INVESTIGATION OF THE EFFECTS OF NANOPARTICLE ADDITION IN DIESEL ENGINE RUNNING WITH BIODIESEL/DIESEL FUEL BLENDS

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Ali Salam Khaleel AL- GBURI

Thesis Advisor
Assoc. Prof. Dr. Samet USLU

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Ali Salam Khaleel AL- GBURI

Thesis Advisor

Assoc. Prof. Dr. Samet USLU

T.C.

Karabuk University

Institute of Graduate Programs

Department of Mechanical Engineering

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I certify that in my opinion the thesis submitted by Ali Salam Khaleel AL- GBURI titled “INVESTIGATION OF THE EFFECTS OF NANOPARTICLE ADDITION IN DIESEL ENGINE RUNNING WITH BIODIESEL/DIESEL FUEL BLENDS” is fully adequate in scope and quality as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Samet USLU ....
Thesis Advisor, Department of Mechanical Engineering

Assoc. Prof. Dr. Duraid F. MAKI ....
Co-Advisor, Department of Mechanical Engineering of Iraq University of Babylon

This thesis is accepted by the examining committee with a unanimous vote in the Department of Mechanical Engineering as a Master of Science thesis. 01/12/2022

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Chairman	: Assoc Prof. Dr. Mehmet Erdi KORKMAZ (KBU)	....
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Member	: Assistant Prof. Dr. Süleyman ŞİMŞEK (IAU)	....
Member	: Assoc. Prof. Dr. Duraid F. MAKI (BAU)	....

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Assoc. Prof. Dr. Müslüm KUZU ....
Director of the Institute of Graduate Programs

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Ali Salam Khaleel AL- GBURI

ABSTRACT

M. Sc. Thesis

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Ali Salam Khaleel AL- GBURI

Karabük University
Institute of Graduate Programs
The Department of Mechanical Engineering

Thesis Advisor:
Assoc. Prof. Dr. Samet USLU
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Biodiesel has been recognized as a potential alternative fuel for the coming years. However, fossil fuels can be substituted by algae biodiesel to reduce emissions and solve its depletion. Hence, biodiesel and diesel are mixed to improve its properties. Critical literature shows that the nano iron oxides improved the biodiesel and diesel blends. This study aims to study experimentally the effect of algae biodiesel adding to pure diesel on emissions and performance. As well as mixing the produced biodiesel fuel with (Fe_3O_4) nano particles and their effect on the emission and performance properties of diesel engines with different loads and variable compression ratios. This investigation was achieved by a single cylinder, water-cooled, four-stroke, variable compression ratio, 3.7 kW at 1500 rpm direct-injection. To be used in diesel engine experiments, test fuels obtained by mixing algae methyl ester (AME) biodiesel produced from microalgae called spirulina and conventional diesel in various combinations were prepared. These fuels are called B0, B10, B20 and B30, where B10 stands for 90% diesel and 10% biodiesel. In all experiments in this study, the emission and performance characteristics of B10, B20 and B30 mixtures were compared with pure diesel at different loads (0%, 25%, 50%, 75 and full load) and compression ratios (145:1, 15.5:1, 16.5:1). The experimental results showed a reduction in the (BTE) of the with a marginal increase at B10 at (0.25 and 0.50) loads, increase in (BSFC), the greater the proportion of biodiesel from algae increase BSFC, the volumetric efficiency decreases in all biodiesel ratios. But it was noted that B10 is better than the rest of the other mixing ratios. By adding biofuels and compared with pure diesel noticed marginal decrease in carbon monoxide and carbon dioxide by (2.5% to 4%) at a compression ratio of (14.5:1 and 15.5:1) and CO_2 decreased 10% at a compression ratio of 16.5:1. As well as a marginal increase in unburned hydrocarbons, and a reasonable reduction in nitrogen oxides. The second type of fuel used in the experiments is prepared from pure diesel, 20% biodiesel and iron oxide (Fe_3O_4) nanoparticles (diesel + best algae biodiesel blend + nanoparticles). The mixing ratios are (80%) neat diesel and (20%) biodiesel mixed with three doses of nanoparticles (25, 50 and 75 ppm) by an electric mixer and an ultra-sonic device. The resulting blending fuel is (DB20N25, DB20N50, DB20N75). Again, the results compared with diesel and B20 for engine performance and emissions.

The results gave an increase in BTE and reduced BSFC. The DB20N75 fuel showed the best BSFC reduction ratio at full load. The volumetric efficiency is marginally improved, the exhaust temperature increases. CO decreases significantly with the increase of nano dose, reducing (CO_2) due to the availability of oxygen that is liberated from nanoparticles, decreasing HC.

Key Words : Nano Iron Oxide, Biodiesel, Diesel Performance, Emission, Algae Biodiesel.

Science Code : 91413

ÖZET

Yüksek Lisans Tezi

BİYODİZEL/DİZEL YAKIT KARIŞIMLARIYLA ÇALIŞAN DİZEL MOTORDA NANOPARÇACIK İLAVESİNİN ETKİLERİNİN İNCELENMESİ

Ali Salam Khaleel AL- GBURI

Karabük Üniversitesi
Lisansüstü Eğitim Enstitüsü
Makina Mühendisliği Anabilim Dalı

Tez Danışmanı:
Doç. Dr. Samet USLU

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Biyodizel, önümüzdeki yıllarda potansiyel ve alternatif bir yakıt olarak kabul edilmiştir. Bununla birlikte, emisyonları azaltmak ve tükenmesini çözmek için fosil yakıtlar alg biyodizel ile ikame edilebilir. Bu nedenle, özelliklerini geliştirmek için biyodizel ve dizel karıştırılır. Kritik literatürler, nano demir oksitlerin biyodizel ve dizel karışımlarını iyileştirdiğini göstermektedir. Bu çalışma, zarif dizele eklenen alg biyodizelinin performans ve emisyonlar üzerindeki etkisini deneysel olarak incelemeyi amaçlamaktadır. Üretilen biyodizel yakıtın demir oksit nanopartiküller ile karıştırılmasının yanı sıra farklı yük ve değişken basınç oranlarına sahip dizel motorların performans ve emisyon özelliklerine etkisi. Bu araştırma, tek silindirli, değişken sıkıştırma oranlı, su soğutmalı, dört zamanlı, 3,7 kW'lık 1500 rpm direkt enjeksiyonlu dizel motor ile gerçekleştirilmiştir. Dizel motor deneylerinde kullanılmak üzere spirulina adı verilen mikroalglerden üretilen alg metil ester (AME) biyodizel ile

konvansiyonel dizelin çeşitli kombinasyonlarda karıştırılmasıyla elde edilen test yakıtları hazırlandı. Bu yakıtlar B0, B10, B20 ve B30 olarak adlandırılır ve B10, %90 dizel ve %10 biyodizel anlamına gelir. Bu çalışmadaki tüm deneylerde, farklı yük (%0, %25, %50, 75 ve tam yük) ve sıkıştırma oranlarında (14,5:1, 15,5:1, 16,5:1) B10, B20 ve B30 karışımlarının emisyon ve performans özellikleri saf dizel ile karşılaştırılmıştır. Deneysel sonuçlar, (0.25 ve 0.50) yüklerde B10'da marjinal bir artışla birlikte (BTE)'de bir azalma olduğunu, (BSFC'de artış) ve biyodizel oranı arttıkça BSFC'nin arttığını, hacimsel verimin tüm biyodizel oranlarında azaldığını göstermiştir. Ancak B10'un diğer karışım oranlarının geri kalanından daha iyi olduğu da not edilmiştir. Biyoyakıt eklenmesiyle ve saf dizel ile karşılaştırıldığında, (14,5:1 ve 15,5:1) sıkıştırma oranında karbon monoksit ve karbon dioksitte (%2,5 ila %4) marjinal azalma ve 16,5:1 sıkıştırma oranında CO_2'de %10 azalma gözlemlenmiştir. Yanmamış hidrokarbonlarda marjinal bir artışın yanı sıra nitrojen oksitlerde makul bir azalma ortaya çıkmıştır. Deneylerde kullanılan ikinci tip yakıt ise saf dizel, %20 biyodizel ve demir oksit (Fe_3O_4) nanoparçacıklarından (dizel + en iyi alg biyodizel karışımı + nanoparçacıklar) hazırlanmıştır. Karıştırma oranları (%80) saf dizel ve (%20) biyodizel olup üç doz nanopartikül (25, 50 ve 75 ppm) ile bir elektrikli karıştırıcı ve bir ultrasonik cihaz tarafından karıştırılmıştır. Ortaya çıkan harmanlama yakıtı (DB20N25, DB20N50, DB20N75)'dir. Yine sonuçlar motor performansı ve emisyonlar açısından dizel ve B20 ile karşılaştırılmıştır.

Sonuçlar, BTE'de bir artış ve BSFC'de bir azalma ortaya koydu. DB20N75 yakıtı, tam yükte en iyi BSFC azaltma oranını gösterdi. Hacimsel verim marjinal olarak iyileştirildi, egzoz sıcaklığı arttı. CO, nanoparçacık artmasıyla önemli ölçüde azalır, nanoparçacıklardan serbest kalan oksijenin mevcudiyeti nedeniyle (CO_2) azalır, HC azalır.

Anahtar Kelimeler : Nano Demir Oksit, Halihazırda Biyodizel, Dizel Performansı, Emisyon, Yosun Biyodizel.

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

%	:	Percent Sign
BP	:	Engine brake power
I	:	current
V	:	voltage
$\eta_{B.Th}$	:	Brake Thermal Efficiency
$\dot{m}_f$	:	Mass of fuel consumed per hour
LCV_d	:	Lower calorific value
η_v	:	Volumetric Efficiency
$\mathring{Q}_a$	:	Actual volumetric of air
$\mathring{Q}_s$	:	Swept volume
V_S	:	Cylinder volume
N	:	Engine revolution per minute rev/min
C_d	:	Coefficient of discharge
A_{orf}	:	Area of orifice
d	:	diameter of orifice
g	:	gravity
t	:	timespan
Φ	:	Equivalence Ratio
m_a	:	mass of air
m_p	:	mass of nanoparticle
m_f	:	mass of fuel
ρ_p	:	density of nanoparticle
ρ_f	:	density of fuel

ABBREVIATIONS

AME	:	Algae Methyl Ester
B0	:	Blend containing 100 % of diesel oil and 0 %biodiesel by Volume
B10	:	Blend of 90% diesel pure and 10% AME by volume
B20	:	Blend of 80% diesel pure and 20% AME by volume
B30	:	Blend containing 70 % of diesel oil and 30 % AME by Volume
D	:	Diesel
N	:	Nanoparticles
DB20N25	:	Blend containing 80 % of neat diesel and 20 % AME biodiesel by Volume with 25ppm concentration of Nano particles (Fe_3O_4).
DB20N50	:	Blend containing 80 % of neat diesel and 20 % AME biodiesel by Volume with 50ppm concentration of Nanoparticles (Fe_3O_4)
DB20N75	:	Blend containing 80 % of neat diesel and 20 % AME biodiesel by Volume with 75ppm concentration of Nanoparticles (Fe_3O_4)
BTE	:	Brake Thermal Efficiency %
BSFC	:	Brake specific fuel consumption Kg/kw.h
CR	:	Compression ratio
℃	:	Degree Centigrade
CN	:	Cetane Number
Vol	:	volumetric
RPM	:	Revolution per minute 1/min
CO_2	:	Carbon dioxide
CO	:	Carbon monoxide
HC	:	Hydrocarbons
UHC	:	Unburned hydrocarbon
DF	:	Diesel Fuel

DB	:	Biodiesel AME
NO_X	:	Nitrogen oxides
EGT	:	Exhaust Gas Temperature
BP	:	Brake power KW
The A/F ratio	:	The air /fuel ratio
CI	:	Compression Ignition
O_2	:	Oxygen

PART 1

INTRODUCTION

Diesel engine is an internal combustion engine using a diesel cycle, the word "diesel" is derived from the name of the inventor Rudolph Diesel in Germany in 1892. Diesel engines use compressed ignition, a process in which fuel is injected after air is compressed in the combustion chamber, which leads to the fuel igniting spontaneously. There are three main reasons to search for alternative fuel or improve diesel, the first concerns human health and in 2012, the World Health Organization (WHO) announced that emissions from diesel combustion are represented as carcinogenic. The second reason is its impact on the climate. A study conducted by a team of international scientists in 2013 showed that diesel smoke consists mainly of black carbon, which has a strong impact on the climate, because it raises the temperature of the globe. More than approximately 3,300 times more carbon dioxide over a period of 20 years [1]. The third reason is that fossil fuels are a major source of energy .whereas the most common types of fuel use in the operation of diesel engines are diesel fuel extracted from fossil fuels as in the industrial revolution, energy requests have led to a rapid depletion of fossil fuels This led to a decline in fossil fuel reserves as well as the exploitation of fossil fuels in transport and energy sectors have led to a negative impact on the environment leading to increased greenhouse gas emissions such as carbon dioxide and carbon dioxide, nitrogen oxides, sulfur oxides etc. Therefore, researchers explore alternative fuel sources to stop unilateral dependence of fossil fuels and as you find ways to improve diesel emissions to reduce environmental pollution [2]. Hence the importance of searching for alternative fuel and improved diesel fuel to reduce emissions. The current research is focused on the use of biodiesel fuel in diesel engine and improve diesel fuel emissions and engine performance through adding to nanoparticles.

1.1. GENERAL BACKGROUND

The combustion operations occur within the combustion room, which is very complex and fully incomprehensible, but many models are used to illustrate and explain the phenomenon of combustion and do the use of simulations. However, these models do not show the full details of the combustion but have made a good and accurate work. The combustion process in pressure ignition engines is an unstable process and the presence of a heterogeneous mixture in many areas does not occur suffocation of air entering the engine, and the change in torque and power is controlled by the amount of fuel injection per cycle because the air is not suffocated. The injection time is always from 15–30-degree before top dead center (BTDC) and ending about 5–10-degree after top dead center (ATDC). After injection the fuel undergoes many processes such as:

1. Atomization: Fuel emitted from injector is divided into very small drops. The smaller the volume of the original droplet from the fuel injection, the faster and more efficient the atomization process. The best shape of injection inside the combustion chamber is coned to cover the largest area of combustion chamber [3].
2. Vaporization: The small droplets of liquid fuel vaporize and become vapor. This happens very quickly due to the hot air temperatures created by the high compression of compression ignition engines. The high air temperature required for this vaporization process requires a minimum compression ratio of around 12:1 for compression ignition engines. About 90% of the fuel injected into the cylinder vaporizes within 0.001 seconds. After the injection. As the first fuel vaporizes, the immediate area is cooled by evaporative cooling [3].
3. Mixing: After evaporation, compressed air is mixed with fuel vapor within the combustion chamber to form the mixture within the specific flammable range of the fuel-to-air ratio. This mixing results from the addition of the high speed of fuel injection to the movement of the air inside the cylinder [3].
4. Auto-ignition: Occurs at about 8° (BTDC), 6_8° at the start of injection, the air-fuel mixture begins to self-ignite. The actual combustion is preceded by secondary reactions, along with the dissociation of massive organic compounds molecules into smaller species and few oxidations. These interactions, caused by

an increase in air temperature, lead to an increase in the air temperature in the immediate original vicinity. This finally ends up with a truly sustainable combustion method [3].

5. Combustion: burn at auto-ignition begins at a time more than one location in the slightly rich area of jet fuel. Burning is precedented by other partial interactions with large HC molecules decomposed into smaller species and some oxidation. These interactions occur due to high air temperature [3]. Diesel engines cause air pollution due to combustion. The process is basically proliferation combustion. The primary cause of soot and smoke pollution is proliferation combustion. The research work was large and still directed at improving combustion. Treatment in diesel engines to better fuel characteristics and decrease pollution. Many techniques are used, such as adding nanoparticles to diesel fuel, or diesel fuel is mixed with biodiesel fuel, and so is mixing diesel with biodiesel and nanoparticles.

