

# Influence of Nanomaterial on Biofuel Extracted from Lemon Seed Feedstock

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## Abstract

*Biodiesel, which is a type of biofuel, offers a replacement to the traditional diesel fuel currently available on the market, which is derived from petroleum that is both more sustainable for the environment and more attractive from an economic standpoint. A plethora of environmental benefits can be obtained through the utilization of this technology, including a reduction in emissions of greenhouse gases and particulate matter, as well as the possibility of biodegradability. Experiments were carried out on a Kirloskar engine, which was a compression-ignition engine with a single cylinder, four strokes, constant speed, and water cooling. These examinations were carried out with the assistance of an AVL smoke metre equipment as well as an AVL DI-gas analyser. Diesel fuel, emulsified biodiesel, and nano emulsified biodiesel were all subjects of the experiments that were carried out. Enhanced pollution characteristics were revealed by the reformulated fuel, which was demonstrated using emulsified lemon seed biodiesel and Nano emulsified biodiesel. A decrease in the amount of smoke emissions was observed from 46.2% to 44% at the time period of maximum power output, and there was also a reduction in oxides of nitrogen emissions from 520 ppm to 320 ppm: both of these reductions occurred simultaneously. The emulsified fuel was improved in terms of its performance properties as a result of the incorporation of nanoparticles of aluminium oxide. In general, the use of nano emulsified biodiesel that is created from lemon seeds is the most effective method for improving the efficiency of combustion and lowering emissions in compression ignition engines.*

**Keywords:** Nano materials, lemon seed biodiesel, aluminium oxide, performance, emissions

## INTRODUCTION

The combustion of fossil fuels results in a number of negative side effects, which is a key contributor to the progression of climate change and the acceleration of global warming. These side effects include the emission of greenhouse gases, the pollution of the air, the depletion of natural resources, concerns

regarding energy security, price volatility, restricted accessibility, excessive water usage, environmental degradation, health implications, and limited long-term sustainability [1]. In light of these effect, there is an increasing emphasis on a global scale on the shift towards energy sources that are cleaner and more sustainable, such as renewable technologies, nuclear power, and better energy efficiency techniques. This is a response to the fact that the current energy system is inefficient and polluting.

The fuel is created locally through the exploitation of waste materials and renewable resources, and it can be integrated easily into regular diesel engines without requiring any adjustments to

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be made [2-3]. Additionally, it offers benefits in terms of energy security, engine performance, and lubricity, hence offering market prospects for individuals working in the agricultural, processing, and transportation sectors. These individuals include farmers, business owners, and job seekers. The term "emulsified biodiesel" refers to a type of fuel mixture that includes both biodiesel and water, producing a stable amalgamation as a result of the combination. This method of mixing results in increased combustion efficiency, lower emissions, and lower levels of particulate matter emissions [4]. Because this kind of energy utilizes renewable resources in addition to having a renewable nature itself, there is less of a need to rely on energy that comes from fossil fuels. Researchers are currently looking into emulsifying agents that have a higher potential, as well as techniques to improve the emulsion process, stability, and performance [5]. It is possible for some nano-additives, such as catalysts, nano emulsions, nanofibers, nano sponges, antioxidants, and nano transporters, to improve the efficiency with which biodiesel is produced as well as its overall performance [6]. However, in order to guarantee the safety, cost-effectiveness, and environmental sustainability of the solution, it is necessary to do exhaustive research and thorough testing [7]. For the purpose of ensuring the safe and ongoing use of nano-additives in the synthesis of biodiesel, it is of the utmost importance to comply to the appropriate local norms and laws [8].

