline blend decreased emissions of hydrocarbons (HC) and carbon monoxide (CO), it increased

 Received: December 23, 2022 | Accepted: February 13, 2023

emissions of nitrogen oxides (NOx). WCO biodiesel blends were found to negatively affect the performance of the turbocharged diesel engine (Senthur Prabu et al 2017).

Combustion and emission studies revealed a higher fuel consumption compared to exhaust emissions, although WCO use typically resulted in lower carbon and hydrocarbon emissions, and the nitrogen oxide generated by WCO was lower than by diesel fuel in most operational conditions (An et al 2013). The addition of WCO biodiesel to diesel blends increased the exhaust gas temperatures of these mixtures. Because spent cooking oil and its derivatives have a lower heating value, they require more fuel overall to provide the same amount of heat. As the biodiesel content of a blend increases, efficiency decreases. With a diesel engine, the researcher conducted an experimental investigation of combustion using WCO at values of 5% and 10%. Emissions of both smoke and hydrocarbons were found to have decreased, while emissions of nitrogen oxide increased. The fatty acid content of used cooking oils from different restaurants in the same area was found to vary, leading them to anticipate that biodiesel would also have a wide range of compositions depending on its source (Can 2014). Using diesel blended with WCO biodiesel, analyzed the effect on emissions from a diesel engine operating at a constant speed. Researchers found that using biodiesel reduced HC and CO emissions but increased NOx levels (Cheung et al 2015; Man et al 2015).

Di-ethyl ether was blended with jatropha biodiesel to boost ignition performance. For DEE10 and DEE20 mixes, it was found during performance testing that fuel consumption increased along with thermal efficiency (Raja et al 2022). It was attempted to optimize the system with the load condition and fuel as the restrictions. The usage of mahua methyl ester and diethyl ether as additives in a diesel engine was studied, along with the resulting engine exploration and exhaust emissions (Rao and Reddi 2020). When compared to the other fuels tested, a diesel-waste-plastic blend containing 10% DEE performed the best under the vast majority of engine loads. Changing the fuel type had no effect on the combustion time (Selvam et al 2022). For the purpose of evaluating bio seed cashew nut shell biodiesel, the cetane agitator dimethyl ether has been added to the engine research and emission requirements. They analyzed the combustion process and measured the levels of emissions produced by a diesel engine. Better thermal efficiency, lower fuel use, and fewer exhaust emissions were indicators of the boost in performance (Joshi and Thipse 2021). The oxygenated addition to assess the engine and emission analysis of plastic waste oil. The results indicated a marginal reduction in emissions of carbon, hydrocarbons, and nitrogen oxides (Sambandam Padmanabhan et al 2022).

There is a positive correlation between load, compression ratio, waste plastic oil, and ethanol in diesel, all of which contribute to greater thermal efficiency and fewer harmful emissions. ANOVA and multivariate analysis found the sweet spot for engine load, compression ratio, and fuel blend, which improved performance and reduced emissions (Das et al 2020). The thermal efficiency of braking and emissions were improved by using a compression ratio of 18.1, along with a blend of diesel fuel containing 20% WPO and 20% ethanol. There were three different amounts of WPO in the tertiary fuel mix, along with ethanol (Bhargavi et al 2022). Optimization of performance, emissions, and fuel economy were studied using a Full Factorial Design. DoE-based optimization using a three-factor full factorial trial design was utilised to achieve optimal pollution reduction and fuel economy. Statistically significant surface contour plots for carbon monoxide, hydrogen chloride, and fuel economy (S Padmanabhan et al 2022).

The purpose of this research is to examine the impact of a 20% and 40% diethyl ether ratio on biodiesel blends made from waste cooking oil and regular diesel. A single-cylinder diesel engine is analyzed for performance and emissions under different loads. For mixes of WCO and DEE, the best results in terms of fuel consumption, hydrocarbon emission, and carbon monoxide emission were achieved by the use of the experimental method "Full Factorial Design".

2. Materials and Methods

Using vegetable oils in diesel engines has led to operational and long-term reliability problems. They may be because vegetable oils are more dense and don't burn as easily. By transesterifying vegetable oils, it was possible to make them less thick while also getting rid of problems with their use and durability. The use of used cooking oils as a source of biodiesel is becoming more and more cost-effective. Used cooking oil might be a cheaper bio resource than edible vegetable oils because it doesn't affect the growth of food crops in any way. Waste cooking oil biodiesel, like biofuels made from seeds, is thicker and denser than regular diesel. However, it can meet the current fuel base requirements (Man et al 2015; Elnajjar et al 2022).

Diethyl ether was generally used as oxygenated additives in CI engines and was described as being very helpful in reducing the viscosity and density of pure biodiesel fuels because they have lower viscosity and density values than conventional diesel fuel. The lower viscosity of oxygenated additives as compared to diesel, allows for more efficient atomization of the fuel injected into the cylinders and better mixing with the surrounding air when oxygenated additives are combined with diesel. A significant amount of latent heat of evaporation exists in alcohol, which means that utilising oxygenated additives in a diesel engine by blending them with diesel is possible (Raja et al 2022). The most efficient technique for purifying biodiesel is liquid-liquid extraction using glycerol at 15 wt% and two-step contact. When evaluating different purification techniques, the after-treatment of the purifying agents is crucial. Soap, methanol, and glycerol can be successfully removed by all of the purification techniques that were examined. Density, kinematic viscosity, and glyceride concentration were unaffected by any of the approaches (Berrios et al 2011).