1.2. NANOPARTICLES

They are very small particles that range in size from 1 to 100 nm and are a new type of additive used in engineering fields and cannot be seen with the naked eye It was found that adding nanoparticles to fuel enhances thermodynamic properties and improves combustion properties. Nanoparticles have proven themselves in all aspects of engineering applications due to their exceptional properties. There are many types of nanoparticles [4], as shown in Table 1.1.

Table 1.1. Types of Nanoparticles [8].

	Nanoparticles	Example
1	Metal	Aluminum, Iron and ferric chloride ($FeCl_3$)
2	Metal Oxides	Cerium oxide, Alumina, TiO_2, ZnO, MnO
3	Magnetic Nano fluid	Ferro fluids
4	Carbon nanotube	Sic, Tic
5	Composite material	Alloyed nanoparticles
6	Nitride ceramics	AIN, SIN
7	Layered	Cu +C, Al+Al_2O_3

1.3. NANO FUEL AND NANOPARTICLE

The need for energy is growing significantly to meet of increased requirements the population and it is estimated that global in 2040, a rise in the energy utilization of more than 30% is anticipated, most of the energy consumed is known to be Derivative of fossil fuels that are rapidly depleted and cause much concern due to harmful emissions. Renewable and effective power is of greatest priority for scientists around the world, Researchers worked hard to improve diesel fuel properties. They use a lot of additives, especially nanoparticles. When they mixed the nanoparticles with fuel, they got a new fuel with different properties than neat diesel, called nonfuel or modified diesel. They have enhanced thermophysical properties like mass propagation, thermal conductivity, and high surface area to volume ratio. It has been found the nano additive with (DF), biodiesel, and mixtures (DF+ DB) have been found to improve flashpoint, fire point, kinetic viscosity, depending on the number of nanoparticles used, you can decrease emissions and improve efficiency [4].

1.4. ADVANTAGES OF NANO FUEL

Nanoparticles are used to improve some physical properties of many fluids such as diesel fuel. The advantages of using nanoparticles with diesel fuel are [5]:

1. Nanoparticles mixed with diesel fuel increase contact surface area and effective thermal conductivity.
2. The rate of evaporation is high for nanoparticles and such atomization is good for them, mixing air with the right fuel and sustaining the acceptable flame.
3. Adding nanoparticles to the diesel or Biodiesel mixture improves CI engine performance such as increasing BTE and reducing SFC.
4. Reduces emissions such as carbon dioxide and nitrogen oxides.
5. Nanoparticles enhance combustion quality and reduce ignition delay.

1.5. INCONVENIENCES OF NANO FUEL

The following point provides a succinct summary of nano fuel's drawbacks [5]:

1. High viscosity: Viscosity increases if the concentration of nanoparticles in the commentator increases.
2. Increased pumping power and reduced pressure. Pressure is reduced further if the size of the nanoparticles increases and so the energy required for pumping also increases.
3. There's a possibility that nanoparticles will congregate into large molecules, resulting in the nozzle opening blockage.

1.6. BIODIESEL FUEL

Biodiesel, also known as fatty acid methyl esters (FAME), is produced by the transesterification of vegetable oils or animal fats with the addition of methanol. Biodiesel is very similar to diesel derived from petroleum in key properties such as cetane number, energy content, viscosity, and phase transition. Biodiesel doesn't contain fossil fuel products, but it is consistent with pure diesel and can be mixed with pure diesel in any proportions to produce a stable biofuel [6]. There are many sources of Biodiesel fuel production as shown in Table 1.2. In our current study, we will use biodiesel fuel produced from algae.

Table 1.2. Show the sources of biodiesel productions [6].

Kind of	Feedstock Sources
Edible vegetable oil	Castor, rapeseed, radish, rice bran, tiger nut, soybean, mustard, sunflower, coconut, corn, peanut, palm, safflower, olive, sesame seed, opium poppy, etc.
Non-edible vegetable oil	Jatropha, pongamia, algae, rubber seed, karanja, jojoba, neem, linseed, orange, moringa peregrina seed, cottonseed, Deccan hemp, mahua, kusum, polanga, tobacco, nahor, soapnut, milk bush, acrocomia aculeata, hodgsonia macrocarpa seed, oil sea mango, silk cotton oil tree, moringa oleifera, macauba coconut, croton megalocarpus, thespesia populnea seed, halophytes paradise, etc.
Algae	Spirulina platensis algae, microalgae, etc
Waste oil	Recycled cooking oil, waste salmon, animal fat wastes, and Moroccan waste frying, etc
Animal fats	Chicken fat, tallow, by-products from fish, yellow grease, animal fats, poultry fat, mucor circinelloides, beef tallow oil pig fat, etc.

1.7. ALGAE BIODIESEL VIABILITY

Algae biodiesel remains a reasonably new technology. Despite the reality that studies commenced over 30 years ago, it become placed on keep for the duration of the mid-1990s, especially because of a loss of investment and a surprisingly low petroleum cost. Microalgae species are becoming a major source of feedstock to produce biodiesel. This is due to its numerous advantages over traditional terrestrial raw materials. Species such as spirulina. Chlorella can grow all year, ensuring a steady supply of microalgal oil while requiring little water. Furthermore, most microalgal species are carbon dioxide tolerant and do not require herbicides or pesticides to grow. Microalgal cells have a lipid composition that is more than 30% higher than that of other sources such as palm oil, jatropha and soybean. Furthermore, manufacturing sewage water from different sources or sewage containing nutrients such as phosphorus and nitrogen can be used for microalgae cultivation instead of providing additional nutrients. What's more, microalgal species have an innate ability to grow in harsh conditions such as coastal seawater or brackish water, which often weakens older generations of biofuel feedstocks. [7]. In our current study, we will focus on biodiesel fuel from algae, use it as fuel in the diesel engine and compare it with other fuels regarding pollutants and efficiency. The methods of producing biodiesel fuel from microalgae have many previous studies showing this, as noted in this review [7].

1.8. THE BENEFITS OF BIODIESEL

The benefits of biodiesel are summarized below [5]:

1. Non-toxic and decomposes four times faster than (DF).
2. Its high O_2 content promotes biodegradation.
3. Neat biodiesel decomposes 84-87% of water.
4. The addition of biodiesel to (DF) improves engine efficiency.
5. The high O_2 level of biodiesel enhances burning and reduces oxidation state.
6. Biodiesel derived from crops has environmental benefits, such as a reduction in acid rain and the greenhouse effect caused by pollution.
7. Because the plants that produce it absorb more CO_2 from the atmosphere during photosynthesis than they emit when used as a fuel in compression ignition engines, biodiesel is considered a carbon neutral fuel.
8. In terms of sulphur content, biodiesel outperforms diesel and generally complies with developing future European regulations.
9. Because biodiesel has more lubricating properties than neat (DF), it can extend the life of diesel engines [6].

1.9. DISADVANTAGES OF BIODIESEL

The following point provides a succinct summary of biodiesel's drawbacks:

1. It has a higher viscosity
2. Copper strip corrosion is more severe

3. Fuel economy on energy fundamentals has decreased slightly (about 10 percent for pure biodiesel).
4. Due to its tendency to gel at low temperatures, which can block up filters or even make it too thick to be pushed from the fuel tank to the engine, biodiesel has poor cold flow qualities.
5. Density is higher than (DF), although sub-freezing circumstances may necessitate the usage of blends.
6. More easily oxidized than pure diesel, resulting in acidity in the fuel as well as the formation of insoluble gums and sediments that can clog filters in advanced stages.
7. Vegetable oil is more expensive due to lower output [6].

1.10. AIM OF THE CURRENT WORK

The aim of the current work is to study the efficiency, emissions, and of a single cylinder, four strokes, and variable (CI) engine operated with nanoparticles blended with (DF-DB AME) fuel. Nanoparticles and Biodiesel fuel are currently being used in some diesel engines to improve its emissions and fuel physical properties. These fuel additives reduce emissions such as CO, CO_2, NO_X and (UHC). The main aims of this experimental work are:

1. Search for alternative sources of energy to solve the decline of fossil fuel and reduce its emissions. Preparing the Biodiesel (AME) from Microalgae algae oil is selected and its biodiesel and test this fuel and check its properties experimentally.
2. Preparing the type of biodiesel fuels while are (DF+B).
3. Preparing the type of Nano fuels while are (DF+B+Fe_3O_4).
4. Running a diesel engine on prepared biodiesel-fuels to study its performance and emissions characteristics compared to diesel fuel operation.
5. Running a diesel engine on prepared nano-fuels (DF+DB+Fe_3O_4) to investigate its emissions and performance qualities and comparing it to pure diesel fuel and biodiesel fuel operation.

6. Preparing and adding Iron Oxide Nanoparticles -fuel with different concentrations (25,50,75) ppm to the best compromise blending ratio of AME and investigate the combustion, performance, and emissions.

1.11. LAYOUT OF THE THESIS

This thesis consists of five chapters which are:

1. The introduction and general overview are introduced in chapter one.
2. Chapter II provides a methodical and comprehensive review of literature on the research problem.
3. Chapter 3 is dedicated to experimental construction and measuring instrumentations.
4. Results of the study are presented and discussed in chapter four.
5. The conclusions and suggestions are summarized in chapter five.

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

The world now goes to explore clean energy sources as well as the traditional fossil fuels fell in recent years and in the future, they will be a little and like the emissions that are harmful to human and ozone layers. This pays researchers to find clean energy sources and find alternative energy Diesel engines have better performance and emissions of diesel product from fossil fuels. Studies at the present time on diesel engines focus on three basic principles: engine performance, pollutant emissions and specific fuel consumption. Most scientists have contributed to reducing emissions from compression ignition in diesel engines in three ways: modifying design, modifying fuel and processing exhaust gas, and the most acceptable method is It is widely accepted by researchers as a fuel modification method to increase fuel efficiency and decrease emissions for diesel engines. This overview is limited to studies dealing with the impact of nanoparticles on fuels, including pure diesel and biodiesel, and the effect of additives on performance, emissions, and specific fuel consumption. Nanoparticles can decrease the emission factor and increase combustion efficiency by enhancing the fuel's ignition delay and properties.

2.2. EXPERIMENTAL STUDY OF NANO IMPACT ON PERFORMANCE AND EMISSIONS OF DIESEL ENGINES WHEN BLENDED WITH DIESEL FUEL

Selvan et al. [9], examined how CeO_2 nanoparticles affected the performance and emissions of compression ignition engines. The test engine had a single cylinder, four-stroke direct injection, variable compression ratio (5:1 to 20:1), and water cooling. It produced 3.7. The addition of CeO_2 nanoparticles at a by 25 ppm resulted in an increase in the oxygen specific to the chemical reaction of carbon monoxide, which resulted in a reduction of nitrogen oxide. additionally decreased smoke emissions and UHC. To 0.358 kg/kW/hr, the BSFC decreased.

Sajeevan and Sajith [10], An experimental study to examine the effect of diesel fuel blend with cerium oxide nanoparticles on the performance, combustion, and emission characteristics of a diesel engine. The test Engine specification was a four stroke, single cylinder, 5.5kW, water cooled and constant speed (1500 rpm). Various doses of CeO_2 (from 5ppm to 35ppm) were used. The results obtained can be summarized as follows:

1. Thermal efficiency improved by 6%. compared to neat diesel.
2. From the experiments, it was found that the best dose is 35PPM of cerium oxide, as the thermal efficiency decreased when increasing the doses more than 35PPM.
3. The flash point and fire point were increased with increasing the percentage of nanoparticles.

Lenin et al. [11], Studied experimentally the effect of manganese oxide and copper oxide nanoparticle (100nm) on the performance and emission of a Dl (direct injection) compression ignition engine. The test engine was a four stroke, single cylinder, 4.4W, compression ratio 17:1, air cooled and (1500 rpm). The dosing of MnO was taken from 200 mg/L During the first test, and in the second test diesel fuel with CuO (200 mg/L). The result also showed that the BTE increased marginally by 4% compared to conventional diesel fuel, hydrocarbon emissions were higher and carbon monoxide emissions decreased by 37%. Also, Nitrogen oxide decreases by 4% when manganese is added. From the experiments, it was observed that manganese had a stronger effect than copper in reducing diesel exhaust emissions.

Nasrin Sabet Sarvestany et al. [12], Experimental study focusing on the effect of magnetic Nano fluid (Fe_3O_4) on the emission of internal combustion and performance of a compression ignition diesel engine. The Specification of the test engine used in the experiments were four-stroke, compression ratio 17.6:1, single cylinder, constant speed of 2200 rpm and water cooled. Fe_3O_4 nanoparticles were taken and mixed with diesel fuel with concentrations (0.4% and 0.8 %) from volume and averaging diameter of 10 nm. The result of this study showed that the concentration of nanoparticles by 0.4% showed better combustion properties compared to the concentration of nanoparticles of 0.8%, where the emissions of NO_X and SO_2 emissions decreased significantly by means of magnetic nanoparticle additives, Nitrogen Oxides was reduced an average by 56%, 67% in the cases of 0.4%, 0.8% respectively, while the emission of Co and smoke density increased. As for the efficiency of the diesel engine, BSFC for pure diesel fuel and compared with diesel mixture with nanoparticles of 0.4vol% was the same. While it appears when mixing pure diesel fuel with 0.8vol% of Fe_3O_4 nanoparticles, a significant improvement in the value of BSFC is about 34% compared to other dose, as well as an improvement in combustion effectiveness.

Santhanamuthu et al. [13], The effect of nano-additive on the emission and performance properties of an IC diesel engine when using nanoparticles of iron oxide nanoparticles as an additive in pure diesel with polanga oil is studied experimentally. The nano particles used were 50 nm in size and they were in doses of 100ppm, 200ppm and 300ppm. The engine used in the test was a single cylinder, 4 stroke, direct injection, variable compression ratio17.5:1to 20:1(Variable) magnitude relation engine, 4.5 kW, 1500 rpm constant speed and water cooling. The results were summarized as follows When the engine is loaded more than 80%, the carbon dioxide emission increases significantly, while the nitrogen oxide decreases in different loading conditions, where the NO was reduced by 50% compared to pure (DF). Among the experiments, the BSEC of the same mixture was the neat diesel, increasing the BTE by 27%.

Sadhik Basha [14] An experimental study looking into how a nano-additive affects emissions and performance in a compression ignition diesel engine. The nano-additive was alumina oxide (Al_2O_3) with neat diesel fuel with a particle size (51 nanometers), with doses (25ppm, 50ppm and 100ppm). The engine for checking specification was a single cylinder ,4 stroke, 4.4kW, compression ratio 17.5:1, with constant speed and air cooling (1500 rpm). The results are summarized by comparing the results of blended diesel fuel with elegant diesel as follows:

1. Greatly improves the ignition temperature and reduces the ignition dela.
2. The brake thermal efficiency increased to 29% at full load at the dose level of 100ppm, and the lowest SFC for the brakes was 0.28.
3. Slight reduction in NO_X, hydrocarbons, CO_2, and smoke compared to neat diesel.

Soukht Saraee et al. [15], an experimental investigation was conducted to determine how adding nanoparticles to diesel fuel affected the engine's efficiency and emissions. The configuration of the test engine utilized in the experiments were Four-stroke, Compression ratio 16:1, 82 kW, six-cylinder, constant velocity of 2300 rpm and air cooled. The Nano additive was silver nanoparticles with dimensions (30-50) nanometers and was used in three doses: 10ppm, 20ppm and 40ppm. The results were summarized as follows, reducing the ignition delay and reducing carbon dioxide and nitrogen oxides by 20.5%, 13%, respectively. Reducing fuel consumption by 3%, improving engine power by 6%, as well as reducing UHC by 28%. Through experiments, it was found that the best percentage to reduce fuel consumption is at doses of 10ppm and 20ppm.