In the experiment, a rotational speed of 1500 revolutions per minute and a pressure of 210 bar were utilised. The engine was fuelled with sea mango biodiesel, and the boiling point decomposition concentration (bTDC) was set at 23. The engine was tested under a variety of load conditions, including 0, 3, 6, 9, and 12 kilogrammes, and at compression ratios of 16:1, 17:1, and 18:1. The findings of the study suggested that increasing the compression ratio of the engine would be beneficial. According to the findings, raising the compression ratio (CR) of an engine is favorable for the overall performance of the vehicle, as well as for the levels of emissions and combustion products produced by the engine [9]. In comparison to those with chain structures, oxygenated fuels with ring molecular structures have a tendency to produce a greater amount of soot. This is because the oxygenated effect is taken into consideration. However, the position of the oxygen functional group is another factor that plays a role in determining the soot emissions generated. After taking into account all of the repercussions, 2,5-dimethylfuran is the more successful option when it comes to achieving high efficiency and clean combustion at low temperatures [10]. Because biodiesel is not easily compressed, the injection delay was found to be slightly shorter than usual. Although biodiesel and diesel have distinct fuel properties, the biodiesel spray pattern is similar to that of diesel. Biodiesel exhibits higher surface tension compared to diesel, leading to greater SMD dispersion. Additionally, biodiesel's droplet momentum exceeds that of diesel, correlating with its spray velocity. This can be attributed to biodiesel's status as a more environmentally sustainable fuel. [11].

In the current body of study, the injection pressure has been taken into account, and the influence that it has on the biodiesel-diesel blend has been researched. For the purpose of the investigation, a single-cylinder compression ignition engine with direct injection and a horsepower rating of five was utilised. The engine was operated at a constant speed of 1500 revolutions per minute. The objective was to achieve enhanced atomization and optimize fuel efficiency. In order to achieve a higher atomization rate and more efficient exploitation of available air, a traditional spring-loaded injector has been switched out for an electronic fuel injection system [12-15]. The investigation of emulsified biodiesel and nano emulsified lemon seed biodiesel in an unmodified CI engine is the primary purpose of the work that is being done at the moment.

## **MATERIAL AND METHODS**

### **Lemon Seed Biodiesel**

During the process, the lemon seeds are first collected and then purified. After that, the seeds are dried out, then pulverised, and finally, the oil is extracted from the seeds. Maceration is a step that extends over a period of several hours or days and is a time-consuming process. The utilisation of a separator funnel or centrifuge is what helps to accomplish the separation process. A methoxide solution is added to the extracted lemon seed oil, and then the oil is heated to a temperature of seventy degrees

Celsius. This accomplishes the process of transesterification. A separate procedure is utilised in order to accomplish the separation of glycerol from the layer of biodiesel. After that, the biodiesel is put through a washing and drying process that involves water. This process will remove any pollutants and catalyst residues that may have been present, and a pH meter will be used to continuously monitor the pH level. This biodiesel has been properly dried, and it is now ready to be used in diesel engines. Alternatively, it can be stored for use in the future. It is shown in Figure 1 that lemon seed oil may be separated from lemon fruit. Diesel and lemon seed biodiesel are compared in terms of their qualities in Table 1.

### Nanomaterial - Aluminium Oxide

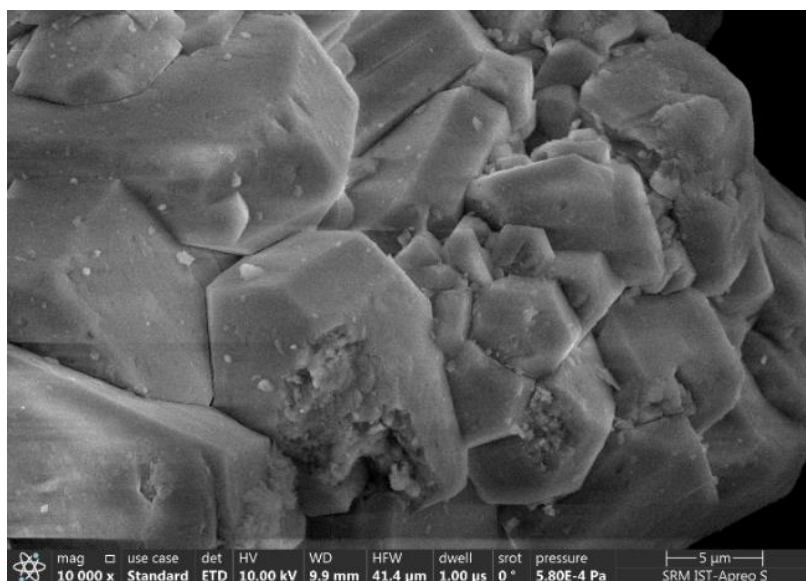
Aluminum oxide (alumina) is an inorganic substance formed by the chemical interaction between aluminium with oxygen. It produces aluminium oxide. Appearance, density, and chemical inertness contribute to the wide range of commercial and scientific uses of this material. This chemical is usually seen to be present in white crystalline crystals as well as gemstones, which makes it an excellent choice for applications that require temperatures in the higher ranges. The microscopic appearance of aluminium oxide is depicted in Figure 2.