Some oxygenated additions can be used to improve the quality of biodiesel so that it is more comparable to diesel. For instance, biodiesel's viscosity is noticeably higher than that of diesel. Fuel injection efficiency can be decreased if the fuel's viscosity is increased, as this can increase the droplet size of the atomized fuel. Conversely, alcohols have a low viscosity. Alcohols are added to diesel-biodiesel blends to reduce the fuel's viscosity and bring it closer to that of diesel (S Padmanabhan et al 2022). Renewable-produced diethyl ether is an oxygenated renewable fuel that may be derived from biomass and is used as an ingredient in ethanol. Through a process called transesterification, any type of vegetable oil can be converted into biodiesel. Vegetable oil, along with an alcohol such as methanol or ethanol and a catalyst, undergoes a chemical reaction known as transesterification (Amenaghawon et al 2022). Vegetable oil undergoes a chemical process that breaks it down into smaller molecules. Biodiesel begins as triglycerides, which are transformed into alkyl esters. If methanol is employed, the resulting product is a methyl ester, while ethanol yields an ethyl ester. The chemical makeup of these two biodiesel fuels is different. Glycerin is produced during the chemical process and must be separated from biodiesel before it can be used. Glycerin's phase in the fluid might cause it to float to the surface or sink to the bottom. Not only is that, but the process of separating it using centrifuges is known as "transesterification." Biodiesel, the product of transesterification, has a lower viscosity than regular diesel fuel and can therefore be used in diesel engines (Suzihaque et al 2022). The properties of waste cooking biodiesel and diethyl ether are tabulated in Table 1.

Table 1 Properties of WCO and DEE.

Sl.No	Fuel Property	Diesel	WCO	DEE
1	Density, at 15 °C (g/m^3)	0.843	0.882	0.710
2	Viscosity, at 40 °C (cSt)	2.45	4.99	0.23
3	Lowest heating Value, (MJ/kg)	42.31	35.82	33.9
4	Flash Point, (°C)	61	162	-40
5	Oxygen (wt %)	0	11	21
6	Carbon (wt %)	86	72	64
7	Hydrogen (wt %)	13	10	13.5
8	Cetane Index	54	47	125

2.1. Experimental Details

Figure 1 shows a single-cylinder, constant-speed, direct-injection engine was used to test waste cooking oil biodiesel blends. The speed of the diesel engine is not affected by either the load or the percentage of biodiesel mix that is being used. The engine was connected to an eddy current dynamometer, which allowed for the loads to be varied anywhere from 0% to 100% of its maximum capacity. According to the 4.4 kW power output of the engine, the load was increased by 25%, 50%, 75%, and 100% for each of the mixes that were put through the testing process. In order to make manual adjustments to the engine loads, an eddy current dynamometer, which measures the flow of current, is utilized. During this investigation, the rate of airflow was studied with the help of a calibrated burette, and the rate of fuel flow was determined with the help of a calibrated orifice that was mounted on an air drum. The fuel flow was measured using two different fuel tanks, one filled with regular diesel and the other with biodiesel that had been esterified. Both fuel tanks were used for the measurement. The testing apparatus was outfitted with AVL software, which enabled the collection of a variety of readings and results even while the machine was functioning normally. Table 2 represents the experimental measurements, instruments, and parameters.

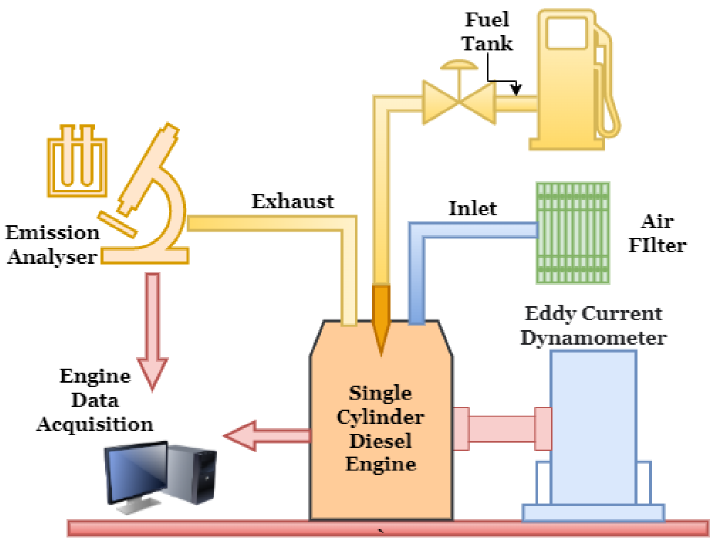

Figure 1 Experimental engine setup.

Table 2 Experimental measurement and its parameters.

Sl. No	Measurement	Range	Accuracy	Percentage of Uncertainty	Instrument
1	Hydrocarbon	0 to 10000 ppm	± 5 ppm	± 0.15	AVL Gas Analyser
2	Carbon monoxide	0 to 20%	± 0.05%	± 0.15	AVL Gas Analyser
3	Nitrogen Oxides	0 to 10000 ppm	± 20 ppm	± 0.15	AVL Gas Analyser
4	Engine Power	0.1 to 4.4kW	± 0.05 kW	± 0.50	Load cell
5	Crank Speed	0- 10000 rpm	± 10 rpm	± 0.50	Digital tachometer
6	Fuel Quantity	0-50 cm^3	± 0.1 cm^3	± 0.50	Burette Measurement

This study focuses on energy recovery from waste cooking oil as the alternative fuel source via the waste utilization approach. In this study, a novel fuel blending method used palm oil and sunflower oil in an equal ratio as the source of waste cooking oil extraction to use as testing fuel. Waste cooking oil obtained from the transesterification process of vegetable oil was blended with diesel at different ratios of 20% and 40% on a volume basis, along with oxygenated additives of diethyl ether. The biodiesel fuel, named D70W20DEE10, is formed by the blends of 20% Waste Cooking Oil biodiesel, 10% diethyl ether on a volume basis mixed with pure diesel of 70%. The biodiesel fuel blends prepared as D50W40DEE10 (50% diesel + 40% WCO+ 10% DEE), D60W20DEE20 (60% diesel + 20% WCO+ 20% DEE), and D40W40DEE20 (40% diesel + 40% WCO+ 20% DEE).