Sajunulal Franc et al. [16], The effect of a nano-additive on the emission properties and performance of a compression ignition (direct injection) diesel engine was studied experimentally. The examination the engine was four stroke, single cylinder, compression ratio 17.5:1, and air cooled. The nanomaterials added were aluminum oxide particles (40 nm) and cobalt oxide particles (50 nm) with neat diesel fuel. The results obtained can be summarized as follows:

1. Reduce ignition delay.
2. Improved thermal efficiency of the brakes and lower specific fuel consumption when compared to neat diesel.
3. Slight reduction in nitrogen oxide, hydrocarbons, carbon dioxide and smoke for sample D2525.
4. 20% lower CO_2 in other samples compared to the elegant diesel for medium and lower loads.

Syed Aalam et al. [17], The effect of aluminum oxide nanoparticles in mixed diesel on the performance, emissions, and combustion properties of a single-cylinder four-stroke diesel engine, 3.7kW, compression ratio 17.5:1, air cooled, and constant speed was investigated experimentally (1500 rpm). The nanoparticles added in different doses (25 ppm and 50 ppm) were blended with pure diesel fuel with a size of (42 to 58 nm). The results obtained can be summarized as follows:

1. Enhancement of fuel characteristics such as cetane number, flash point and calorific value when Al_2O_3 nanoparticles are added to diesel fuel.
2. (BSFC) decreases for all tests when the load is 80%, but when the loads are increased and full load is reached, BSFC for a dose of 25PPM is like the values of neat diesel fuel While fuel at a dose of 50ppm, BSFC was significantly reduced by up to 7% compared to the other cases.
3. CO emissions reduced by up to 49% and 53.5% at 25ppm and 50ppm respectively.
4. A slight improvement in BTE, in comparison to the neat diesel were 26% when at 50PPM, at 25.2% when at 25ppm and 24.45% for the full load of neat diesel.
5. Reduction HC by 52% for 50PPM and significantly increased NO_X emissions using a diesel blend compared to a neat diesel.

Babu and Raja [18], the effect of nanoparticle additive on engine efficiency and emissions with compression ignition is investigated theoretically and experimentally. The nanoparticles used were alumina (Al_2O_3) with particle sizes around 50nm, a density of 3.97g/ml, and dosages of 25ppm, 50ppm, and 75ppm. The engine tested was a four-stroke, single-cylinder engine with 7.5hp, a compression ratio of 17.5:1, a constant velocity of 1800 rpm, and water cooling. The results were summarized as following:

1. Increased flash point from 55°C (diesel) to 62°C (diesel+75ppm Al_2O_3).
2. pressure increased from 54 bar (DF) to 58 bar (diesel + 75ppm).
3. At a dosing level of 75ppm, BTE increased to 39.6 percent at full load. In addition, BSFC was 0.224 (kg/kW.hr).

4. The lowest smoke observed was 80 ppm for the DF+75ppm Al_2O_3. Carbon monoxide and UHC decreased. CO_2 slightly increased but it decreased at full load.

Rolvin et al. [19], An investigational study to examine the result of adding titanium oxide particles to neat diesel fuel on the performance and emission properties of a compression ignition engine. The engine used for testing was rotating at a constant velocity of 1500rpm and a(CR) of 17.5. The size of the (TiO_2) particles used in the experiments is (10-20 nm) and at doses of 80 mg/L. The results obtained can be summarized as follows:

1. Improving the characteristics of neat diesels such as viscosity, fire point, density, and calorific value.
2. The brakes thermal efficiency increased by 0.9% at complete load.
3. (BSFC) of the has been reduced by 22%.
4. Reducing unburned hydrocarbon emissions by 18.36% and carbon monoxide emissions by 25% at complete load with Addition of TiO_2 nanoparticles to neat diesel fuel.

Mahendravarman et al. [20], An experimental investigation study to determine the emission characteristics and performance of a compression ignition diesel engine (direct injection) and the effect of using Fe_3O_4 nanoparticles as an additive in diesel fuel. The size of the nanoparticles used in the experiments was (100 nm) and at doses (150-300) mg/L. The test Engine specification was a four stroke, single cylinder, 3.5kW, compression ratio 17:00 and constant velocity (1500 rpm). The results obtained were summarized as follows, the thermal efficiency of the brakes was increased by 23%-36%, reducing specific fuel consumption from 22% to 30%, respectively, reducing nitrogen oxides and hydrocarbons by 22% and 30%, respectively as well as a slight increase in CO when especially in comparison to regular diesel fuel.

Chen et al. [21], An experimental study examining the effect of a diesel fuel mixture and nanoparticles on the efficiency, combustion, and emissions properties of a diesel engine. The test Engine specification was a single cylinder, four stroke, 15kW, CR 17.7:1, Constant velocity (2400 rpm) and water cooling. Three types of nanoparticles were used, and their size was aluminum oxide (20-30 nm), carbon nanotubes (diameter x length 5 x200), silicon oxide (200 -30 nm) with doses of (25ppm), (50ppm), and (100ppm) of nanoparticles mixed with fuel neat diesel. The results obtained can be summarized as follows:

1. The (BSFC) of the has been reduced by 19.8%.
2. BTE improved by 18.8%.
3. 3. The results revealed that the Sio2 mixture outperforms the Al_2O_3 mixture in many ways, including higher combustion pressure, and carbon monoxide emissions, and low brake fuel consumption specific
4. Reducing the HC emissions of the mixture of Al_2O_3 and SiO_2 by 1.76 units due to the ignition delay and in turn negatively affects the increase of NO_X emission by 0.59% for Al_2O_3 and 4.29% for SiO_2 due to the high HRR.
5. Reducing NO_X emissions by 4.48 for the CNT mixture but increasing the emissions of CO, CO_2, and HC.

Adel Sharif Hamadi et al. [22], An experimental investigation to investigate the impact of diesel fuel mixture and zinc oxide (ZnO) nanoparticles on the achievement, combustion, and exhaust emissions of a diesel engine. The test Engine specification was a four stroke, 4 cylinders, with the pressure fuel delivery (400 bar), Compression ratio 17:1and water cooled. Various doses of (ZnO) (from 50ppm to 100ppm) were used. The results obtained can be summarized as follows:

1. Increase doses of zinc oxide nanoparticles improve thermal efficiency and reduce specific fuel consumption.
2. The adding of zinc oxide to natural diesel fuel lowers the combustion temperature, lowering nitrogen oxide emissions.
3. The use of nanoparticles reduced UHC, CO, and smoke emissions.

Venkatesan and Kadiresh [23], An experimental investigation into the effect of adding cerium oxide to pure diesel fuel on the performance and emissions of a diesel engine.

The examination showed the engine was four stroke, single cylinder, 3.5kW, and water cooled. Two different doses of cerium oxide (750 mg and 1000 mg) and DDSA (2.5 and 5% vol) were used, five samples were made with different doses of cerium oxide and DDSA and mixed with pure diesel in order to compare and get the best mixture The samples were in the following doses (1lite D+750mg CeO_2), (1 LD+1000mg CeO_2), (1LD+1000mgCeO_2+2.5%DDSA), (1LD+1000mgCeO_2+5%DDSA) and one pure diesel sample. The size of the (TiO_2) particles used in the experiments is (10-20 nm) and at doses of 80 mg/L Thermal efficiency increased by 7% was at full load for blend (1LD+1000mg CeO_2+DDSA), which was the best of the five mixtures.

1. Slightly increased fire point, flash point and kinematic viscosity values for mixed CeO_2 mixtures.
2. Reducing specific fuel consumption by 5.6% for the blend (D+100mg CeO_2 .+50DDSA) compared to the pure diesel at the full load.
3. Reducing emissions of carbon dioxide, hydrocarbons, smoke, and nitrogen oxides by 38.5%, 46.1%, 26% and 40% respectively at full loading of the mix (D + 1000cerium + 50DDSA).

Giulio Solero [24], A test was conducted to see how adding aluminum oxide affected the performance, combustion, and emission characteristics of the fuel combustion process. The used nanoparticle size (10 nm). The results of this addition were improvements in combustion properties, reduced carbon monoxide formation, and improved combustion stability and efficiency.

Senthil kumar et al. [25] An investigation into the effects of adding titanium oxide nanoparticles to DF. The test engine was a four stroke, single cylinder, 4.5kW, 17.5:1 compression ratio, air cooled, and constant speed 1500 rpm. Doses (50ppm - 100ppm) of TiO_2 nanoparticles were used and mixed with neat diesel. The results obtained can be summarized as follows:

1. Reducing the HC emissions of ($TiO_2$50+D100) and ($TiO_2$100+D100) mixtures by 1.7 and 2.3%, respectively. As well as reducing the ignition delay time.

2. Reducing the NO_X emissions of the mixture ($TiO_2$50+D100) and ($TiO_2$100+D100) by 3.7 and 4.1%, respectively, compared to the elegant diesel.
3. Reducing the CO emissions of the mixture ($TiO_2$50 + D100) and ($TiO_2$100 + D100) by 1.4 and 2.2%, respectively, compared to the regular diesel.

Abdulkadir Yaşar et al. [26], An experimental study was conducted to investigate the impact of adding nanoparticles to pure diesel fuel on the performance, combustion, and emission properties of a diesel engine. The examination the engine was four stroke, single cylinder, 3.5kW, compression ratio 16:1-18:1, and water cooled. The added nanoparticles were titanium dioxide, copper nitrate, cerium, and acetate hydrate with doses from (50ppm to 100ppm). The results obtained can be summarized as follows:

1. The test fuel's calorific value and cetane number increased, but its viscosity and density decreased slightly.
2. Because of the large surface area of mineral additives, the brakes specific fuel consumption has been reduced for all types of particles added to neat diesel fuel.
3. The addition of cerium acetate hydrate results in the highest reduction in CO and hydrocarbon emissions when compared to diesel, as well as the highest value of nitrogen oxides was obtained when adding CuNO3.

Dhahad et al. [27], An experimental study to see how adding nanoparticles to Iraqi diesel fuel affects the performance and combustion characteristics of a diesel engine. The test Engine specification was a four stroke, four cylinders, 3.5kW Compression ratio 17:1, Injection type Direct injection and velocity (1600 rpm). The nanoparticles added to the Iraqi diesel were aluminum oxide, with a size of (30-35 nanometers) and zinc oxide with a size of (20-30 nanometers) and the diesel was mixed with nanoparticles in concentrations of (50ppm-100ppm). The results obtained can be summarized as follows:

1. Reduce fuel consumption by 7% and 8% for doses of (D + 100 ZnO) and (D + 100Al_2O_3) respectively.

2. BTE increased by 5% and 6% for doses of (DF + 100ZnO) and (DF + 100Al_2O_3) respectively when compared to conventional diesel.
3. Carbon monoxide emissions reduction was very specific was the highest dose17% for (D + 100Al_2O_3).
4. Reduce emissions of HC, TSP, SO2 and H2S by 17%, 26%, 19% and 19% respectively.
5. Nitrogen oxides increased by 10% in comparison to DF.

Jiangjun Wei et al. [28], An experimental study to examine the effect of adding nanoparticles to DF on the efficiency, combustion, and emission characteristics of a diesel engine. The test Engine specification was a four stroke, single cylinders, 11.32 kW Compression ratio 17.5:1, Injection type Direct injection, water cooled and speed 2200 rpm. The nanoparticles added to the neat diesel were aluminum oxide, with a size of (30 nanometers) and the diesel was mixed with nanoparticles in concentrations of (25 ppm-100 ppm) with methanol. The results obtained can be summarized as follows:

1. When nanoparticles (Al_2O_3) were added to the diesel and methanol mixture, an improvement in the brake thermal efficiency, peak pressure of the cylinder and the heat release rate resulted in 3.6%, 2.5% and 16.1%, respectively.
2. When adding nanoparticles at a dose of 100 ppm, the ignition delay and combustion duration decreased by 6.9% and 16% respectively.
3. Increasing engine performance by 3.6% by increasing BTE and decreasing (BSFC and BSEC) by 3.7% and 3.5%, respectively.
4. Significantly reducing CO emissions to 83.3% and as well hydrocarbons and smoke opacity emissions, with 40.9% and 69.2% respectively. Nitrogen oxide emissions increased by 14.4%.

2.3. EXPERIMENTAL STUDY OF EFFECT OF NANOPARTICLES WHEN MIXED WITH BIODIESEL FUEL ON DIESEL ENGINE PERFORMANCE AND EMISSION

Rajinder Kumar Moom et al. [29], An investigation into the effect of a mixture (diesel-biodiesel, biodiesel-ethanol, and diesel-ethanol ethyl acetate) on the emission combustion, and performance properties. Biofuels were a product of waste cooking oil. The inspection the engine was a four-stroke, single-cylinder, 4.8 kW, 16.5:1:1 compression ratio, water cooled, and 1500 rpm. The findings obtained can be summarized as follows:

1. Increase brake thermal efficiency (BTE) by 7.26%.
2. Increase in (BSFC) for (B100) by 14.9 compared pure diesel.
3. Increase BSEC by about 10% compared to pure diesel on full loading.

Shaafi et al. [30], Experimental investigated to study the effect on fuel blends, B20 (Diesel- soybean biodiesel) and diesel- soybean Biodiesel- ethanol blends, with alumina as a nano additive (D80SBD15E4S1 +alumina), and the results are compared with those of neat diesel on the emission properties and performance of a Dl compression ignition engine. The test engine has a four stroke, direct injection, single cylinder, rated power 4.4kW, air cooled, Compression ratio17.5:1 and Rated Speed 1500 rpm. The dosing of Al_2O_3 was taken from 100 mg/L, Al_2O_3 nanoparticles of size less than 50 nm. The results of the (D80SBD15E4S1 + alumina) fuel blend, which is due to the maximum heat release rate, The BSEC is higher for the B20 and D80SBD15E4S1 + alumina fuel blends compared to neat diesel at 25% and 50% load, reduce emission such as CO, CO_2, UBHC compared to neat diesel and this alumina nanoparticle enhances the NO_X emission, due to the maximum cylinder pressure and higher heat release achieved during the combustion process.

Syed Aalam et al. [31], An experimental study will look at how a diesel engine's performance, combustion, and emission characteristics are affected by the addition of aluminum oxide nanoparticles to the fuel. The test Engine specification was a four stroke, single cylinder, 5.2kW, Compression ratio 17:1, water cooled 1500 rpm. The nanoparticle size used was 31.6 to 47.5 nm and doses (25ppm and 50ppm). The results obtained can be summarized as follows:

1. For a 50ppm dose of (AONP50), brake-specific fuel consumption was reduced by 6% compared to other cases.
2. A 2.5 percent improvement in brake thermal efficiency at 50 ppm (AONP50).

3. The CO and HC emissions are reduced when using biodiesel (AONP25) compared to neat diesel.
4. Nitrogen oxide emissions are lower than that of neat diesel for (AONP) but increase when nanoparticles are added.

Jeryajkumar et al. [32], presented a study that tested the effects of dosing calophyllurn iodophilic biodiesel with nanoparticles such as cobalt oxide (Co_3O_4) and titanium oxide (TiO_2) at a rate of 50 mg/l on the performance of a water-cooled single-cylinder, four-stroke compression-ignition diesel engine. The following results were obtained:

1. Brake Specific Fuel Consumption (BSFC) for (Co_3O_4) and Titanium Oxide (TiO_2) has been reduced by 4% and 2% respectively. Cobalt oxide (Co3O4) blended with biodiesel also showed a 7% higher (BTE) compared to pure biodiesel.
2. The emission of carbon monoxide (CO) was reduced with biodiesel in combination with nanoparticles. By adding cobalt oxide (Co_3O_4), a CO reduction of 30% was achieved, while biodiesel in combination with titanium oxide (TiO_2) showed a CO reduction of 25%.
3. Unburned hydrocarbons were reduced by 80% and 70%, respectively, using cobalt oxide (Co_3O_4) and titanium oxide (TiO_2).