**Figure 1.** Lemon seed biodiesel.

**Table 1.** Properties of Diesel and lemon seed biodiesel.

S N	Property	Diesel	Lemon seed biodiesel
1	Density [kg/m <sup>3</sup> ]	830	900
2	Viscosity [mm <sup>2</sup> /s at 40°C]	4.1	4.8
3	Flash Point [°C]	55	140
4	Cetane Number	45	55
5	Calorific Value [MJ/kg]	44	38



**Figure 2.** Microscopic image of  $\text{Al}_2\text{O}_3$ .

### Fuel Preparation

An emulsion is a heterogeneous blend of two liquids that are mutually insoluble, most often water and oil. The presence of a surfactant in a combination causes the creation of an emulsion, which can be defined as a mixing of different liquids. In order to achieve a combination that is uniform throughout, it is necessary to use an emulsifier, which is also referred to as a surfactant to get the desired results. Choosing a surfactant that has a hydrophilic-lipophilic balance (HLB) ratio that is less than 7 is a critical step in the process. The water-diesel emulsion that was created was made with the use of a surfactant called SPAN 80, which had an HLB value of 4.2. 4.2 was the HLB value that was assigned to SPAN 80. The emulsion was produced by applying the method of mechanical stirring, which was made possible by the utilisation of a mechanical stirrer that functions in accordance with the rules and regulations that are outlined in Fleming's left-hand rule. Among the many components that comprise the stirrer, the stator and the rotor, which are accompanied by an electromagnet and an iron core, are considered to be the most essential components. An electromotive force (EMF) is induced by the electromagnet, which in turn forces the shaft to revolve in a direction that is anticlockwise. The electromagnet results in the generation of a magnetic flux. For the purpose of homogenising immiscible substances like oil and water, the non-ionic surfactant known as Span 80, which may also be referred to as sorbitan monooleate or sorbitan oleate, is utilised in the food business, the pharmaceutical industry, and the cosmetics industry within the cosmetics industry. Substituted sorbitan monooleate and sorbitan oleate are two more names that are used to refer to Span 80. The substance is ideal for use in applications that include coating, spreading, and wetting because it has the ability to reduce surface tension. This makes it suitable for use in these applications. The fact that Span 80 can be effectively dissolved in water is one of the properties that makes it appropriate for a wide range of different formulations. When utilising surfactants such as Span 80, however, it is of the utmost importance to make certain that one is in full and complete compliance with all of the established safety regulations and regulatory criteria.

### Stability Test

The stability test would result in a decrease in the overall calorific value of the emulsion, and the presence of more than ten percent of surfactant would lead to the emulsion having a poor stability. The stability test was carried out in this manner, and the results were below the critical limit of surfactant and water. According to the results of the stability test that are presented in Table 2, it was discovered that the test 3 [consisting of 83% diesel, 15% water, and 2% surfactant] demonstrates the highest level of stability for a period of 8 days. The remaining proportions are separated within the shortest possible time frame.

**Table 2.** Stability test.

Test	Continuous medium [Diesel] %	Dispersed phase [water]%	Surfactant [span80]%	Stability
1	93	5	2	
2	88	10	2	
3	83	15	2	Max stable
4	78	20	2	
5	91	5	4	
6	86	10	4	
7	81	15	4	
8	76	20	4	
9	89	5	6	
10	84	10	6	
11	79	15	6	
12	74	20	6	
13	87	5	8	
14	82	10	8	
15	77	15	8	
16	72	20	8	
17	85	5	10	
18	80	10	10	
19	75	15	10	
20	70	20	10	

## EXPERIMENTAL SETUP

### Lubrication System

In this particular investigation, the lubricant that was utilised was classified as SAE30/SAE40. The lubricating mechanism that is utilised in the engines is of the splash kind.