3. Results and discussion

3.1 Performance Characterizes

It can be observed in Figure 2 that the Brake Thermal Efficiency (BTE) had an effect on the engine's maximum output power. At maximum load condition, the BTE of D70W20DEE10, D50W40DEE10, D60W20DEE20, and D40W40DEE20 were 28.88 %, 28.18 %, 30.54 %, and 28.66 %, respectively. The thermal brake efficiency of D60W20DEE20 was found to be about 5.2 % higher than that of pure diesel when tested under maximum load conditions. A higher oxygen concentration in DEE means that it will burn more efficiently, resulting in increased thermal performance (Raja et al 2022). Because of the higher viscosity and resulting lower combustion rate caused by the high content of DEE in the mix, the BTE is lower than that of WCO40.

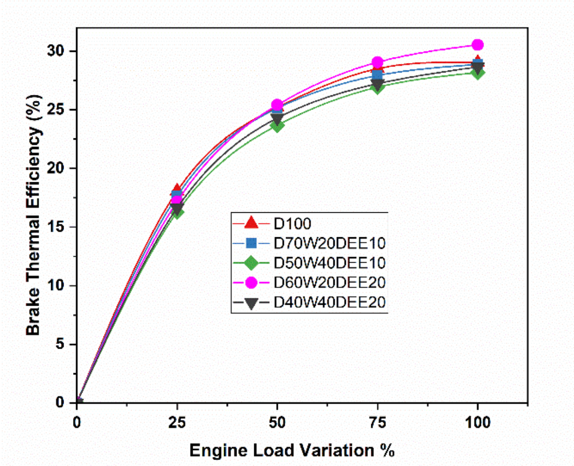

Figure 2 Effect of DEE on WCO's brake thermal efficiency.

It was determined that the rise in specific fuel consumption (SFC) was due to the increase in injected fuel that occurred concurrently with the increase in load. As can be seen in Figure 3, the SFC drops with increasing engine load and DEE ratios. Both D50W40DEE10 and D40W60DEE20 have greater SFC values than diesel. The more oil mixes that are used in place of diesel oil to get the same output power, the more fuel is consumed. Consequently, the fuel injected into the combustion chamber had smaller droplet sizes, less fuel penetration, incorrect fuel-air mixing, and decreased combustion efficiency because of the lower viscosities of the oil mixes (Hwang et al 2016). Blends of D70W20DEE10 and D60W20DEE20 achieved SFC reductions of 8.75% and 15%, respectively, compared to diesel, while blends of WCO40 achieved SFC reductions of 6.25 percent and 12.5%, respectively, compared to diesel.

3.2 Emission Characteristics

CO emissions are shown as a function of engine load in Figure 4 for blends of D70W20DEE10, D50W40DEE10, D60W20DEE20, and D40W40DEE20. Reducing the equivalency ratio and increasing the in-cylinder temperatures of WCO20s results in fewer CO emissions. Due to the rich fuel mixture at WCO40 and DEE blends, large levels of CO were reported to be generated during both start and full load conditions. From low to half load, CO2 emissions decrease for all WCO blends before increasing dramatically from there to full power. At varying loads, the D60W20DEE20 reduced carbon monoxide emissions by 7–9 percent compared to the diesel engine. Less carbon dioxide was released as a result of the lower C/H ratio. When the mix ratio was increased, carbon monoxide levels were reduced. Reduced carbon emissions can be attributed to DEE's enhanced atomization, combustion efficiency, and vaporization compared to those of pure diesel (Degfie et al 2019).

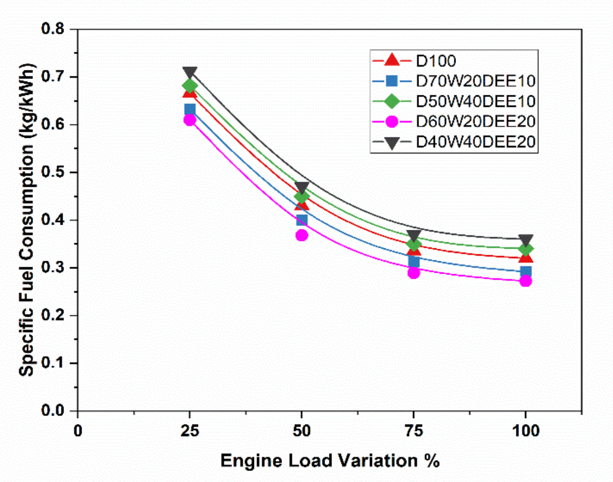

Figure 3 Effect of DEE on WCO's specific fuel consumption.

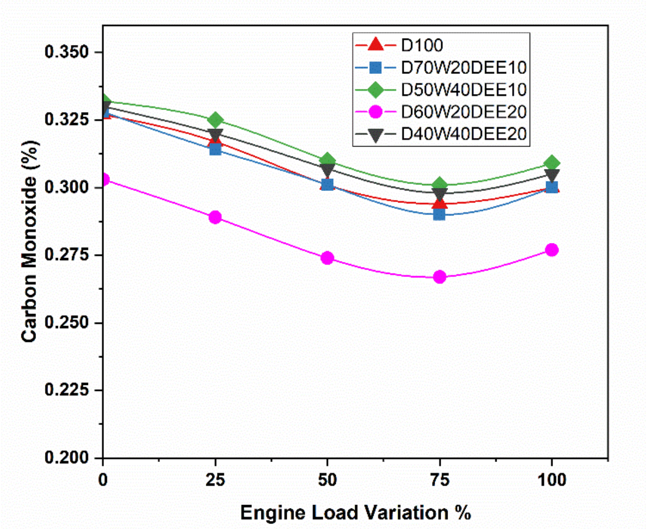

Figure 4 Effect of DEE on WCO's Carbon Monoxide emission.