Khadijeh Heydari-Maleney et al. [33], Experimental study of the effect of mixing diesel fuel and ethanol with biodiesel in different proportions, as well as mixing nanoparticles with fuel to improve it. In this study, carbon nanotubes were used and combined with diesel fuel and ethanol with biodiesel, with concentrations of 20,60,100ppm of carbon tubes. The test engine was a four stroke, single cylinder, direct injection, 9 kW, air cooled, at (2300 rpm) and rated speed (3000 rpm). The results of this study showed that torque, power, and brake thermal efficiency increased by 15.5:12%, 15.5:12% and 13.97%, respectively. Additionally, there was a 1.865-degree reduction in exhaust gas temperature and an 11.73 percent reduction in specific fuel consumption. However, there was a 12.22% increase in nitrogen oxide emissions.

Seyyed Hassan Hosseini et al. [34], Experimental investigation into how a diesel engine's performance, and emission properties are affected by the addition of Carbon Nanotubes (CNTs) to biodiesel. The test Engine specification was a four stroke, single cylinder, 9kW, CR17.5:1, air cooled and rated speed (3000 rpm). Biodiesel was made from used cooking oil in this study. Nanoparticles (CNTs) at different doses of 30, 60 and 90 ppm were mixed with biodiesel fuel in a ratio of B5 and B10. The experiments were conducted during three speeds of the diesel engine which are 1800, 2300, and 2800 rpm at full load. The results obtained can be summarized as follows:

1. Increased power and (BTE) and (EGT) by 3.67%, 8.12% and 5.57%, respectively of the B5C90 fuel blend compared to pure diesel.
2. Specific fuel consumption reduced by 7.12% for B5C90 fuel blend compared to pure diesel.
3. Reducing emissions of carbon dioxide, hydrocarbons, and soot by 65.70%, 44.98% and 29.41%, respectively.
4. NO_X emissions increased by 27.49%.

Ashok et al. [35], studied the effect of Nano additive on the performance and emission characteristic on the CI engine. an engine was manufactured to run CI to work 100% Calophyllum Inophyllum Methly Ester (CIME) and biodiesel fuel with fuel additives. The percentage of added zinc was 50 and 10 ppm, while the additive ethanox was at rates of 500 to 200 ppm. The engine tested was 4 stroke, twin cylinder, 21 kW and cooled by water with 2000 rpm, Compression Ratio 18.5:1 The results of this study showed Through experiments, it was found that adding 100 ppm of zinc oxide improves efficiency by 4.7% and reduces nitrogen oxides by 12.6% when fully loaded, and it was found that the best addition of ethanox by 500 parts per million reduces nitrogen oxides by 17. 8. But in return for this there is a slight improvement in HC and CO And a slight improvement in BSFC and BSEC in various additive kinds.
Alok Ranjan et al. [36], An experimental investigation into the properties of marketing and cold storage of biodiesel fuel, as well as the impact of nanoparticles admixture on the performance and emissions of a CR engine. The nanoparticles used were magnesium (MgO) in doses of 30ppm,40 ppm,50 ppm and they were mixed with using biodiesel made from used cooking oil methanol with petroleum-based diesel fuel PBD

at rates of 0%,80%,90%. The test drive specification was 4 stroke, single cylinder, cooled by water, 1500(rpm), Power rating 7 hp. The results are summarized as follows:

1. The cloud point, cold filter clogging point, pour point, and flash point of the test fuel all improved when magnesium particles were used.
2. The calorific value of B100W30A, B20W30A, B10W30A was improved by 0.81%, 0.7%, 0.63% compared to B10, B20.B100 fuels respectively.
3. The test fuel mixed with nanoparticles contains a higher percentage of BTE, BP. BSFC compared to B10, B20, and B100 fuels.
4. The emissions of fuel mixed with nanoparticles are lower in terms of CO and hydrocarbons, but CO_2 emissions are more compared to B10, B20, B100.

Örs et al. [37], The performance and combustion, properties of a diesel engine are the subject of an experimental study to determine the impact of combining biodiesel fuel made from used cooking oil with titanium dioxide and n-butanol (C4H9OH). The fuel mixture used in tests was composed of diesel -biodiesel - n-butanol and TiO_2 nanoparticles. The doses of fuel used in the experiments were (D100), (B100), B20, B20 + TiO_2, B20But10 and B20But10 + TiO_2, respectively. The test Engine specification was a four stroke, single cylinder, 9kW, Compression ratio 17:1, cooled by water and 1500 rpm The outcomes can be summed up as follows:

1. Reduce brake torque about 21%, 6.61%, 10.97% and 2.31% respectively for B100, B20, B20BUT10 and B20But10 + TiO_2 respectively while increasing About 2.89% for B20 + TIO2 Compared to euro diesel.
2. Reducing fuel consumption of the BSFC for (B20 + TiO_2) and (B20But10 + TiO2) by 27.73%, 28.37%, respectively, compared to the other cases.
3. Reduce CO, HC, and emissions smoke darkening emissions, and in contrast emissions of nitrogen oxides and carbon dioxide increased compared to diesel fuel.
4. The addition of n-butanol decreased the emissions of CO, HC, and NO smoke opacity, but the CO_2 values rose in comparison to diesel.

Yuvarajan et al. [38] An experimental study to determine how titanium dioxide added to biodiesel fuel (oil methyl ester) affects a diesel engine's operation, combustion, and emission characteristics. The test Engine specification was a four stroke, single cylinder, 4.2kW, Compression ratio 17.5:1, air cooled and speed 1500 rpm. The size of TiO2 nanoparticles was (50 nm) and doses (100 and 200ppm) The results obtained can be summarized as follows:

1. The HC, CO and smoke emissions are reduced in MOME, MOMET100 and MOMET200 compared to diesel.
2. Increase nitrogen oxides for MOMET100 MOME and MOMET200 compared to diesel fuel.
3. Addition of TiO_2 in methyl mustard oil Produces decreased HC and CO emissions and smoke emissions.
4. The NO_X emissions of MOMET100 and MOMET200 are significantly reduced when TiO_2 nanofluid is added to them.

Prabhu Appavu & M. Venkata Ramanan [39], An experimental study was conducted to determine how the combustion, and emission characteristics of a diesel engine would change when biodiesel fuel (pongamia methyl ester, or PME) was combined with cerium oxide (CeO_2) nanoparticles. The test Engine specification was a four stroke, two cylinders, 4.5kW, Compression ratio 18.5:1water cooled and constant speed (1800 rpm). CeO_2 nanoparticles were mixed with (PME) in doses (50ppm and 100ppm). The results obtained can be summarized as follows:

1. Reducing emissions of CO, HC for PME and blends (CeO_2) with biodiesel in doses (50 and 100PPM) compared to neat diesel fuel.
2. Increased nitrogen oxide emissions when versus pure diesel for PME, PMEA50, and PMea100.
3. When cerium oxide particles are added to PME, the emissions of CO, HC, and smoke opacity are reduced, and for PMEA50 and PMEA100, the emissions of nitrogen oxides are also reduced when (CeO_2) is added.

Ahmed I. El-Seesy et al. [40], A test was done to determine the impact of mixing biodiesel fuel (Jojoba (JB20D)) added to alumina nanoparticles (Al_2O_3) on the performance and combustion characteristics. The test Engine specification was, a single cylinder, four stroke engine ,5.77kW, cooled by air and different speeds. The AL_2O_3 nanoparticle size used was (20 to 50nm). alumina nanoparticles were mixed with Jojoba biodiesel-diesel (JB20D). The results obtained can be summarized as follows:

1. The addition of Al_2O_3 nanoparticles to the fuel mixture (JB20D) produces high pressure rate in roller and heat rate compared to pure JB20D.
2. The addition of alumina nanoparticles enhanced the brake thermal efficiency (BTE) by 15%.
3. By adding Al_2O_3, you can cut the brake specific fuel consumption (BSFC) by 12%.
4. Reduce nitrogen oxides, carbon oxide, UHC, and smoke opacity when adding alumina nanoparticles to the JB20D fuel mixture by up to 70%, 80%, 60% and 35% respectively compared to (JB20D).
5. Through the results, the best performance of the diesel engine was obtained at a concentration of 40 mg / liter of nanoparticles of alumina (Al_2O_3), while the best dose was obtained for a decrease in engine emissions at the dose level. 20 mg/L.

EL-Seesy and Hassan [41], An experimental investigation to see how the efficiency, combustion, and emission characteristics of Jojoba biodiesel fuel is affected by the addition of nanoparticles of titanium oxide (TiO_2). The test Engine specification was a four stroke, single cylinder, 5.7kW, cooled by air and velocity 2000 rpm. The nanoparticle doses used were (25 and 50 mg/L). The proportions of the blended materials were 50% jojoba biodiesel, 40% diesel, and 10% n-butanol (symbolized by J50D10Bu). The outcomes obtained can be summarized as follows:

1. Boost the heat release rate by 1.5 percent and the peak pressure by 2 percent, respectively.
2. Increased BTE by 17% and reduced brake specific fuel consumption by 15% when TiO_2 was added to J50D10Bu, compared to pure (J50D10Bu) blend.

3. Reducing CO and Unburned Hydrocarbons emissions by 30% and 50%, respectively, with the addition of TiO_2 to J50D10Bu, compared to pure J50D10Bu.
4. Increase nitrogen oxides by 30%.

Harish Venu & Prabhu Appavu [42], Study to examine the impact of zirconium nano additives to biodiesel fuel on the efficiency, burning, and emission properties. The test Engine specification was a four stroke, single cylinder, direct injection ,4.4kW, CR 17.5:1, cooled by air and constant speed (1500 rpm). Zirconium nanoparticles (25ppm) were mixed with Jatropha biodiesel (20%) - diesel (80%) B20. The results obtained can be summarized as follows: In comparison to other situations, full load of the diesel engine causes the cylinder's peak pressure and heat release to be higher for B20 , The decrease in BSFC of the blend (B20 + Zr) is the lowest compared to (B20 and diesel) , The addition of nanoparticles reduced CO and HC emissions compared to B20 and diesel, Carbon dioxide and nitrogen oxide increased for B20, increased brake specific efficiency (BTE) slightly for B20 + ZR and smoke emissions have been significantly reduced, indicating full combustion of nanoparticles.

Gada, S. Jayaraj [43], Experimental research aims to examine the effect of nano-additives (CNTs, TiO_2 and Al_2O_3) to Jatropha biodiesel fuel on the performance, combustion, and emission characteristics of diesel engines. The test Engine specification was a four stroke, single cylinder, 5.775kW, Compression ratio 17.:1and air cooled. The mix was prepared from 20% diesel and biodiesel oils and mixed with nanoparticles (CNTS, TIO_2 and Al_2O_3) dose (50.25, and 100 PPM) respectively. The results obtained can be summarized as follows:

1. 6.5% increase in BTE at 75% of the diesel engine load for the J20Al100 blend compared to the neat diesel and all other fuels tested.
2. Obtaining the highest reductions in CO_2 and NO_X emissions by about 35 and 52%, respectively for the (J20C50) blend compared to all fuels.
3. . Compared to all other fuels, the J20T25 blend achieved the highest reductions in hydrocarbon and smoke emissions, of about 22 and 50 percent, respectively

Elwardany et al. [44], The efficiency, combustion, and emission characteristics of a diesel engine are being studied experimentally to see how adding ferrocene nanoparticles to the fuel affects those aspects. The test Engine specification was a four stroke, 6 cylinders, 3.5kW, Compression ratio 22:1 and cooled by air. To conduct experiments, three additional samples of B30 were combined with various ferrocene nanoparticle concentrations (200, 250, and 300 mg/L). The concentrations of the mixed fuels were 30 percent biodiesel and 70 percent diesel, and the concentrations of ferrocene nanoparticles in diesel fuel where they were (50, 75, 150, 200, 250, and 300 mg/L). The outcomes obtained can be summarized as follows:

1. Increased brakes thermal efficiency when adding ferrocene to diesel and basic fuel(B30) by 3% and 8% respectively.
2. Through experiments, it was found that the best doses of ferrocene nanoparticles in diesel and (B30) are 250 and 300 mg/L, respectively.
3. Increasing pressure inside the cylinder with the addition of ferrocene nanoparticles.
4. The addition of ferrocene nanoparticles resulted in an increase in carbon dioxide.
5. Because of adding ferrocene nanoparticles to pure fuel, nitrogen oxides decreased at all loads while increasing with ferrocene added to B30 at low loads.

Suleyman et al. [45], Experimental study to examine the effect produced of animal fat-produced biodiesel (AFDB) and vegetable biodiesel (VEND). The test Engine specification was a four stroke, single cylinder, 6.7hp, air coo injection compression ignition and speed (3000 rpm). Five different concentrations of fuel were used in the experiments D100, AFBD100, VEBD100, VEBD50 (50% Diesel + 50% Vegetable Biodiesel), AFBD50 (50% Diesel + 50% Animal Biodiesel). The results obtained can be summarized as follows:

1. The brakes thermal efficiency decreased, and the brakes specific fuel consumption increased with) AFBD100 and VEBD100)fuels This is due to the high viscosity,
2. Reduce carbon monoxide emissions and hydrocarbons with (VEBD and AFBD) fuel types.

3. The percentages of CO emission reductions obtained from fuels (VEBD100, AFBD100, VEBD50 and AFBD50) by 34.28%,25.68%, 17.20% and 9.63% respectively, compared to Diesel.
4. Increase carbon dioxide emissions with) VEBD and AFBD) fuel types.
5. Increase nitrogen oxides when using VEBD and AFBD fuel species compared to diesel.

Mujtaba et al. [46], The efficiency and combustion properties of diesel engines are being investigated experimentally to determine the impact of nano-additives (CNT and TiO_2) to biodiesel fuel.

The test Engine specification was a four stroke, single cylinder, 7.7kW, Compression ratio 17.5:1, water cooled and Maximum engine speed (2400 rpm). Biodiesel is obtained from a complementary blend of palm and sesame oil. The mix was prepared from 30% diesel and biodiesel oils and mixed with 5% (DEE) and 10% (DMC) and nanoparticles (CNT andTiO_2) dose (100 PPM) respectively. The results obtained can be summarized as follows:

1. When using a mixture of B30 + TiO_2 and B30 + CNT, BSFC was reduced by 4.1 and 3.5 percent, respectively.
2. The B30 + DMC is shown maximum force for brakes, followed (B30 + Dee) and (B30 + CNT) and (B30 + TiO_2).
3. The brake thermal efficiency of all three-dose fuel blends (B30 + DMC and B30 + TiO_2) increased by 9.88% and 5.495 respectively compared to B30 fuels.
4. Significant reduction in CO emissions for the following doses (B30 + DMC and B30 + DEE) by 29.9% and 21.9% respectively compared to B30 fuel.
5. Reducing the HC emissions of the fuel mixture for the following doses (B30 + DMC and B30 + DEE) by (21.4%) and (15.17%) respectively compared to B30 fuel.
6. Reduce the emissions of nitrogen oxides for the following fuel mixture (B30 + CNT and B10) by 3.92% and 2.94% respectively compared to B30 either other case showed an increase in NO_X.