### Injection System

The experiment was carried out with the injection pressure set at 200 bar, and the timing of the injection was set at 270 degrees before the top dead centre. In order to carry out the diesel injection procedure, a mechanical injector was utilised. An illustration of the experimental setup for the single-cylinder diesel engine may be found in Figure 3.

### Cooling System

The heat generated by combustion is managed and dissipated by a water-cooled engine by the use of a liquid coolant, which is typically composed of water and antifreeze. The engine block and cylinder head are responsible for absorbing heat from the various components of the engine through the circulation of coolant through tubes and channels. For the purpose of air cooling, the coolant is transported to a radiator. Heat is transmitted to the air through the radiator, which results in a decrease in the temperature of the coolant. The temperature of the engine is controlled by a thermostat, which also guarantees that it quickly reaches the recommended operating temperature. Dissipation of heat, fuel efficiency, emissions management, durability, and quiet operation are all areas in which water-cooled engines excel.

The experimental setup involved using a single-cylinder Kirloskar engine with a bore and stroke of 80 mm × 110 mm, operating at a speed of 1500 RPM. The engine, with a maximum power output of 5 hp (3.7 kW) and a swept volume of 780 cm<sup>3</sup>, featured a compression ratio of 16.5:1. This setup was chosen to evaluate the effects of different biodiesel blends under controlled conditions, allowing for precise measurements of performance parameters such as brake thermal efficiency and specific fuel consumption. The use of a single-cylinder engine provides a simplified yet effective model to test fuel efficiency, emissions, and other key combustion characteristics. At the same time, the braking thermal efficiency of nano emulsified lemon seed biodiesel demonstrates a 2.5% increase when compared to that of emulsified lemon seed biodiesel. The catalytic response of nanoparticles, which promotes more efficient burning in the combustion zone, is responsible for this increase, which can be attributed to the latter. The relationship between the thermal efficiency of the brakes and the load on the engine is

illustrated in Figure 4, which reveals that the nano particle blend brings about a significant improvement. The current operating state of the engine are presented in Tables 3



**Figure 3.** Experimental set up.

**Table 3.** Operating condition.

S N.	Parameter	Range
1	Stirring speed	1500 rpm
2	Stirring duration	30 min
3	Temperature	303K
4	Pressure	Atm. pressure