Unburned hydrocarbon emissions and engine load for WCO and DEE blends are shown in Figure 5. A higher volume of fuel being injected into the engine is responsible for the increase in HC emissions seen in response to increased engine load at all blending ratios. Mixes of D70W20DEE10 and D60W20DEE20 reduced HC emissions by 2% and 9%, respectively, compared to pure diesel, while WCO40 blends attained 3% and 12% increased hydrocarbon emissions compared to diesel. This is because the flame quench has increased as cylinder temperatures have risen. However, the extremely low viscosity of the oil, which caused smaller droplet sizes and impeded diffusion, contributed to an increase in HC concentrations as the oil blending ratio was raised (Sambandam et al 2022). As a result of the poor fuel-air mixture, combustion efficiency dropped, and HC emissions rose. Increased HC emissions and decreased vaporization and spray penetration were the results of the WCO40 mixes' higher viscosity (Erchamo et al 2021).

As shown in Figure 6, the quantities of nitrogen oxides in oil mixtures changed in response to varying engine loads. Increased engine load was attributed to the rise in NOx emissions as a result of increased fuel consumption. The NOx emissions of D70W20DEE10, D50W40DEE10, and D60W20DEE20 are 4.2%, 5.5%, 6.8%, and 13.4% higher than those of diesel, respectively. Combustion temperature, time, fuel nitrogen content, and air oxygen content all play a role in the amount of nitrogen oxides (NOx) released into the atmosphere. Some of the variables that affect the total amount of nitrogen oxides produced are the temperature of the combustion chamber, the oxygen content, the amount of supplementary air, and the duration of the combustion process. The principal source of the pollutant is NOx, which is created when oxygen and nitrogen react. The combustion temperature rises, and more NOx is produced at higher oxygen concentrations (Hwang et al 2016).

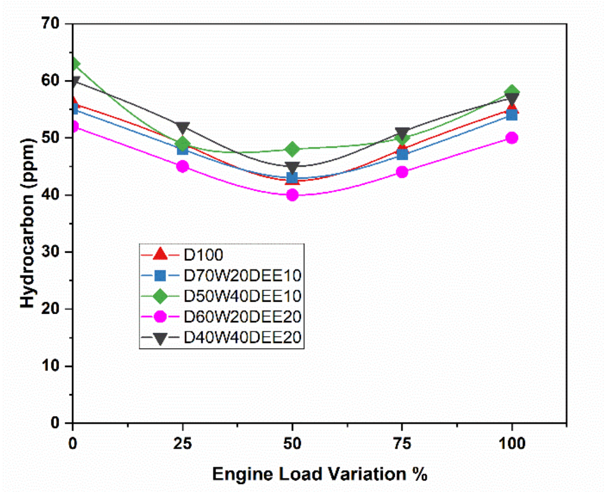

Figure 5 Effect of DEE on WCO's hydrocarbon emission

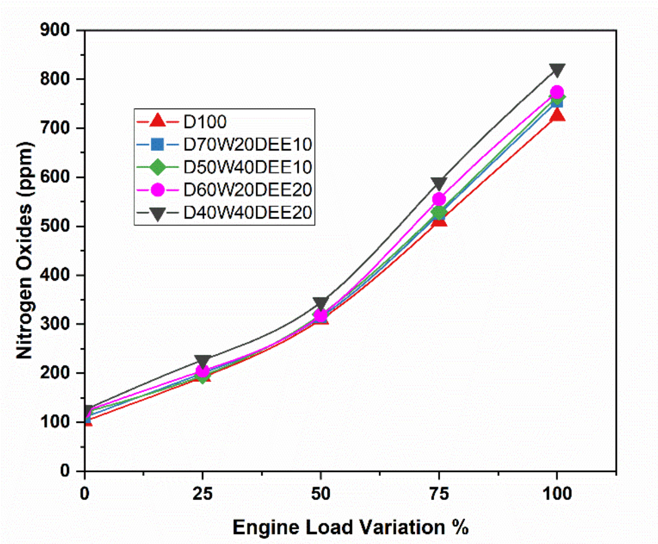

Figure 6 Effect of DEE on WCO's Nitrogen Oxide Emission.

3.3 Optimization of WCO and DEE blend ratio on Emission

Design of Experiment (DOE) is frequently utilized in process improvement to provide the most exhaustive solution to a solvable issue. In contrast to the conventional approach, this strategy employs statistical data acquired from a small number of trials to predict the knowledge and outcomes of a complicated and multivariable process that is now underway. DOE is the most prevalent numerical method for optimizing results compared to all other research methods. Full Factorial Design (FFD) is an analytical and systematic strategy for evaluating the key effects and interactions in research projects (Padmanabhan et al 2022; Ganesan et al 2022). A number of process parameters and their corresponding levels were required to develop a complete factorial model for the study investigation. In this study, the impact of WCO and DEE on fuel consumption and CO and HC emissions was examined.