Harish Venu et al. [47], Custom study for experimental analysis on the impact of alumina nano additives to biodiesel fuel on the performance, combustion, and pollution properties. The test Engine specification was a 4 stroke, vertical diesel engine, single cylinder, 4.4kW, Compression ratio 18.:1, air cooled and 1500 rpm. Doses of nanoparticles (Al_2O_3) used were (10ppm,20ppm.30ppm), and biodiesel fuel (TF) was prepared from mixing 70% diesel, 20% JB and 10% ethanol. The results obtained can be summarized as follows:

1. Increased brake thermal efficiency and low BSEC by 7.8% and 4.93%, respectively for fuel mixture (TF) 20 ppm from Alumina Material Added (TF20).
2. Reduce HC, Co, NO_X, and smoke emissions by 5.69%,11.24%, 9.39% and 6.48%, respectively for fuel mixture (TF) 20 ppm of Alumina Material Added (TF20) compared to TF.
3. Through the experiments have been getting the best proportion of nanoparticles 20 ppm Improve engine performance and combustion.

Prabhu Kishore Nutakki et al. [48], Experimental study to examine the effect of nano-additive silicon dioxide nanoparticle to biodiesel fuel on the performance, combustion, and emission properties of diesel engines. The test Engine specification was a four stroke, single cylinder, 3.7kW, CR17.5:1, water cooled and Torque/Power 30 Nm@2000 RPM, 9 bhp@3000 RPM. Silicon dioxide nanoparticles were mixed in doses (50ppm - 120ppm) with Mahua methyl ester (MME) The blends of biodiesel fuel and nanoparticles used in the experiments were (MME20 + SIO40, MME20 + SIO80, and MME20 + SIO120). The outcomes obtained can be summarized as follows:

1. Reduce Brake Specific Fuel Consumption significantly for the MME20 and Sio120 compared to other cases.
2. Improving Brake thermal efficiency for MME20 and SIO120 compared to other cases.
3. Slight reduction in emissions (smoke, CO and UHC) for all three blends of biodiesel and nanoparticles fuels due to oxidation by silicon dioxide which

enhances combustion quality and reduces ignition delay. Increase nitrogen oxides.

2.4. THEORETICAL STUDIES OF DIESEL FUEL MIX WITH NANOPARTICLES, BIODIESEL AND THEIR EFFECT ON EMISSIONS AND DIESEL ENGINE PERFORMANCE

Gaurav Paul et al. [49], Experimental and theoretical study on the impact of Jatropha biodiesel to mineral diesel on the performance, pollution, and properties. The examination the engine was a four-stroke, vertical diesel engine with two cylinders., 7.35kW, Compression ratio 17.5:1and cooled by water. Theoretical calculations were carried out using a simulation program (Diesel-RK). The fuels used in the experiments are neat diesel (B0) and (JB100). The results obtained can be summarized, these results include an experimental and numerical analysis of the efficiency and emissions traits of a diesel engine using a different biodiesel mixture. Reduce BTE and torque, Increased brake specific fuel consumption, Increased NO_X emissions when using Jatropha biodiesel compared to pure diesel, increase carbon dioxide emissions in the exhaust tube when adding the Jatropha biodiesel fuel to the diesel engine. The characteristics that were calculated numerically to know the performance of the engine using the (Diesel-RK) program are the brake force, the brakes mean effective pressure, brake torque, specific fuel consumption and volumetric efficiency. Emission parameters such as NO_X formation, soot emission, PM and CO_2 emissions are also simulated by this software using various models and empirical relationships available in the literature. Modeling of NO_X formation: Nitrogen oxides such as nitrogen monoxide (NO) and nitrogen dioxide (NO_2) are collectively referred to as NO_X. The simulation result is compared numerically with the experimental results under the same operating conditions and the comparison is done in three parameters to verify its relevance which are BTE, BSFC and NO_X emission. The results obtained can be summarized as follows:

1. The measured thermal efficiency numerically measured by (Diesel-RK) for fuel type (B0) and (JB100) is 20.27% and 14.6% from simulation and experiment, respectively. The actual operational load of the fuel type (B0) and (JB100) is

18% and 10.3%, respectively, with the simulation and experimental results with diesel is close enough.

2. The simulated BSFC value is 0.4209 kg/kWh while the experimental value is 0.531 kg/kWh for diesel.
3. The empirical NO_X emission ratio was 220.77 ppm and 290 ppm respectively for diesel fuel. The simulation result is 300 ppm, while the experimental value is 470 ppm when fed with jatropha Biodiesel. The simulated value and experimental results with diesel are close enough.

Ghanbari et al. [50], An experimental and theoretical investigation to determine how adding carbon nano tubes (CNT) and nano silver debris to biodiesel fuel will affect its performance, combustion, and pollution characteristics. The test Engine specification was a four stroke, single cylinder, 190kW, CR 17:1, air cooled operated at different engine speeds and. Multi wall (CNT) (40, eighty and one hundred twenty ppm) and nano silver debris (40, eighty and one hundred twenty ppm) have been produced and introduced as additive to the DB-DF mixed gas. The results obtained can be summarized as follows:

1. The results of the experimental tests showed that adding nanoparticles to diesel and biodiesel fuels multiplied engine power and torque output by up to 2 percent, and brake specific gas consumption (BSFC) decreased by 7.08 percent compared to the use of regular diesel fuel.
2. Compared to natural diesel gas, CO_2 emissions increased by a maximum of 17.03 percent, while CO emissions decreased noticeably (by 25.17 percent) in a biodiesel-diesel gas with nano-debris.
3. UHC emission was reduced by 28.56 percent with silver nano-diesel-biodiesel mixed gas, whereas it increased by 14.21 percent with fuels containing CNT nano debris.
4. In comparison to internet diesel gas, NO_X increased by 25.32%.

Additionally, offers a genetic programming (GP)-based model to predict the performance and emission parameters of a CI engine in terms of nano fuels and engine speed. It was discovered that the GP version can be expecting engine overall performance and emission parameters with correlation coefficients (R2) in the range of 0.93-1 and RMSE close to zero. The simulation results confirmed that the GP version is an excellent device for predicting the CI engine's overall performance and pollution parameters.

Upendra Rajak et al. [51] The effect of using D100 (diesel) and AB100 (Algae-biodiesel) as fuels at various compression ratios (16.5:1-18.5:1) on the performance, combustion, and emission characteristics of a diesel engine was studied experimentally and theoretically. The test Engine specification was single cylinder, 3.7kW, CR (16.5:1–18.5:1), cooled by water and velocity 1500 rpm. In this study, a digital program Diesel-RK was used to simulate direct injection of a diesel engine. Also, practical experiments were conducted on the test engine with a compression ratio of 17.5:1 at full load conditions and were compared with the numerical results. At a constant engine speed and 100 percent load, simulations were run to predict diesel engine characteristics such as cylinder pressure, EGT, BTE, specific fuel consumption, and CO_2, NO_X, and particulate emissions. The outcomes obtained can be summarized as follows:

1. The use of AB100 reduced the thermal efficiency of the brakes by 2.73%, torque by 6.66%, EGT by 1.6%, CO_2 by 6.1%, NO_X by 0.5% and particulate matter by 60%. In addition, SFC. In CR 17.5 it increased by 6.4% compared to diesel.
2. In the numerical study, it was found that the increase in the compression ratio within these ratios (CR 16.5:1 to CR 18.5:1, CR 17.5:1) was the best. The cylinder pressure at CR 17.5 to D100 was 98.5 bar while the pressure for the fuel mixture was D80B20 and AB100 99.67 and 99.5 bar, respectively. By noting the results obtained, it has been shown that algae biodiesel fuels can be an excellent renewable source of energy.
3. In the theoretical look at the cylinder temperature even as the use of AB100 turned into observed to be decrease than whilst the use of D100. (At CR17.5:1) 365° CA, AB100 and (D80B20) result1961 K and 1972.2 K, respectively, even as D100 result 1976 K. The ignition postpones passed off in each the fuels with appreciate to the boom in compression ratio.

4. In the numerical study, it was noted that the brake torque and brake force decreased using the D80B20 and AB100 fuel mixture compared to the D100 fuel when fully loaded, the SFC of the D80B20 and AB100 is also increased compared to the D100.
5. Reducing nitrogen oxide emissions for D80B20 and AB100 (2352.7 ppm, 2372.0 ppm) respectively compared to D100 (2384.0 ppm) at CR17.5:1.
6. Reducing the emission of the specified carbon dioxide for fuel mix (AB100) (846. g/kW h1) compared with fuel D100 (904.02 g/kW h) at 17.5:1 compression ratio.

Edam and Al – Dawody et al. [52], In this study, a numerical analysis was performed on the effect of adding nanoparticles (alumina) to castor methyl ester (CME) biodiesel fuel on the efficiency, combustion and emissions properties of diesel engines. The program used in simulation was (DIESEL-RK. In this study, aluminum nanoparticles were used in three concentrations (25,50 and 100 ppm) and blended with biodiesel produced from castor methyl ester (CME) with a percentage of B20%. The results obtained can be summarized as follows:

1. Increase the dose of nanoparticles for (Al_2O_3) while decreasing the brake specific fuel consumption and increasing BTE.
2. The numerical outcomes calculated by Diesel-RK emissions (SE) emissions are obtained at 6.58%, 7.08% and 6.27% for fuel mixture 20BCME+ 25ppmAL2O3, 20BCME+50ppmAl_2O_3 and 20BCME+100ppm AL2O3 respectively as compared with 20BCME at full load.
3. Adding nanoparticles (Al_2O_3) resulted in a decrease in nitrogen oxides emissions by 11% compared to CME diesel fuel.
4. Of the numerical results obtained, 25 ppm Al_2O_3 was the best concentration to add nano.

Jafarmadar [53], In this study, a numerical investigation of the addition of nanoparticles (titanium oxide) has been conducted to two fuels, diesel and synthetic performance, combustion and emissions for diesel engines. A one-dimensional model of a diesel engine was made in GT-power software and simulation was carried out using the model. Engine performance and emissions checked at partial loads at three variable speeds for the engine with diesel and again under the same conditions by adding TiO_2 nanoparticles of Anatase to the fuel. It will serve four different types of wavelet functions and was best chosen in neurons for network layer for predicting the engine performance. Using genetic algorithm (GA), optimization and WNN parameters are selected. The obtained numerical and predictive results were in good agreement with the experimental results. Therefore, as it showed that modeling by GT-power and WNN has a very high efficiency in predicting performance and engine emissions, without the need for any costly and time-consuming engine tests. The test Engine specification was Kind of Engine Diesel with Direct Fuel Injection System, direct injection, Compression ratio 17.2:1, and Maximum Power 128 kW@2600RPM The results obtained can be summarized as follows:

1. Reducing (BSFC) when adding TiO_2 nanoparticles to diesel fuel at different speeds.
2. Increased engine power when adding nanoparticles TiO_2 compared to diesel fuel.
3. Reducing HC emissions when TiO_2 nanoparticles are added.
4. Reduce carbon monoxide when adding TiO_2 nanoparticles.
5. Nitrogen oxides increase when TiO_2 nanoparticles are added.
6. The combined WNN-GA has a low error rate and fast convergence, as well as the ability to estimate with high accuracy, and is suitable for predicting IC emissions and efficiency.

PART 3

EXPERIMENTAL SET UP AND PROCEDURE

3.1. INTRODUCTION

An experimental study is conducted to evaluate the thermal performance, emission properties, and heat release phasing in a diesel engine fueled with nanoparticles and algae biodiesel fuel. In this study, Algae biodiesel, and type of nanoparticle (Fe_3O_4) with different doses (25ppm, 50ppm and 75ppm) are used. The diesel engine on which the experiments are conducted does not need to be modified, which is powered by the combination of biodiesel and nanoparticles. The formal testing instruments are enough to achieve the targets of research and give fully parameters measuring either input or output. This chapter explained in detail the design of experiment parameters, the experimental setup components, and the uncertainty. The scientific procedures to build the experiments are followed. The sensors and measuring devices are calibrated to standard values and limited the precise and errors ratio in readings. Section 3.2 provides a detailed description of the setup, while Section 3.3 describes the procedure used during the various experimental studies.

3.2. DESCRIPTION OF THE EXPERIMENTAL MATERIAL AND EQUIPMENT

In the current study, a 4-stroke, single-cylinder, direct-injection diesel engine with a displacement volume of (553 cm^3), variable compression ratio, and an output of 3.7 kW at 1500 rpm on a dynamometer is used. Manufacturer-recommended injector opening pressure is 160 bar. The engine is equipped with a traditional fuel injection system, which features a three-hole nozzle with a 0.2mm diameter that is 120 degrees apart and 60 degrees inclined to the cylinder axis. The engine is equipped with a centrifugal governor that enables automatic engine speed regulation.

The combustion chamber is hemispherical in shape and has an overhead valve arrangement that is controlled by push rods. To measure cylinder pressure, a piezoelectric pressure transducer is mounted flush with the cylinder head surface. The engine's cylinder head is equipped with a piezoelectric pressure transducer (Kistler Instruments, Switcher Land, model 6613CQ09-01) to record the history of combustion pressure and crank angle. Figure 3.1 shows the front view of the engine. The sensitivity of the pressure transducer is 4-20mA/0-250bar. The charge amplifier's output is read by a personal computer (PC) using an analog to digital converter (PCI-1720HGU). Due to charge leakage in the pressure transducer, there is a slight drift in the measured current (4–20 mA/cycle). The schematic diagram of the experimental setup is shown in Figure (3.1), and the definition of the system's components is shown in Table 3.1.

Figure 3.1. The front view for the diesel engine used in the experiments.

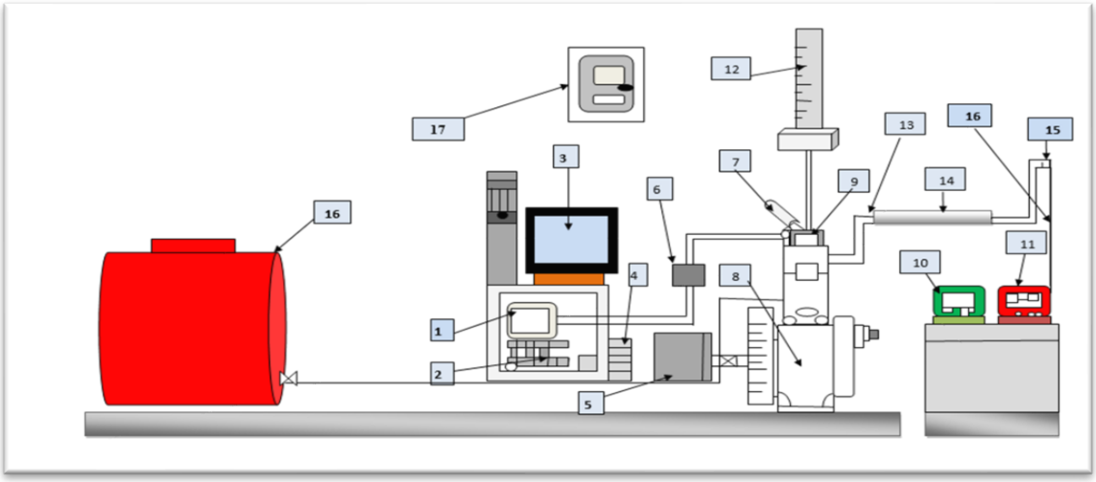

Figure 3.2. Experimental setup schematic diagram.

Table 3.1. Defines the components of the figure's system (3.2).