## RESULT AND DISCUSSIONS

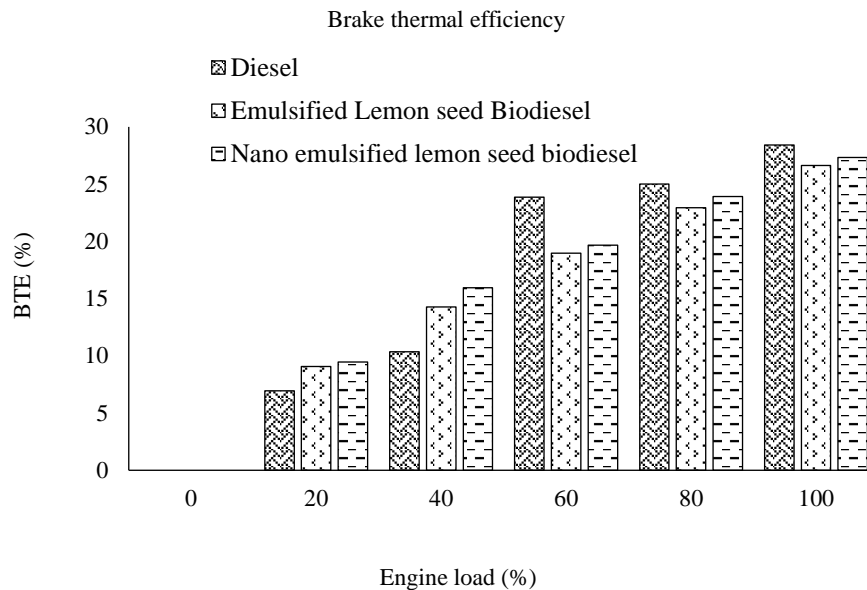
### Brake Thermal Efficiency

The Brake Thermal Efficiency holds considerable importance as a performance parameter in internal combustion engines, since it plays a crucial part in determining fuel efficiency and economy. The operational efficacy of an engine is contingent upon a multitude of factors that exert influence, encompassing but not restricted to dissipation of heat, mechanical inefficiencies, combustion effectiveness, temperature regulation, air-fuel mixture ratio, and the design of the engine.

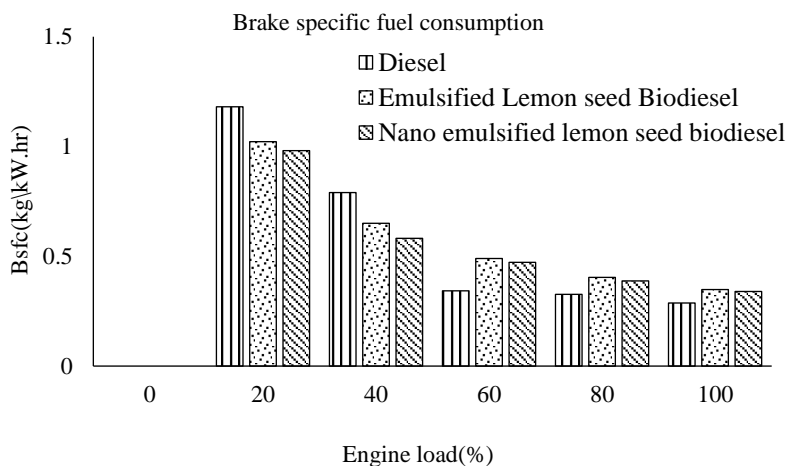
Enhancing brake thermal efficiency is a fundamental goal within the field of engine development, as it is closely associated with improved fuel efficiency and decreased emissions. The objective of this endeavor is to enhance the economic viability and environmental sustainability of engines in their operational processes. As illustrated in Figure.4, emulsified lemon seed biodiesel has 6.28% less brake thermal efficiency than diesel. In the same way, nano-emulsified lemon seed biodiesel has 3.38 % less brake thermal efficiency than diesel.

### Brake Specific Fuel Consumption

Brake specific fuel consumption is an essential metric in both the automotive and aviation sectors, as it calculates the fuel needed to generate a unit of power. Lower brake specific fuel consumption signifies enhanced fuel efficiency, making it a preferred choice in scenarios where fuel economy is critical. Compared to diesel, emulsified lemon seed biodiesel shows a 21% rise, while nano-emulsified lemon seed biodiesel exhibits a 17% increase in brake specific fuel consumption. However, at high load conditions, the brake specific fuel consumption is reduced by 2.5% in comparison to emulsified lemon seed biodiesel. This decrease can be attributable to the increases in calorific value that have occurred due to nano emulsified biodiesel. Figure 5 illustrates the relationship between engine load and brake specific fuel usage.