The DEE has a positive effect on fuel consumption and emissions, with the lowest value attained at 20% DEE mix. This is considered to be associated to a faster combustion rate due to a higher oxygen concentration in the DEE. Additionally, because WCO has a greater viscosity, emissions have increased when the blend ratio has been increased, which has led to a decrease in the burning effect. This is because the higher viscosity of WCO is a result of the higher viscosity of WCO. There is a correlation between an increase in the DEE ratio and a decrease in emissions, with the lowest levels of carbon monoxide and hydrocarbon emissions formed at 20% of the DEE ratio. This is primarily because of the higher rate of combustion that occurs at this ratio, which is the most significant factor. Because of the more oxygenated mixture that is formed as a result of using a 20% blend of WCO and DEE, the amount of CO and HC that is produced is decreased (Bhargavi et al 2022). This is made possible by the fact that the combustion process is aided in its completion by using the WCO and DEE. Because WCO fuel has a higher viscosity than conventional fossil fuel, the quantity of hazardous pollutants discharged increases as the WCO ratio increases. This phenomenon arises as a result of faulty fuel combination and spray creation, which leads to incomplete combustion as the blend ratio increases. This phenomenon is caused by poor fuel combination and spray formation. According to the contour plots (Figures 7, 8, and 9), the most significant influence on the ability of the engine to operate with the fewest possible emissions and the most efficient use of fuel is exerted by the DEE blend at its highest concentration, while the minimum blend of WCO has the opposite effect.