1-Air Surge Tank	10-Gas Analyzer
2-Data Logger	11-Smok Meter
3-PC to Control DFC	12- Exhaust Gas Probe
4-Water Manometer	13-PT-100 Scanner
5-Eddy Current Dynamometer.	14- Calorimeter
6-Intak Air	15-Silence Tip
7- Fuel Injector	16- Fuel Tank
8- Engine Block	17-Voltage Regulator
9- Cylinder Head	18-Water Tank

3.2.1. Diesel Engine

The diesel engine was installed on a static frame with an appropriate cooling system. The engine is characterized by bore x stroke of (80 mm x 110 mm) and variable (Cr) at rated speed (1500 rpm). The size clearance V_C is 33.5151 cm^3 and is equipped with suitable lubrication and cooling water supply systems. The specification of the Engine is given in table 3.2. The experimental study consists of thermal performance assessment, along with mission properties and heat release phasing of diesel engines working with pure diesel and mixed fuel (diesel + biodiesel algae) (diesel + biodiesel algae + nanoparticles). This work analyzes the interaction between three groups of variables, which are shown in figure (3.3). The details of the engine and its make and specification are given in Table 3.2.

Table 3.2. The specification of the Engine.

Make and Model	**Kirloskar**
General details	Single cylinder, four stroke, compression ignition, vertical, direct injection, water cooled
Bore	80mm
Stroke	110mm
Rating speed	1500 rpm
Swept Volume	553cm^3
Clearance Volume	0.03687 m^3
Compression ratio	12.5-17.5
Rated power	3.7KW
Static injection timing	-30 BTDC
Injection pressure	160 bar
Density of fuel	828 kg/m^3
Start of Injection	150℃A
End ogf Injection	190℃A
Injection Duration	40℃A
Discharge Coefficient of Orifice	0.65
Nozzle Diameter	0.02mm
Water Flow Transmitter	0 to 10 lpm
Air Flow Transmitter	0 – 250 we
Weighing Balance for fuel	0 – 2 kg
Piezo sensor	0 to 5000 psi with low noise cable
software	Labview
Combustion Chamber	Hemispherical open/Hand start with cranking handle

3.2.2. Design of Experiment

The design of the experiment needs to be made before starting the tests where many parameters affect the test. In general, three types of parameters affected the named experimental test (input, output, and environment). Input variables of this investigation are engine load, compression ratio and biodiesel and nano-biodiesel mixture. Meanwhile, the output parameters or responses are BTE, volumetric efficiency, BSFC, air-fuel ratio, equivalence ratio, and EGT. Furthermore, we can consider the components of the exhaust emissions as output or response parameters, such as CO, CO_2, Unburned hydrocarbon UHC, ratio of oxygen and NO_X. The environmental variables are atmospheric pressure and temperature, and the specification of diesel and biodiesel fuels. Figure (3.3) shows the block diagram of this research experiment design.

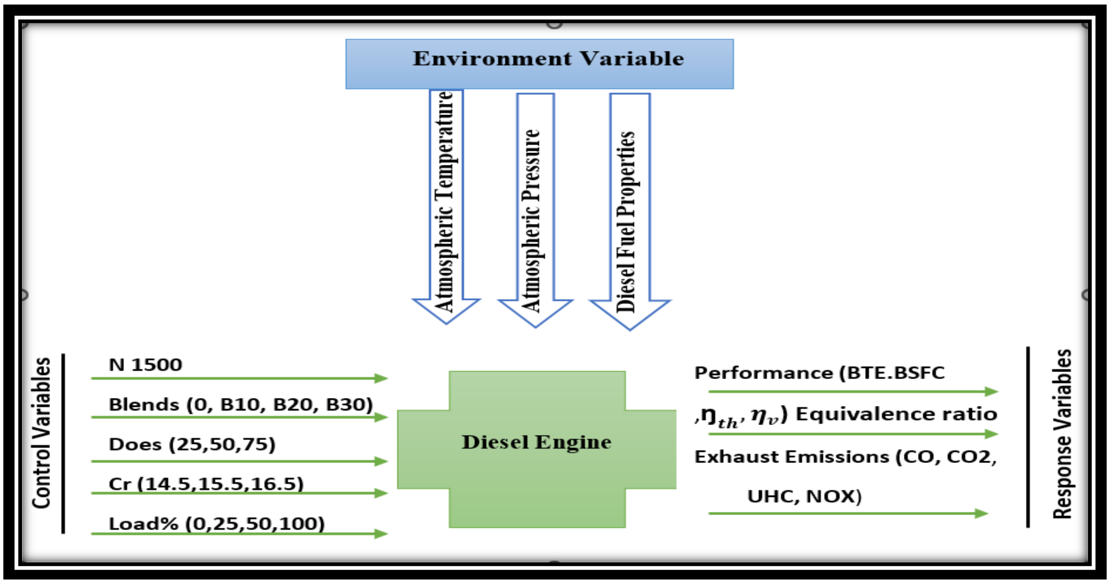

Figure 3.3. Shows the system's control, environment, and response variables (engine).

3.2.2.1. Input Control Variables

The control variables are the number of nanoparticles, the load, the speed, and the compression ratio. The measurement systems for these variables are described in this section:

1. Variable Dosage of Nanoparticles: In this experimental test, ferro oxide nanoparticles (Fe_3O_4) were used with three different doses (25 ppm, 50 ppm and 75 ppm).
2. Variable Compression Ratio Arrangement: The diesel engine has a mechanical system to change the compression ratio. The range of this engine is 12.5:1 to 18.5:1. the change of compression ratio is occurred by mechanical screw in the top of cylinder where can be turn clockwise rotation increases the compression ratio and counterclockwise rotation decrease it from the value them.
3. A digital tachometer: A digital tachometer is fixed to the engine to measure its speed. The measuring speed sends as a digital signal to computer programmer to show it on computer screen. Engine speed can be varied across the range from idle speed to a maximum of 1700 rpm. Engine speed is measured by a digital tachometer. Engine speed can be increased by increasing the fuel supply.
4. Dynamometer as Loading System: An electrical dynamometer is connected to the engine. The dynamometer controller enables the engine to run in two modes. constant speed and constant torque modes. The dynamometer is run in torque mode because the engine has a speed governor. A digital tachometer is used to measure speed. The engine output is varied by controlling load current of heating resistance. The electrical power generator is dispensed through four resistances connected in parallel. Loading can be easily done by switching on the required resistance bank according to the testing requirements.

3.2.2.2. Environmental Variables

Environmental variables include atmospheric temperature, properties of nanoparticles, atmospheric pressure and properties of diesel fuel which are shown in Table 3.3.

3.2.2.3. Response Variables

Response variables are classified into two main parts: the concentrations of the emitted components and thermal performance factors. The response variables for the thermal performance are the brake force, the fuel consumption rate, the engine load, the air consumption rate, and the engine exhaust temperature. The emission components are

CO, CO_2, HC, $O_2$and NO_X. Heat release phases are the percentage of pre-mixing and diffusion heat release during each test. The following sections describe the measurement system used for each variable.

3.2.3. Measurement of Thermal Performance Parameters

The experimental studies for the evaluation of the performance of a diesel engine operated with and without nano-additives or biodiesel need the measurement of brake power, fuel consumption rate, engine load, air flow rate and EGT.

1. Engine Load and Brake Power: The engine is loaded by an electric dynamometer. Four electrical warmers retain the produced electrical power. The Voltage Regulator figure (3.4) measures the current and voltage. The principal motivation behind this gadget is managing and keeping the voltage consistent between (210-220) volts. No matter what the increasing or diminishing the engine speed, the restriction of speed between (1300-2000) rpm. Knowing the current and voltage of the electric power generated is determined equation (3.1).

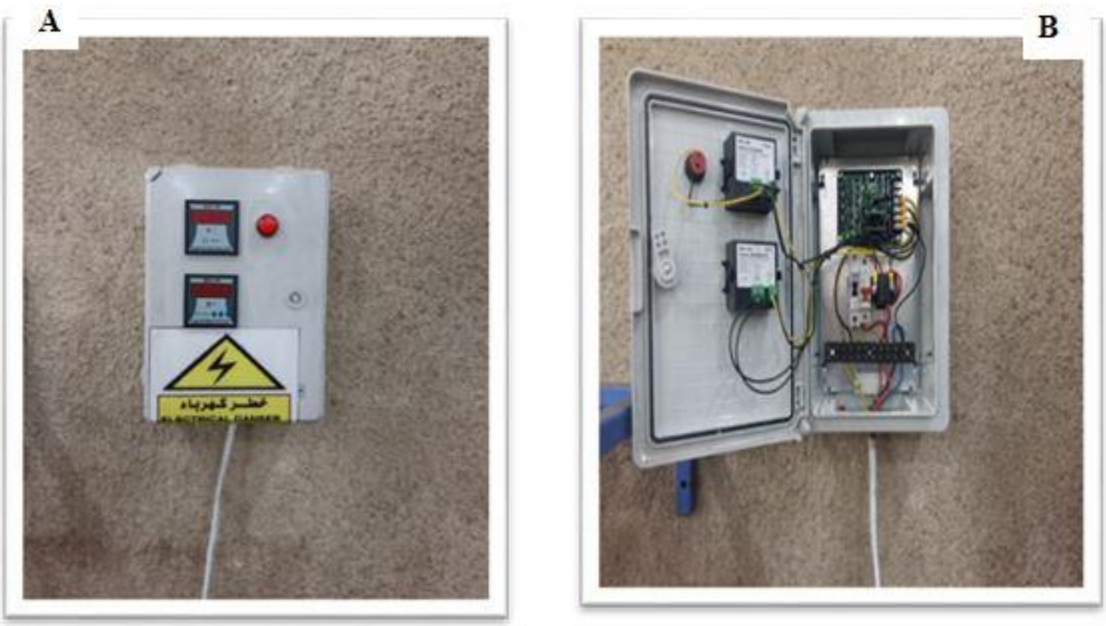

Figure 3.4. Voltage regulator of the generator connected to the diesel engine .

$$BP = I * V * COS\beta \tag{3.1}$$

1. **Brake Thermal Efficiency ($\eta_{B.Th}$):** The brake thermal efficiency is calculated by using equation (3.2).

$$\eta_{B.Th} = \frac{BP}{\dot{m}_f * LCV_d} \tag{3.2}$$

2. **Volumetric Efficiency(η_V):** Volumetric Efficiency is calculated by using the following formula (3.3).

$$\eta_v = \frac{\dot{Q}_a}{\dot{Q}_s} * 100\% \tag{3.3}$$

$$\dot{Q}_s = V_s * \frac{N}{60 * 2} \tag{3.4}$$

$$\dot{Q}_a = C_d * A_{orf} * \sqrt{2 * g * \Delta h_a} \tag{3.5}$$

3. **Diesel Fuel Consumption Rate:** Estimation framework for the fuel consumption rate comprises of a fuel tank provided with cantilever load cell (strain measure). The load range for the strain check is 0 to 1000 ml. Consequently, the load of fuel in addition to the tank weight shouldn't surpass 1000 ml to stay away from harm of the strain measure. The fuel consumption rate is the difference between the last (mf2) and initial (mf1) weights of the fuel in the tank during a timespan (t) as displayed in equation (3.6). Fig (3.5) gives a picture of the unit of gas.

$$\dot{m}_f = (m_{f1} - m_{f2})/t \tag{3.6}$$

Figure 3.5. The unit of fuel flow rate measurement.

4. **Brake Specific Fuel Consumption:** The brake specific fuel consumption is calculated by using the following formula (3.7).

$$B.S.F.C = \frac{\dot{m}_f}{B.P} * 3600 \tag{3.7}$$

5. **Brake Specific Energy Consumption:** The brake specific energy consumption is calculated by using the following formula (3.8). Its unit (kJ/kW*hr).

$$B.S.E.C = B.S.F.C * LCV \tag{3.8}$$

6. Air Flow Rate: The amount of air entering the engine varies with the speed and load. An air surge tank with water manometer is used to measure the air flow rate. It has an orifice with 1.5 cm diameter and is connected to a water manometer to measure the difference in the pressure across the orifice due to the air sucked by engine. The air volume flow rate is calculated by using the relationship (3.5) [42]:

$$\dot{Q}_a = C_d * A_{orf} * \sqrt{2 * g * \Delta h_a} \tag{3.9}$$

7. **Equivalence Ratio:** The equivalence ratio is calculated from the following formula (3.9).

$$\Phi = \frac{\left(\frac{m_f}{m_a}\right)_{act}}{\left(\frac{m_f}{m_a}\right)_{sto}} \tag{3.10}$$

3.2.4. Measurement of Engine Exhaust Gas Emission

The exhaust gases analysis unit consisted of a Gas Analyzer 953254 for measuring {CO, CO_2, Unburnt Hydrocarbon (UHC), NO_X, O_2.

3.2.4.1. Analyzer of Exhaust Gases

The exhaustion gas analyzer type 953254 has been used to measure CO, UHC, and CO_2 in engine exhaust using the non-dividing infrared absorption principle, as well as NO_X and O_2 using the electrochemical cell principle. Figure 3.6 shows the images of the gas analyzer and its connections. The technical specifications of the gas analyzer are given in Table 3.3. Figure (3.6) depicts the gas analyzer and its connections. Table 1 shows the technical specs of the gas analyzer (3.3)

Table 3.3. Gas analyzer technical specifications.

ID	Measurement parameters	Range	Resolution
2	CO	0% to 10%	0.01%
1	HC	0 to10000 ppm	1 ppm
3	CO_2	0% to 20%	0.01%
5	NO	0 to 5000 ppm	1 ppm
4	O_2	0% to 25%	0.01%
9	Frequency	50Hz± 1Hz	
7	Atmospheric pressure	70 kPa to 106 kPa	
8	AC Power supply	AC 220V±15%	
6	Operating temperature	+ 5°C to + 40°C	
10	Warm up time	10 minutes	
11	Net Weight	7kg	

Figure 3.6. The gas analyzer's pictures and their connection

3.2.5. Data Acquisition and Engine Management System

The engine control system, which was based on a custom microprocessor controller and specially created software, allowed for the variation of several engine operational variables., such as the diagram of (p, ɵ), the speed and exhaust temperature. Figure 3.7 shows the system for acquiring data used in the experimental investigation.

Figure 3.7. System for acquiring data.

3.3. THE DIESEL FUEL USE AND FUEL BLENDS PREPARATION

The fuel used in this study is gas oil (diesel). The molecular formula is $C_{12.3}H_{22.2}$ [54] The physical properties of the diesel fuel are shown in table (3.4). The nanoparticles of Fe_3O_4 were used in the present work to prepare Nano-Diesel -Biodiesel algae fuel and Biodiesel algae fuel. The physical properties [55] of this Nanoparticle are depicted in Table (3.5). The average size diameter of the Nan-particles is (<50) nm. Three blending ratios of Nanoparticles are used namely 25, 50, and 75ppm and three volume ratios from biodiesel: (10%, 20%, 30%). The following procedure represents the steps used in the present work to mix diesel fuel and nanoparticle and biodiesel to prepare the biodiesel fuel and nano biodiesel fuel.

Table 3.4. Properties of pure diesel fuel.

Analysis	Unit	Standard Method	Sample
Flash Point	˚C	ASTM D-93	68
Viscosity@40℃	cst	ASTM-D-445	2.520
Density@15 ˚C	g/cm^3	ASTM-D1298	0.8239
Water Content	ppm	ASTM D-6304	77.8
Pour Point	˚C	ASTM D-97	-16
Sulfur	Wt.%	ASTM D-4294	0.2759
Cetane Number		CORR.ASTM D-613	53.7

Table 3.5. Shows the physical properties of nanoparticles.

Particle	Fe_3O_4
Density (kg/m^3)	5180
Specific heat (J/kg.K)	104
Thermal conductivity (w/m.k)	17.65
Diameter (nm)	<50 nm
Shape	Spherical
Appearance	black
Diameter	<50nm

3.3.1. Steps for Preparing Nano Fuel and biodiesel Blended Fuel

1. To prepare biodiesel algae fuel, chemical measuring tubes are used to determine the volume of diesel and biodiesel. The volumetric chemical tubes used to measure fuels are shown in Figure (3.8). In this experiment, there are four different mixing ratios. The neat AME biodiesel is blended with regular diesel in four biofuel blends by volume: B0, B10, B20, and B30 (the critical literature suggests that the blend limit is B30 percent, after which the engine's performance suffers). B10, for example, denotes a blend of 90% diesel and 10% biodiesel.