**Figure 4.** Brake Thermal Efficiency of Nano emulsified biodiesel.

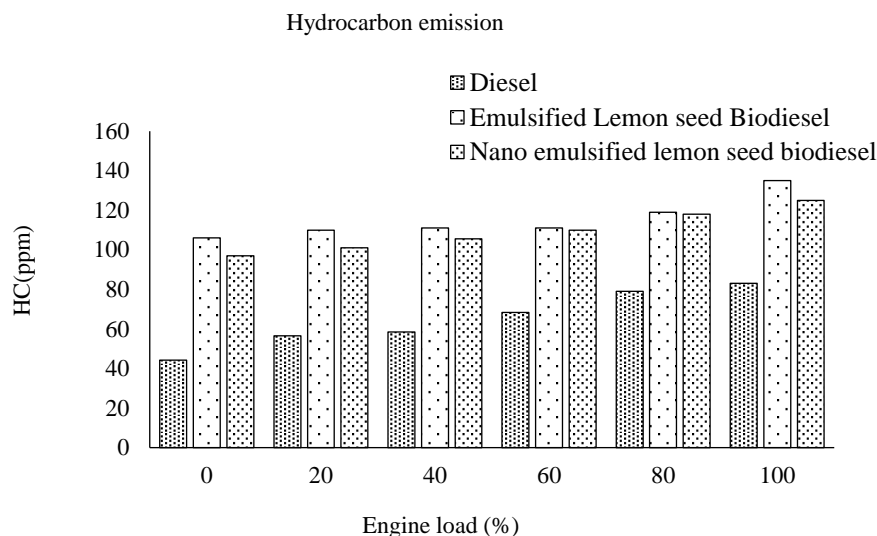


**Figure 5.** Brake specific fuel consumption of Nano emulsified biodiesel.

### Hydrocarbon Emissions

The release of hydrocarbons, resulting from anthropogenic activities like fossil fuel combustion and industrial operations, substantially impacts the environment and human health. These pollutants are accountable for the formation of ground-level ozone, the occurrence of climate change, and the manifestation of detrimental health impacts. To address these environmental concerns, there is a growing focus on implementing stricter industrial norms, increasing the utilization of renewable energy resources, and enforcing rules on vehicular emissions. The potential to mitigate hydrocarbon emissions can be observed through the implementation of technology-driven initiatives, exemplified by the utilization of emissions control systems and catalytic converters. In contrast to diesel, the emission of hydrocarbons in emulsified lemon seed biodiesel exhibits a 62% increase, whereas nano emulsified lemon seed biodiesel shows a 50% increase. A significant amount of the drop in cylinder temperature that occurs as a result of the diesel emulsion that is contained within the cylinder is caused by the high latent heat of vaporisation of water that is present in the diesel emulsion. The utilisation of nano-emulsified biodiesel results in a reduction of evaporation and fuel mixing rates, with a reduction of 7% when compared to the utilisation of emulsified lemon seed biodiesel under pressure circumstances. It is possible that this is due to the inclusion of nanoparticles in the fuel, which increases the calorific value

of nano-emulsified biodiesel. As a result of the nanoparticles' ability to promote enhanced evaporation and fuel mixing, the combustion rate in the fuel-air combination was also improved. Fig. 6 illustrates the relationship between engine load and HC emissions