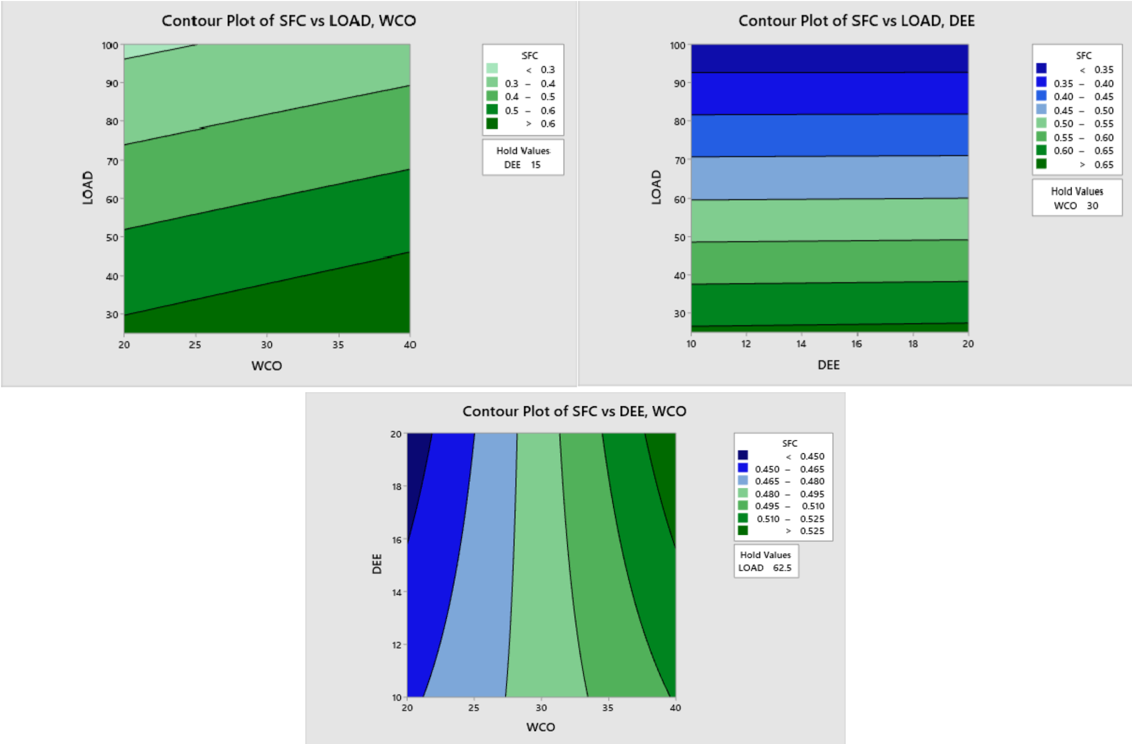

Figure 7 Influence of WCO and DEE blend on SFC

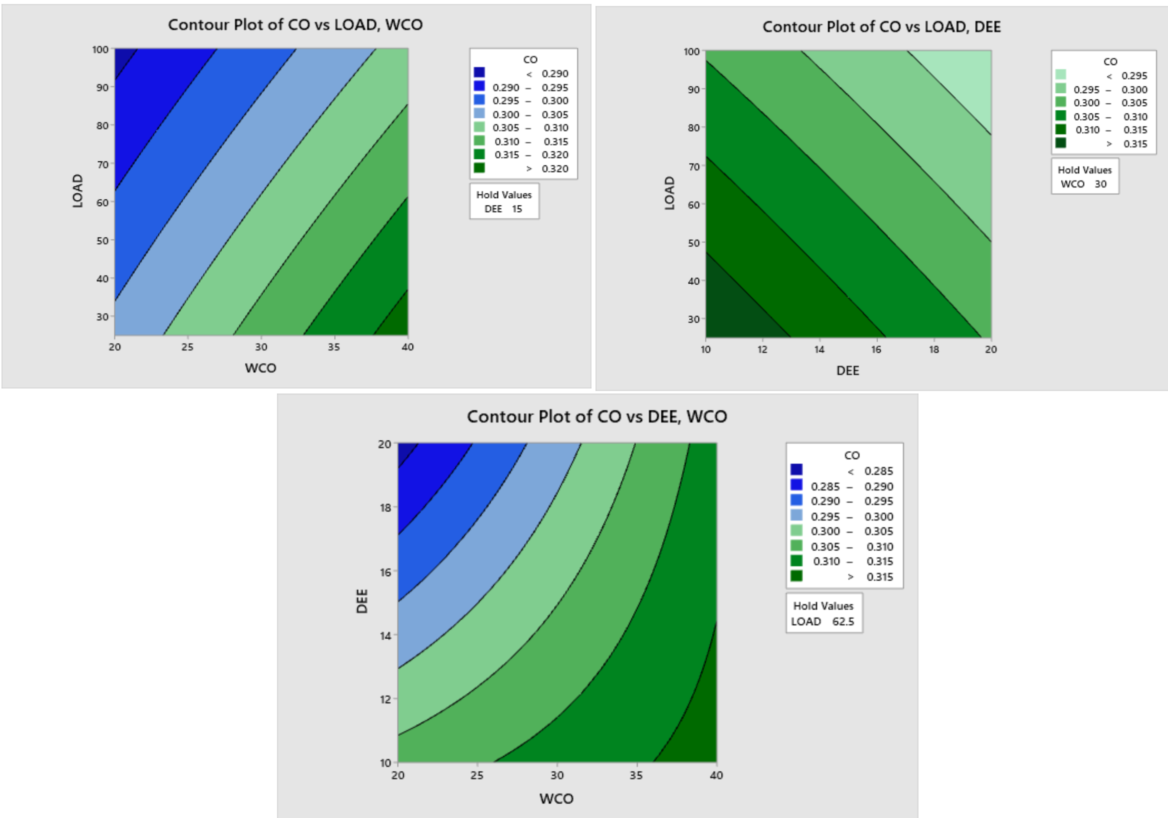

Figure 8 Influence of WCO and DEE blend on CO emission

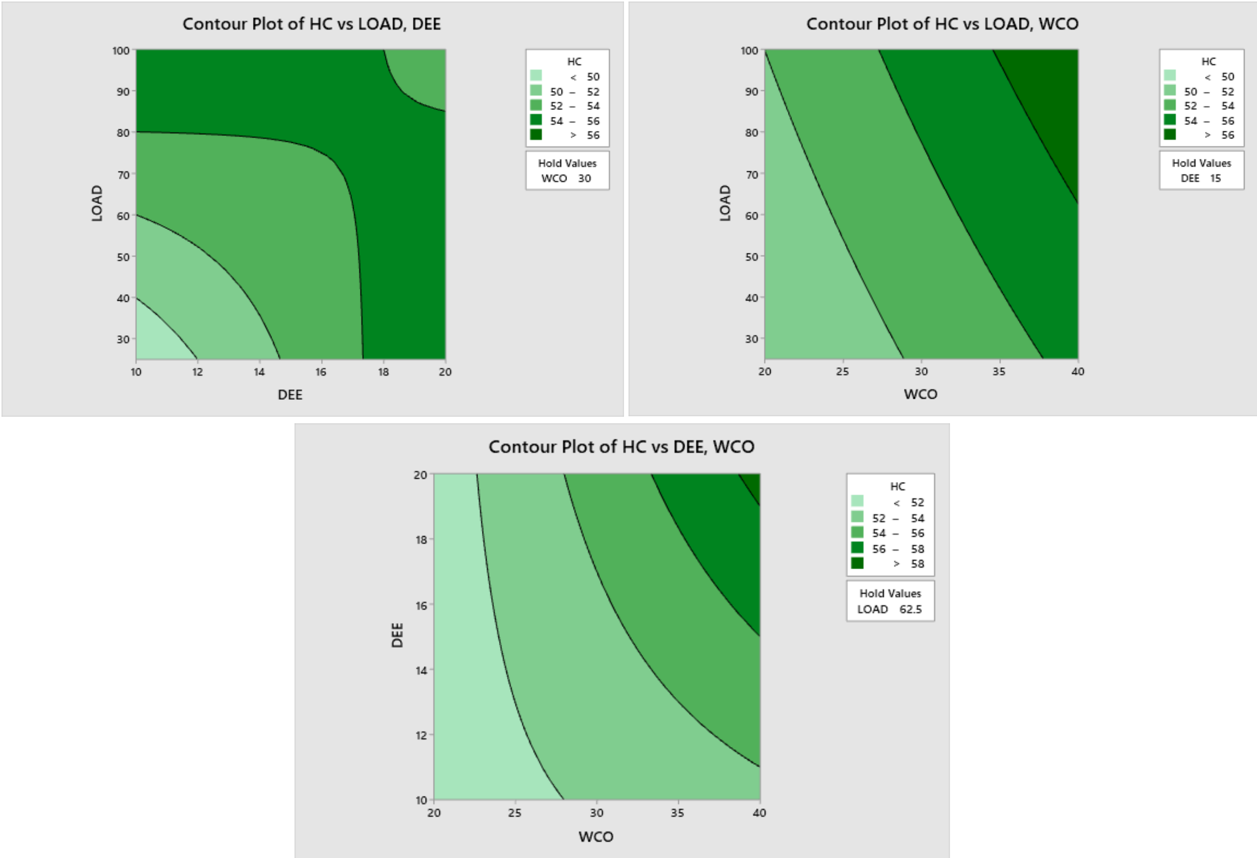

Figure 9 Influence of WCO and DEE blend on HC emission

3.4 Response Optimization of SFC, CO, and HC

Response optimization examines the connection between different types of input factors and the optimal combination of those parameters in order to enhance the quality of an answer or a set of responses. For each possible combination of input variables, the response optimizer feature of statistical analysis software generates an optimization graphic that displays the optimal solution (Sambandam Padmanabhan et al 2022). The visual used for optimization may or may not have any sort of interactivity. Changing the values of the input variables can be a useful strategy for enhancing an optimization problem.