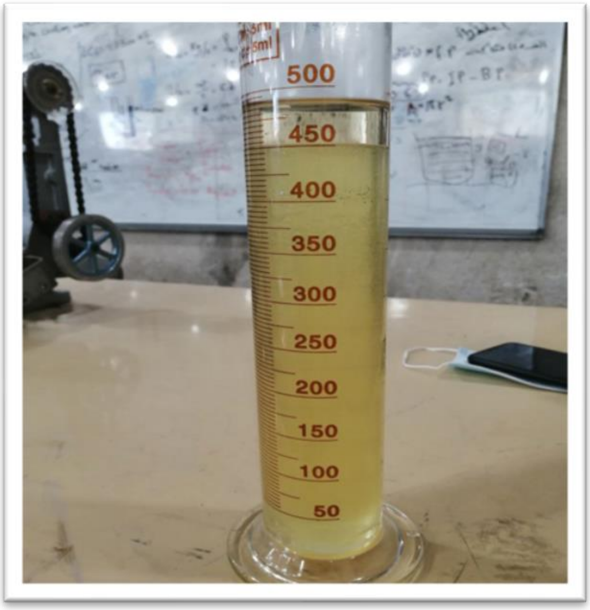

Figure 3.8. Chemical tube to measure fuel.

2. We have type of nanoparticles are selected namely Fe_3O_4 are shown in Figure (3.9). With particle size of (<50 nm).
3. Select the nanoparticles dose. The decision was made in light of information from the literature. Three doses—25, 50, and 75 ppm—are employed.
4. Select the biodiesel dose. The selection depended on information available in literature. Three doses are used, namely B0, B10, B20 and B30 (the critical literature suggests that the blend limit is B30 percent, after which the engine's performance suffers).
5. Equation 3.9 is used to determine the mass of nanoparticles needed for each dose.

$$\varphi = \frac{\frac{m_p}{\rho_p}}{\frac{m_p}{\rho_p} + \frac{m_f}{\rho_f}} \tag{3.11}$$

(ϕ) Solid volume fraction of nanoparticles density

ρ_p : density of nanoparticle

ρ_f: density of fuel

m_p : mass of nanoparticle

m_f: mass of fuel

6. Using the sensitive balance in figure (3.10), calculate the amount of powder needed for each concentration.

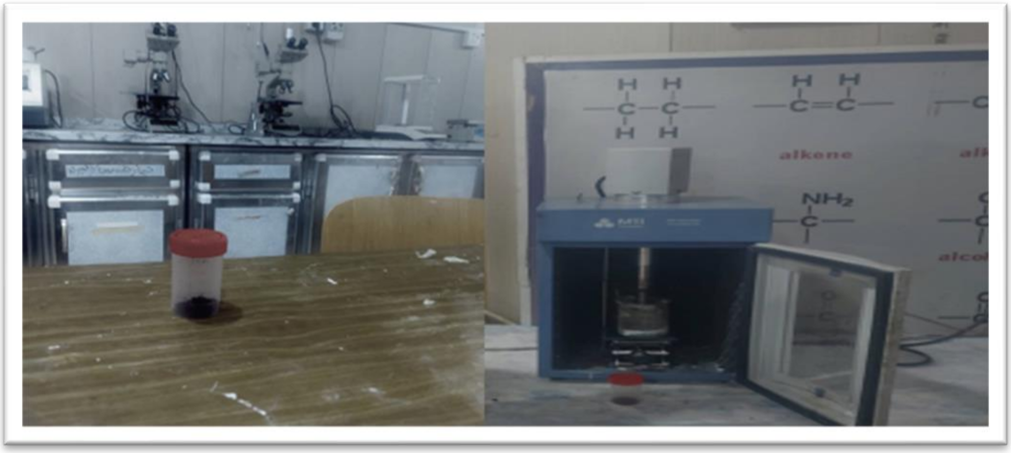

Figure 3.9. Image of nanoparticles used to prepare nano fuels.

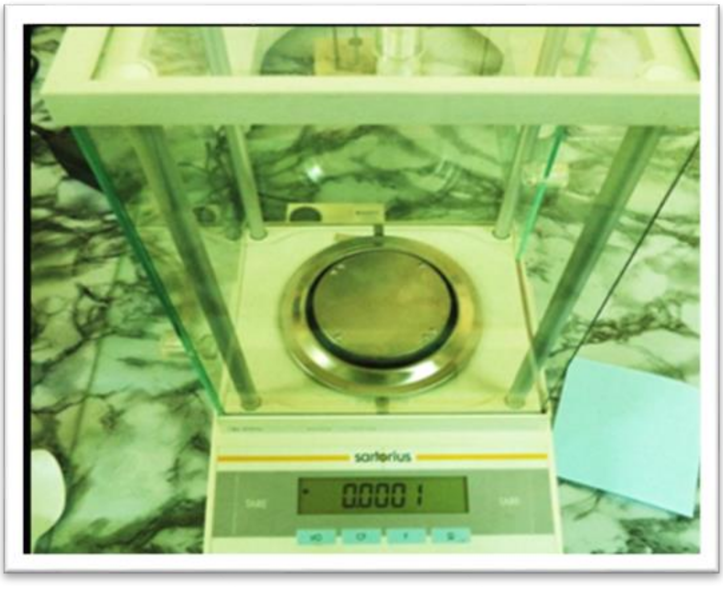

Figure 3.10. Photograph of sensitive balance.

7. Two mixtures of fuel used in the experiments are prepared with different doses (diesel + algae biodiesel) and (diesel + algae biodiesel + nanoparticles). The fuel produced from the mixtures consisting of diesel, nanoparticles and biodiesel blends are:

- First, biodiesel is added to diesel in three volume ratios: 10%, 20%, 30% (B10), (B20), (B30) and they are practically tested by the engine. As a result of the results, we found that the ratio is 20 % of biodiesel is the best mixing ratio between diesel and biodiesel.
- Secondly, we test the effect of adding iron oxide to the best proportion of biodiesel, which is 20% biodiesel with 80% diesel and three doses of nanoparticles (25, 50 and 75 ppm) on three values: N25, N50, N75, so the ratios of blending are (DB20N25, DB20N50, DB20N75).
- Added mass of nanoparticles to five liter of the diesel and then mix it. The complete mixing of nanoparticles, biodiesel is done in a magnetic stirrer device for one hour (RZR 2021 overhead stirrer, digital display, mechanical speed control, with 10.5 mm chuck, maximum torque 400 N.cm, maximum stirring capacity 25 L H20, maximum viscosity 60 Pa.s), to ensure the spreading of nanoparticles molecules and prevented particles aggregation to avoid agglomeration and uniform dispersion of Fe_3O_4 nanoparticles in the fuel (DF and DB) as shown in Figure 3.11.

Figure 3.11. Photograph of mixing for Diesel ,Biodiesel and nanoparticles.

8. Use ultrasonic cleaner bath, which is filled up to 75% of its volume by water to make sure no damage happened to the device as recommended by the instructions of the supplier, and then put the basket inside the bath as shown in fig (3.12). The mixture takes around six hours after that the mixture will be

ready. The ultrasonic cleaner is shown in Figure 3.12 and its specifications are given in Table 3.6.

Figure 3.12. Photograph of ultrasonic cleaner.

Table 3.6. Specifications of ultrasonic cleaner bath.

Model	**JTS-1018**
Water tank dimensions (mm)	L_1= 406, W_1=305, H_1=460
Overall dimension (mm)	L_1= 586, W_1=485, H_1=680
Ultrasonic frequency	40 kHz
Ultrasonic power	720 Watt (variable)
Digital timer control	1-30 min
Capacity	54 liters
Temperature control range (ºC)	< 90 ºC
Ultrasonic power output	800 W

Figure 3.13. Photograph of biodiesel fuel AME Mixed with neat diesel .

9. Repeated the same procedure above for each concentration for each dose.

3.4. UTILIZED BIODIESEL EXTRACTION TECHNIQUE

This part portrays the methodology for extracting algae oil and producing biodiesel from it. Spirulina microalga is oil's raw material. For extraction, the soxhlet chemical apparatus was used, and Algae methyl ester was produced. Mechanical and chemical extraction techniques are used to extract oil from solid raw materials. The solvent is added to the chemical extraction technique. This method is more efficient than others because it can extract nearly 93-95 percent of the oil from the algae.

3.5. THE PROCESS OF EXTRACTING OIL FROM ALGAE

1. The first step we Collect the spirulina algae from the local river in al imam district, Hillah, Babylon Figure 3.14.

Figure 3.14. The spirulina algae in the local river.

2. The second step we collect the algae, then wash and clean it and remove all impurities and leave all the algae collected under the sun to dry as in Figure 3.15. The algae remain in the sun for three days to be dried from the water, as shown in Figure 3.16.

Figure 3.15. The washed and cleaned spirulina algae.

Figure 3.16. Drying algae under the sun.

3. The third step we Are converting solid and dry algae by crushing them to powder by knocking them out in a special container as shown in Figure (3.17).

Figure 3.17. Algae grinder Pulverize algae and make it into small parts .

4. Step Four: How to extract oil from algae powder using a soxhlet device, as shown in the figure (3.18). The following is an explanation of the extraction procedures, In the main chamber of the Soxhlet extractor, 200 grams of dried spirulina microalgae are placed in the filter. 222 mL methanol is placed in the circular flask and heated for 12 hours in a water bath with temperature controller. The rotary evaporator is used to separate the oil from the methanol and obtain the algae oil. The solvent that was removed can be reused for the next extraction. This procedure was repeated until the methanol was completely removed. In each flask, 3.3 grams of oil were obtained. The amount of extracted oil is calculated using the equation (3.10) [56].

$$efficiency\ of\ oil\ \ Extracted = \frac{Mass\ of\ oil\ Extract}{Total\ mass\ of\ dried\ agae} \times 100 \qquad (312)$$

Figure 3.18. The soxhlet apparatus [57].

3.6. SYNTHESIZE THE BIODIESEL

To make biodiesel from algae oil, traditional transesterification is used. The general equation of transesterification, as shown in equation (3.11) in the critical papers, is as follows:

$$
\begin{array}{llll}
CH_2 - O - CO - R_1 & & CH_2\text{-OH} & \text{R-O-CO-R}_1 \\
 & \text{(Catalyst)} & & \\
CH - O - CO - R_2 + 3ROH & & \text{CH-OH} & \text{R-O-CO-R}_2 \\
CH_2 - O - CO - R_3 & & CH_2\text{-OH} & \text{R-O-CO-R}_3
\end{array}
\quad (3.13)
$$

(Triglyceride) (Alcohol) (Glycerol) (Mixture of fatty acid esters)

To successfully convert oil to biodiesel, the transesterification process requires three main parameters. The catalyst (NaOH or KOH), as well as the alcohol (methanol or ethanol) that is mixed with the catalyst to produce methoxide or ethoxide, depending on the alcohol type, are the three parameters. The methoxide or ethoxide reacts with the oil and begins to change the roots R to produce biodiesel. Finally, the temperature of the oil during the reaction is the third active parameter [57]. To make biodiesel, follow these steps:

- As a catalyst, 2 grams of NaOH
- 25 mL methanol
- The oil temperature for the reaction is 63°C

The following is an example of the procedure:

1. Fill a suitable flask with 100 mL of microalgae oil. The oil-filled flask is placed in a water bath at 65°C, bath is supplied to guarantee a fixed temperature as seen in Figure (3.19). and the heat is gradually transferred to the oil until it reaches 63°C.
2. Addition 25 mL of methanol with 2 g of powdered catalyst (NAOH). A mechanical stir is used to thoroughly combine both ingredients for 15 minutes.

3. Dissolve the Methoxide in 100 mL of hot algae oil and stir for 20 minutes to ensure that the reaction is complete.
4. Keep the mixture in a separation funnel for 12-14 hours to separate the glycerin. After the glycerin has separated, remove it mechanically using the valve at the funnel's end. The separation funnel in Figure (3.20) contains biodiesel and glycerin.
5. After the algae methyl ester is synthesized, it is washed in hot water and dried by heating the biodiesel to 100 °C for 4 hours to ensure that till all water is removed, and the purity is maintained is noticed, Finally, filtering process is done to make sure that the final product is of excellent quality [57], as found in Figure 3.21.

Figure 3.19. A water bath with 3-neck flask has a capacity of 1 Liter

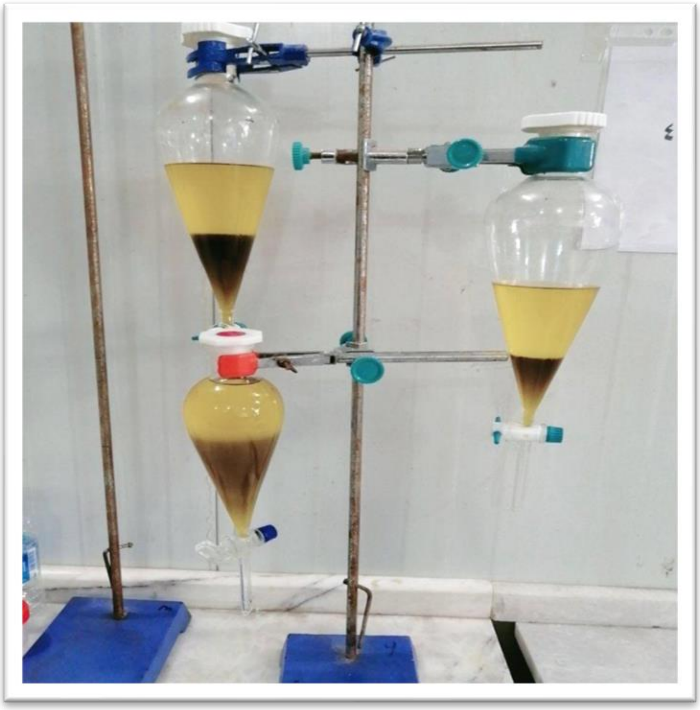

Figure 3.20. Glycerin separation funnel.

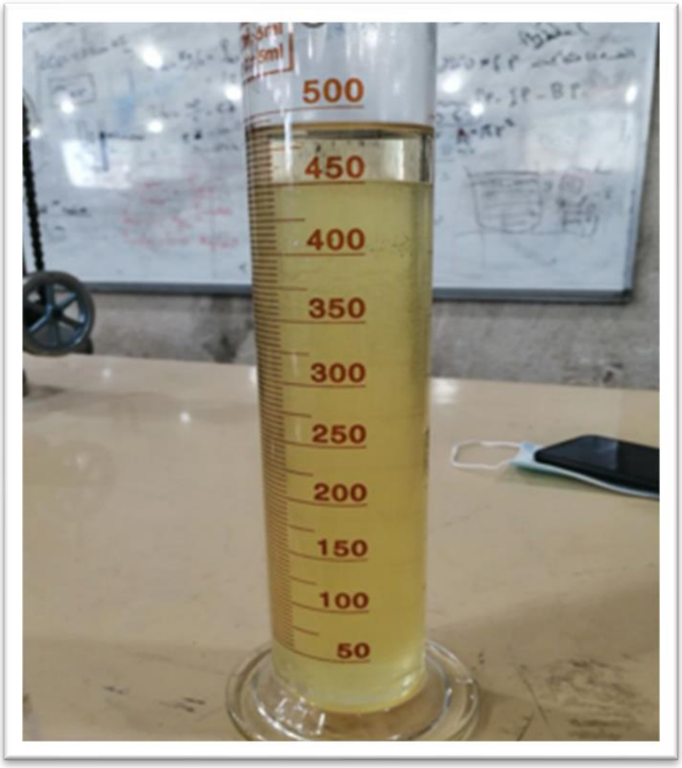

Figure 3.21. Pure AME biodiesel extracted from algae .