**Figure 6.** Hydrocarbon emissions of Nano emulsified biodiesel.

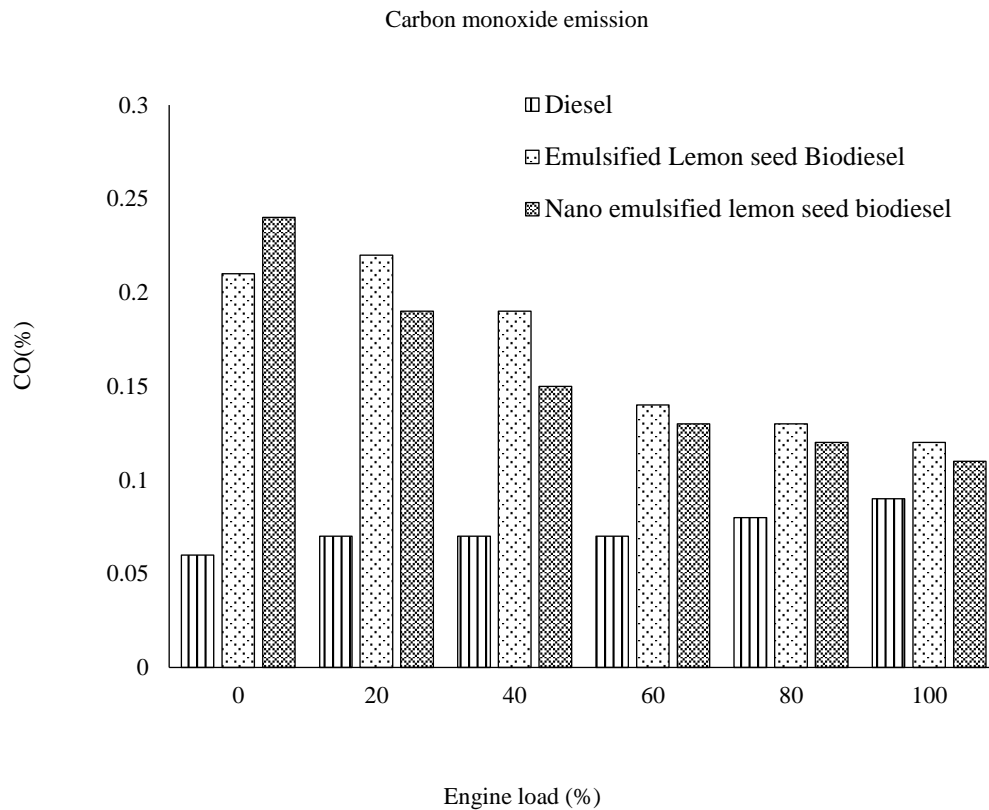
#### Carbon Monoxide Emissions

The emission of carbon monoxide into the atmosphere, which occurs as a consequence of the incomplete combustion of fuels that contain carbon, is associated with considerable dangers to the health of both people and animals. Pollutants in the air, such as by-products of incomplete combustion of fuels, can be produced by a variety of activities and sources, such as industrial processes, household heating systems, car emissions, and forest fires. In order to accomplish both the preservation of the quality of the environment and the improvement of public health, it is of the utmost importance to get rid of carbon dioxide emissions.

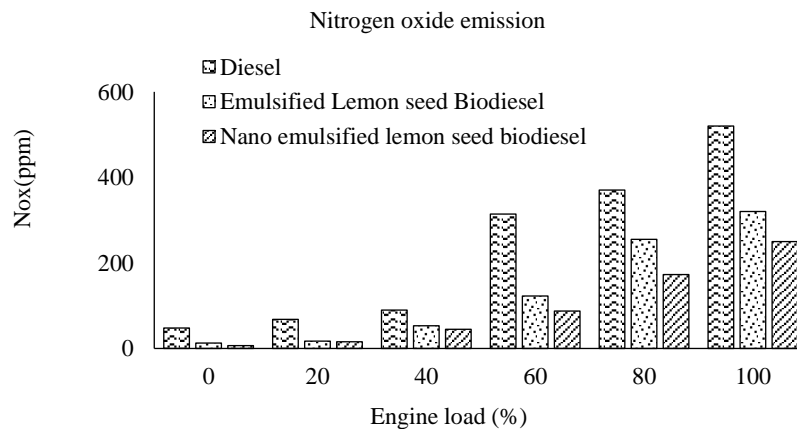
In order to accomplish this objective, a number of different strategies have been implemented. These strategies include the utilisation of energy sources that are less harmful to the environment and the improvement of combustion processes. Fig. 7 demonstrates Carbon monoxide emission is increased by 33% in emulsified lemon seed biodiesel and 22% in nano emulsified lemon seed biodiesel when compared to diesel. However, carbon monoxide emission is reduced by 8.3% when compared to lemon seed biodiesel that has been emulsified because of the increased evaporation rate, which causes carbon monoxide to be converted into carbon dioxide when the load is high.

#### Nitric Oxide Emissions

The emissions of nitric oxides, which are the outcome of processes involving combustion, constitute a significant issue in terms of both the impact they have on the environment and the health of the general public. It has been discovered that increased concentrations of nitrogen oxides have harmful effects on air quality. These effects include the production of acid rain, the creation of ozone, and the exacerbation of global warming. Emission standards have been implemented by regulatory organizations with the intention of limiting the discharge of nitrogen oxide emissions in order to protect the quality of the air that humans breathe and to advance human health.