The response optimizer Table 3 and Figure 10 indicate that the lowest blend ratio of WCO at the highest DEE additive is obtained to be best for attaining low exhaust emissions and the lowest fuel consumption under maximum loading circumstances, and this conclusion is supported by the results. At these blend ratios, total combustion occurs as a result of a faster combustion rate and a higher oxygenated mixture, resulting in incomplete combustion. All reactions will improve if the WCO/DEE combination is increased. To a much lesser extent than CO and HC emissions, however, was the impact felt on SFC. Therefore, the best settings of the WCO and DEE mix were at the minimal levels in the experiment when reducing the composite's appeal. Based on these findings, researchers may want to try out other blend ratios of WCO and DEE to see if they improve engine performance. Increasing the load on the engine reduces SFC and CO emissions while slightly increasing HC emissions. During the testing, the maximum load condition yielded the best SFC and CO settings. This finding hints that attempting to boost the engine's load might increase its efficiency.The best conditions for achieving these results are when the engine is filled with fuel and a combination of 20 % WCO and DEE with the diesel fuel blend, respectively. When operating at maximum load, the ideal minimal emissions generated by a 20 % WCO and DEE mix are CO at 0.277 % and HC at 50 parts per million. Under identical operating conditions, the lowest feasible fuel usage of 0.2720 kg/kWh was achieved.

Table 3 Response Optimized results of HC, CO and SFC.

Solution	WCO	DEE	LOAD	HC Fit	CO Fit	SFC Fit	Composite Desirability
1	20.0000	20.0000	100	50.0000	0.277000	0.272000	0.980144

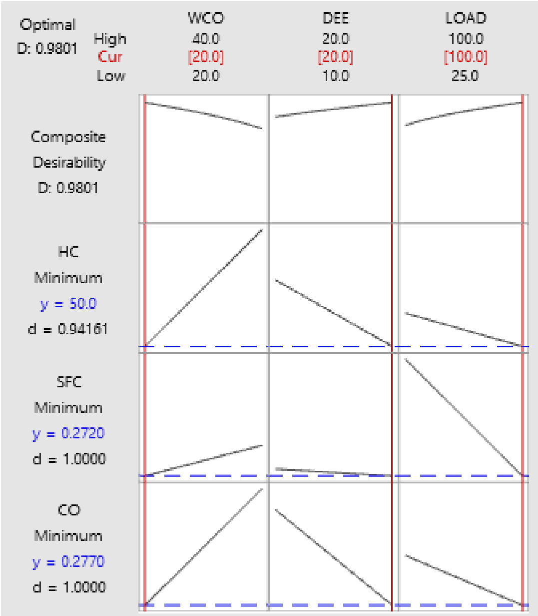

Figure 10 Optimization plot for HC, CO, and SFC

4. Conclusions

Biodiesel has recently acquired appeal as a way to minimize pollution from the combustion of fossil fuels. Waste cooking oil is the best material for biodiesel production because it is inexpensive and reduces waste. It is viable to use oxygenated fuels to reduce diesel emissions. In this investigation, a diesel engine operated with varying levels of diethyl ether additives and biodiesel made from waste cooking oil. The following observations were made during the investigation of waste cooking oil for biodiesel:

Under maximum load conditions, it was determined that the thermal efficiency of D60W20DEE20 brakes was approximately 5.2% higher than that of pure diesel. D70W20DEE10 and D60W20DEE20 blends obtained 8.75% and 15% lower SFC than diesel, respectively, whereas WCO40 blends achieved 6.25 and 12.5% higher fuel consumption than diesel, respectively. D70W20DEE10 and D60W20DEE20 blends reduced HC emissions by 2% and 9%, respectively, compared to diesel; however, WCO40 blends increased hydrocarbon emissions compared to diesel.

Compared to the diesel engine, the D60W20DEE20 had lower carbon monoxide emissions by between 7% and 9%, depending on the load. D70W20DEE10, D50W40DEE10, and D60W20DEE20 have NOx emissions that are 4.2%, 5.5%, 6.8%, and 13.4% greater than diesel, respectively. When the engine is fully loaded and a 20% blend of WCO and DEE is added to diesel fuel, the best results are obtained with the DEE. At maximum load, the optimal minimal CO and HC emissions from a 20% WCO and DEE blend are 0.277% and 50 ppm, respectively. At the same operating conditions, the lowest achievable fuel usage of 0.2720 kg/kWh was attained. A bio-economy requires the recycling of organic materials into valuable fuel and materials. Integration of recycling and bioconversion for enhanced process performance is also assessed. The goal of this work is to make it easier to recycle bio-waste for use in closed-loop systems. Biofuels reduce global warming by using the planet's carbon cycle. Biofuel reduces greenhouse gas emissions by one gallon per gallon.

Ethical considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflict of interest.

Funding

This research did not receive any financial support.

References

Amenaghawon AN, Obahiagbon K, Isesele V, Usman F (2022) Optimized biodiesel production from waste cooking oil using a functionalized bio-based heterogeneous catalyst. Clean Eng Technol 8:100501. DOI: 10.1016/j.clet.2022.100501

An H, Yang WM, Maghbouli A, Li J, Chou SK, Chua KJ (2013) Performance, combustion and emission characteristics of biodiesel derived from waste cooking oils. Appl Energy 112:493–499. DOI: 10.1016/j.apenergy.2012.12.044

Berrios M, Martín MA, Chica AF, Martín A (2011) Purification of biodiesel from used cooking oils. Appl Energy 88:3625–3631. DOI: 10.1016/j.apenergy.2011.04.060

Bhargavi M, Vinod Kumar T, Ali Azmath Shaik R, Kishore Kanna S, Padmanabhan S (2022) Effective utilization and optimization of waste plastic oil with ethanol additive in diesel engine using full factorial design. Mater Today Proc 52:930–936. DOI: 10.1016/j.matpr.2021.10.310

Can Ö (2014) Combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a waste cooking oil biodiesel mixture. Energy Convers Manag 87:676–686. DOI: 10.1016/j.enconman.2014.07.066

Cheung CS, Man XJ, Fong KW, Tsang OK (2015) Effect of Waste Cooking Oil Biodiesel on the Emissions of a Diesel Engine. Energy Procedia 66:93–96. DOI: 10.1016/j.egypro.2015.02.050

Das AK, Padhi MR, Hansdah D, Panda AK (2020) Optimization of Engine Parameters and Ethanol Fuel Additive of a Diesel Engine Fuelled with Waste Plastic Oil Blended Diesel. Process Integr Optim Sustain 4:465–479. DOI: 10.1007/s41660-020-00134-7

Degfie TA, Mamo TT, Mekonnen YS (2019) Optimized Biodiesel Production from Waste Cooking Oil (WCO) using Calcium Oxide (CaO) Nano-catalyst. Sci Rep 9:18982. DOI: 10.1038/s41598-019-55403-4

Elnajjar E, Al-Omari SAB, Selim MYE, Purayil STP (2022) CI engine performance and emissions with waste cooking oil biodiesel boosted with hydrogen supplement under different load and engine parameters. Alexandria Eng J 61(6):4793–4805. DOI: 10.1016/j.aej.2021.10.039

Erchamo YS, Mamo TT, Workneh GA, Mekonnen YS (2021) Improved biodiesel production from waste cooking oil with mixed methanol–ethanol using enhanced eggshell-derived CaO nano-catalyst. Sci Rep 11(1):6708. DOI: 10.1038/s41598-021-86062-z

Ganesan S, Padmanabhan S, Hemanandh J, Venkatesan SP (2022) Influence of substrate temperature on coated engine piston head using multi-response optimisation techniques. Int J Ambient Energy 43(1):610–617. DOI: 10.1080/01430750.2019.1653988

Hwang J, Bae C, Gupta T (2016) Application of waste cooking oil (WCO) biodiesel in a compression ignition engine. Fuel 176:20–31. DOI: 10.1016/j.fuel.2016.02.058

Joshi MP, Thipse SS (2021) Combustion analysis of a compression-ignition engine fuelled with an algae biofuel blend and diethyl ether as an additive by using an artificial neural network. Biofuels 12(4):429–438. DOI: 10.1080/17597269.2018.1489675

Li M, Zheng Y, Chen Y, Zhu X (2014) Biodiesel production from waste cooking oil using a heterogeneous catalyst from pyrolyzed rice husk. Bioresour Technol . 154:345–348. DOI: 10.1016/j.biortech.2013.12.070

Man XJ, Cheung CS, Ning Z (2015) Effect of Diesel Engine Operating Conditions on the Particulate Size, Nanostructure and Oxidation Properties when Using Wasting Cooking Oil Biodiesel. Energy Procedia 66:37–40. DOI: 10.1016/j.egypro.2015.02.020

Padmanabhan Sambandam, Giridharan K, Stalin B, Kumaran S, Kavimani V, Nagaprasad N, Tesfaye Jule L, Krishnaraj R (2022) Energy recovery of waste plastics into diesel fuel with ethanol and ethoxy ethyl acetate additives on circular economy strategy. Sci Rep 12(1):5330. DOI: 10.1038/s41598-022-09148-2

Padmanabhan S, Kumar TV, Giridharan K, Stalin B, Nagaprasad N, Jule LT, Ramaswamy K (2022) An analysis of environment effect on ethanol blends with plastic fuel and blend optimization using a full factorial design. Sci Rep 12(1):21719. DOI: 10.1038/s41598-022-26046-9

Panwar NL, Kaushik SC, Kothari S (2011) Role of renewable energy sources in environmental protection: A review. Renew Sustain Energy Rev 15(3):1513–1524. DOI: 10.1016/j.rser.2010.11.037

Phan AN, Phan TM (2008) Biodiesel production from waste cooking oils. Fuel 87(17):3490–3496. DOI: 10.1016/j.fuel.2008.07.008

Raja K, Srinivasa Raman V, Parthasarathi R, Ranjitkumar K, Mohanavel V (2022) Performance analysis of DEE-Biodiesel blends in diesel engine. Int J Ambient Energy 43(1):1016–1020. DOI: 10.1080/01430750.2019.1670262

Rao KP, Reddi V (2020) Parametric optimization for performance and emissions of DI diesel engine with Mahua biodiesel along with Diethyl ether as an additive. Biofuels 11(1):37–47. DOI: 10.1080/17597269.2017.1338126

Sambandam P, Murugesan P, Thangaraj VK, Vadivel M, Rajaraman M, Subbiah G (2022) Environmental impact of waste plastic pyrolysis oil on insulated piston diesel engine with methoxyethyl acetate additive. Pet Sci Technol 1–18. DOI: 10.1080/10916466.2022.2092498

Selvam MAJ, Sambandam P, Sujeesh KJ (2022) Investigation of performance and emission characteristics of single-cylinder DI diesel engine with plastic pyrolysis oil and diethyl ether blends. Int J Ambient Energy 43(1):3810–3814. DOI: 10.1080/01430750.2020.1860127

Senthur Prabu S, Asokan MA, Roy R, Francis S, Sreelekh MK (2017) Performance, combustion and emission characteristics of diesel engine fuelled with waste cooking oil bio-diesel/diesel blends with additives. Energy 122:638–648. DOI: 10.1016/j.energy.2017.01.119

Suzihaque MUH, Alwi H, Kalthum Ibrahim U, Abdullah S, Haron N (2022) Biodiesel production from waste cooking oil: A brief review. Mater Today Proc 63:S490-S495. DOI: 10.1016/j.matpr.2022.04.527

Venkatesh AP, Muniyappan M, Joel C, Padmanabhan S (2021) Investigation on the effect of nanofluid on performance behaviour of a waste cooking oil on a small diesel engine. Int J Ambient Energy 42(5):540–545. DOI: 10.1080/01430750.2018.1557554