**Figure 7.** Carbon monoxide emissions of Nano emulsified biodiesel.



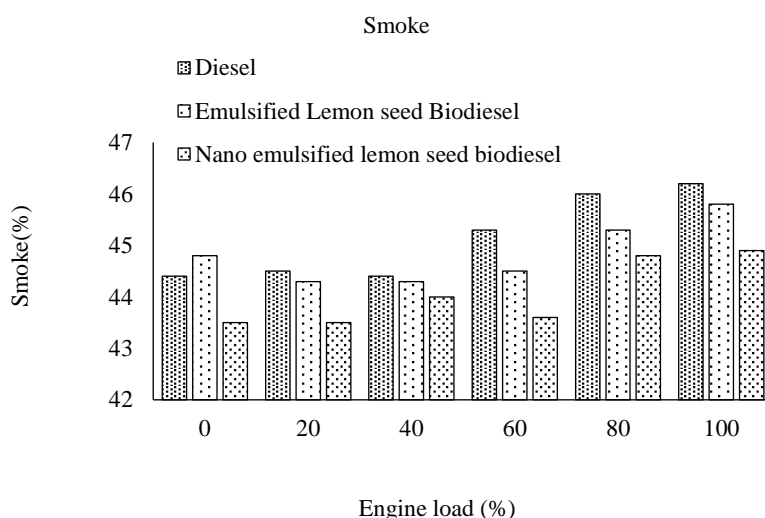
**Figure 8.** Nitrogen oxide emissions of nano emulsified biodiesel.

According to Figure 8 Nitrogen oxide emission is reduced by 38% in emulsified lemon seed biodiesel and by 51% in nano emulsified lemon seed biodiesel when compared to diesel. This may result from a decrease in peak cycle temperature in the combustion zone due to the elevated latent heat of vaporization of the water content in the diesel emulsion. This will result in a lower rate of fuel evaporation and mixing, but only a 21% reduction compared to emulsified lemon seed biodiesel when the load is high. The enhanced thermal conductivity of aluminum oxide nanoparticles results in a further reduction in peak cycle temperature.

### Smoke Emissions

The combustion process results in the production of smoke, which can have negative repercussions not only for the environment but also for the health and wellbeing of individuals. Scrubbers, catalytic

converters, and particulate filters are three examples of the many different types of pollution control technology that are utilized in industrial processes as well as in automobiles. Conversely, it is imperative to recognize that regulations and restrictions have been established to reduce the emission of smoke and pollutants. When it comes to preventing and dealing with smoke incidents, the implementation of early warning systems and public awareness initiatives is of the utmost importance. According to Figure 9 in comparison to diesel, smoke emission is reduced by 0.86% in emulsified lemon seed biodiesel and by 2.81% in nano emulsified lemon seed biodiesel. However, at high loads, the reduction in smoke emission is only 1.96% when compared to emulsified lemon seed biodiesel. This is due to micro explosions, which result in secondary atomization of the fuel.



**Figure 9.** Smoke emissions of nano emulsified biodiesel.

## CONCLUSION

The research examines the performance and emission attributes of emulsified lemon seed biodiesel and nano-emulsified lemon seed biodiesel in a single-cylinder, constant-speed, water-cooled, direct injection diesel engine. Compared to emulsified biodiesel nano emulsified fuel shows better performance and emission characteristics. Burning in the combustion zone due to nanoparticle catalysis increases brake thermal efficiency by 2.5% compared to emulsified lemon seed biodiesel. Due to the Nano particle's higher calorific value, nano emulsified biodiesel has a 2.5% lower brake specific fuel consumption than emulsified lemon seed biodiesel at high load. Hydrocarbon emission is 7% lower than emulsified lemon seed biodiesel at high load due to the nano particle's increased calorific value due to high evaporation and mixing rates, which improve combustion. Higher evaporation rates convert carbon monoxide into carbon dioxide, reducing emissions by 8.3% compared to emulsified lemon seed biodiesel at high load. Aluminum oxide Nano particle thermal conductivity reduces peak cycle temperature and nitrogen oxide emission by 21% compared to emulsified lemon seed biodiesel at high load. Smoke emission is 1.96 % lower than emulsified lemon seed biodiesel at high load due to micro explosions that secondary atomize the fuel.

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