3.7. GAS CHROMATOGRAPH TEST

The composition of the fatty acid methyl ester (FAME) obtained from the spirulina microalgae oil after the transesterification process was analyzed by gas chromatography-mass spectrometer (GC-MS) as shown in Figure (3.22). The analysis is done with a Porapak -Q column (2 x 2.5 m). GC conditions are inlet temperature: 240°C; Column: 120°C and detector temperature: 270°C; Helium with a flow rate of 20 (ml/min) is used as the carrier gas. The GC focuses on a sample to determine the amount of biodiesel collected after the transesterification process. Linoleic acid methyl ester, Oleic acid methyl ester and Stearic acid methyl ester are the main components of (FAME) a 39.92%, 28.89% and 9.50%, respectively. The components mentioned make up 78.39% of all FAME. The approximate chemical formula of the manufactured seaweed methyl ester is C_{16} $H_{33}O_2$ [57].

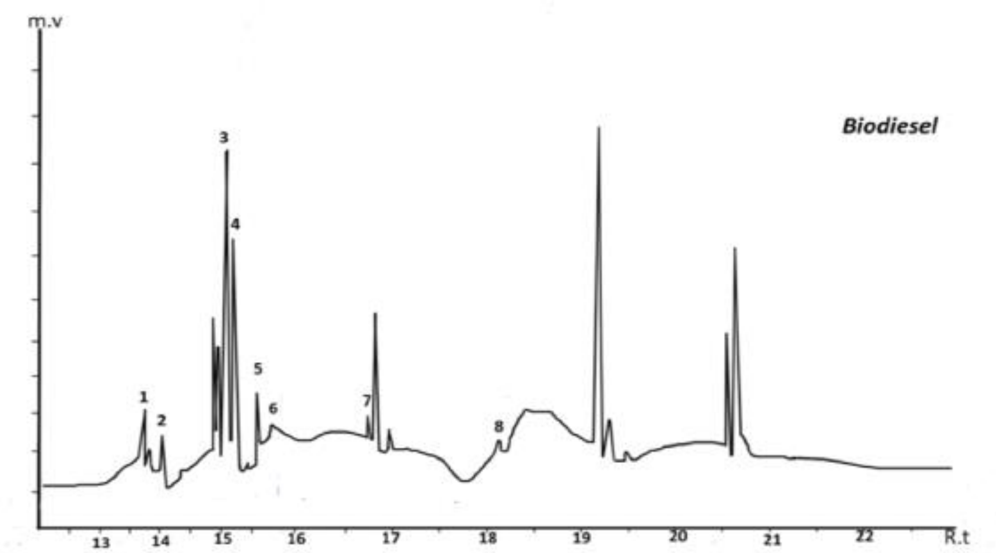

Figure 3.22. GC analysis of spirulina biodiesel [57].

3.8. VALIDATION OF SYNTHESIZE OIL

Physical and chemical properties are checked as part of the validation process to ensure that the synthesize by diesel is genuine Chemical test using Fourier transform infrared spectroscopy (FTIR), which revealed all chemical roots of biodiesel. The purpose of this test is to identify the functional groups in the biodiesel sample under investigation.

The FTIR spectra of algae methyl ester are shown in Figure (3.23). (AME). The spectra area is between 3200 and 3400 cm [1], indicating that the current absorption overlaps (OH). The appearance of beams in the (2890 - 2980 cm^{-1}) range is linked to the aliphatic bonds of CH in the biodiesel structure. In 1725 cm^{-1}, characteristic beams indicate (C=O) vibrations in the ester group, and aromatic (C=C) vibrations are indicated at 1548 cm^{-1}. The (C-H) bonds for the (CH3) groups of the biodiesel structure produce characteristic bonds in the range of (1375 - 1450 cm^{-1}). The appearance of the beams in the (1000 - 1100 cm^{-1}) range indicated the presence of (C – O) bonds [57].

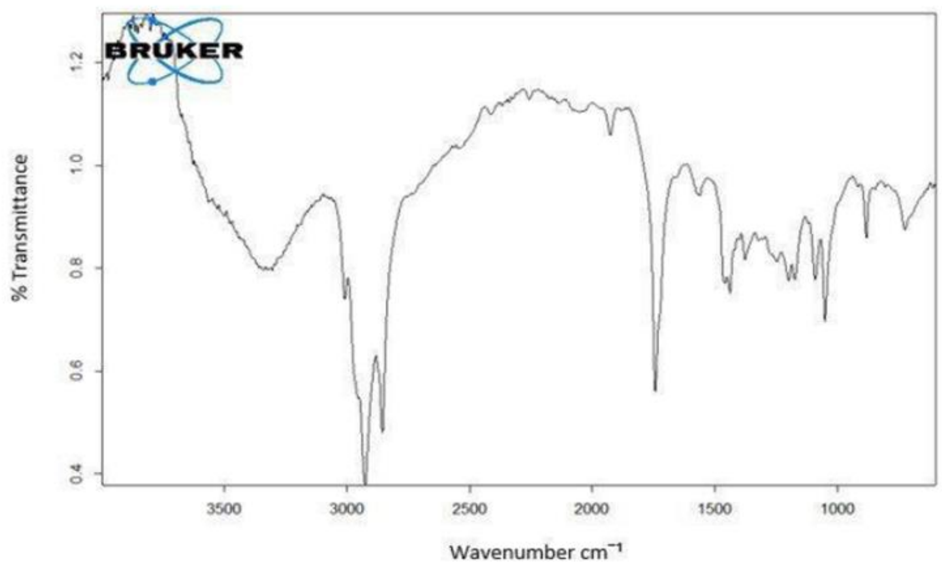

Figure 3.23. The FTIR test for synthesize biodiesel [57].

3.9. PHYSICAL PROPERTIES

The properties of the prepared algae biofuel and ordinary diesel are measured precisely at the new sciences labs, Diwaniyah city. Table (3.7) reports physical properties of diesel fuel, and biodiesel along with ASTM standards. Other details are mentioned in Appendix B. Physical testing occurs when some of the fuel index for synthesized oil is tested. Tests are done in al-Dorra refinery – Baghdad Iraq.

Table 3.7. Diesel and AME physical properties [57].

Property	Diesel	AME	10%AME	20%AME	30AME	ASTM6785 STANDARD
Chemical formula	$C_{14.44}H_{26.31}O_{0.6}$	$C_{14.22}H_{25.35}O_{0.4}$	$C_{14}H_{25.2}O_{0.2}$	$C_{16}H_{33}O_2$	$C_{13.77}H_{23.44}$	C12 -C22
Density Kg/m^3	841.7	837.8	835.1	869	830	860-900
Viscosity (pa.s)	0.002867	0.002658	0.002496	0.004327	0.002241	0.0019-0.006
Calorific value (MJ/kg)	43.7612	44.4528	45.1233	38.9200	45.836	36-39
Surface tension(N/m)	0.02837	0.028248	0.0281	0.02924	0.028	--
Cetane no	52.335	52.69	53	49.85	53.4	>47
Molecular weight (g/mol)	207.9532	201.9688	196.7	249.8439	190	_

3.10. EXPERIMENTAL PROCEDURE

The experimental procedure followed in the present study to analyze the effect of nanoparticles and biodiesel on engine performance, emissions and heat release phasing, all tests were performed at a constant speed of 1500 RPM. IN all tests the sampling procedure is not started until the engine reaches thermal equilibrium (about 30 mints period). Before each subsequent test, the engine was run for 10 mints on the new fuel to clean the fueling system from any previous fuel before starting the new test. To avoid experimental errors and obtain more accurate results duplicate tests were performed for each fuel test. is as follow,

3.10.1. Diesel Oil Only as Fuel

1. Check all the instruments, connection to all piping for leakage, fuel level, oil level and cooling water line.
2. Switch on all the digital and electric instruments.
3. Inspect the engine's cooling, lubrication, and fuel systems for smooth operation.
4. Start the engine by cranking.
5. Run the engine for a brief period with no load to warm the system until thermal equilibrium.
6. Set a predetermined speed under no load and wait for the steady state condition to be reached. When the exhaust temperature becomes constant, the steady state condition is said to have been reached
7. Record all the input control variables and environmental variables through the various systems that are incorporated with the engine. Most of the variables are fed into the computer via the data logger.
8. Repeat the observations under different loading conditions using electrical resistance dynamometer and different speeds.
9. Put the engine to no load condition before switching off the engine.

3.10.2. Diesel Oil with Biodiesel

The same above procedure is followed but using biodiesel.

3.10.3. Diesel Oil with Nanoparticles and biodiesel

The same above procedure is followed but using Nanoparticles and biodiesel.

3.11. DESIGN OF EXPERIMENT UNCERTAINTIES

It isn’t longer acceptable in most experiments to show experimental results without describing the uncertainties involved. Besides its obvious role in dissemination, uncertainty analysis provides the experimenter with a rational way to assess the significance of dispersal in repeated trials. Empirical uncertainties can arise due to instrument choice Calibration, environment, and experience planning and data collection Thus, there is a need to demonstrate the accuracy of experiments by performing uncertainty analysis. For this, all that is observed and calculated. The performance and emission parameters were used in the uncertainty equations (3.12, 3.13) to obtain the uncertainty ratio in the experiments. The uncertainty analysis consists of the mean Repeat the measurements to estimate the true value. To measure errors in experiments, few Calculations and estimation should be used in machines, sensors, and instruments. [56]. Combustion properties, engine performance and emission measurements for every test condition were taken once applying the engine load and engine speed for five min such there have been no changes within the measured parameters. The experiment was performed a minimum of three times for each fuel. The measure range and accuracies of measurable parameters are shown as in Table 3.8.

$$R = X_1^a\ X_2^b\ X_3^c \dots . X_M^m \tag{3.13}$$

$$\frac{\delta R}{R} = \left\{ \left(a \frac{\delta X_1}{X_1} \right)^2 + \left(b \frac{\delta X_2}{X_2} \right)^2 + \cdots + \left(m \frac{\delta X_m}{X_m} \right)^{1/2} \right. \tag{3.14}$$

Table 3.8. Uncertainty ratios.

Uncertainty	**Quantity**
+0.5%	Torque
+ -0.2%	Speed
3%	Fuel mass Temperature
2.5%	Air flow rate
0.1%	Exhaust Temperature

PART 4

RESULTS AND DISCUSSION

4.1. INTRODUCTION

This chapter highlights the importance of research through the experimental results and its discussion. Most important factors in all internal combustion research are focused on the thermal performance and exhaust emission exhaust. The thermodynamic parameters such brake efficiency, brake specific fuel consumption, etc. are presented and graphed. The main exhaust constituents such as CO, CO_2, UHC, and NO_X are plotted against variation of load at different compression ratios. Discussion of results for performance and emission diagrams are carried out to explain the behavior of diesel engine performance and emission when it fueled partially by diesel, algae biodiesel and diesel, and biodiesel with diesel and nano iron oxide. The experiments were repeated three times to avoid error diverging.

4.2. PREPARING FUEL SAMPLES FOR EXPERIMENTAL TEST

The biodiesel that is synthesized is blended with diesel on base of volume. Different ratios of blending are adopted for tests. The blends are presented by B0 or neat diesel, B10 (means 10% biodiesel with 90% diesel), B20, and B30. However, B0 is pure diesel or the blend which contains 0% by volume biodiesel. The base line of engine performance and emissions are tested at different loads named 0, 1/4, 1/2, 3/4, and full engine load. Also, the engine compression ratio varies at 14.5:1, 15.5:1and 16.5:1. This set of base line tests is used to comparison purpose of clarifying and understanding the changes due to add biodiesel and nano fuel. The properties of those blends are tested in all – Dorra refinery, Baghdad. Table 4.1 gives the fuel properties of those blends.

Table 4.1. The algae biodiesel – diesel blends properties.

Property	B0	B10	B20	B30
Chemical formula	$C_{13.77}H_{23.44}$	$C_{14}H_{25.2}O_{0.2}$	$C_{14.22}H_{26.31}O_{0.4}$	$C_{14.44}H_{25.2}O_{0.6}$
Density (kg/m3)	830	835.1	837.8	841.7
Viscosity (Pa.s)	0.002241	0.002496	0.002658	0.002867
Caloric value (MJ/kg)	45.8360	45.1233	44.4528	43.7612
Surface tension (N/m)	0.028	0.0281	0.02825	0.02837
Cetane number	53.4	53	52.69	52.34
Molecular weight (g/mol)	190	196.7	202	208

4.3. PERFORMANCE OF DIESEL ENGINE FUELED BY ALGAE BIODIESEL

The diesel engine is fueled by biodiesel- diesel blends B0, B10, B20, and B30. The parameters of performance are studied as bellow:

4.3.1. Brake thermal Efficiency

The relation between BTC and load at different blends and different compression ratios (14.5:1,15.5:1, and 16.5:1) are plotted in figure 4.1- 4.3 respectively. Generally, the adding of biodiesel to diesel reduces the engine brake thermal efficiency at compression ratio 14.5:1,15.5:1 and 16.5:1 respectively. It can be noticed also marginally increased in brake efficiency at B10 and low load (0.25% and 0.50%) and again decreased to 0.75% and full load. The low caloric value of blends 10%, 20%, and 30% of algae biodiesel as compared with caloric value of net diesel is the main reason behind this brake efficiency. Although, the biodiesel oxygen enhanced the combustion and increased the brake power at B10 where the caloric value is reduced had little effect. The effect of compression ratio appears clearly by increasing the brake efficiency for all loads with increment of compression ratio as shown in Figure 4.1 and 4.3.

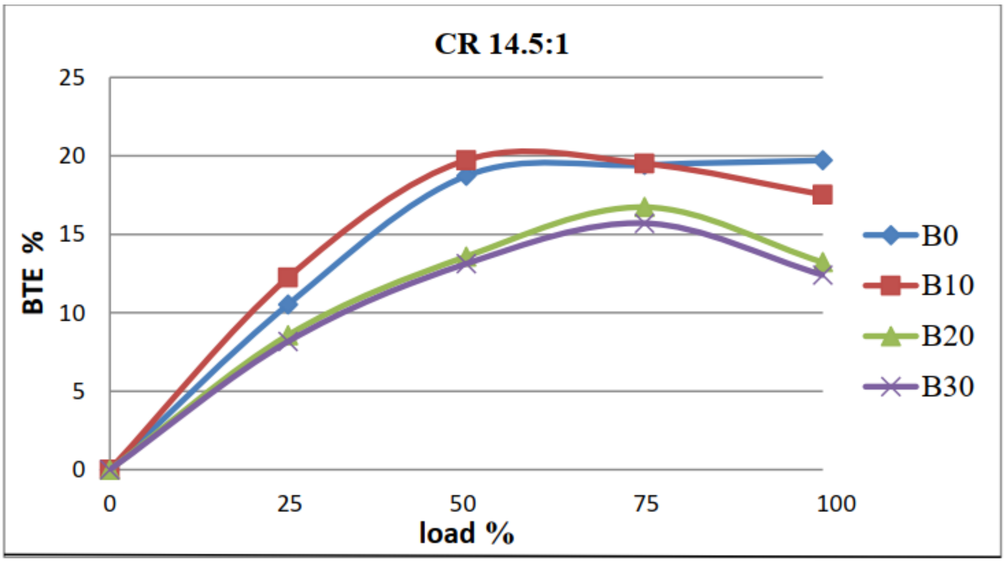

Figure 4.1.BTE vs. engine load at different blends and 14.5:1 CR.

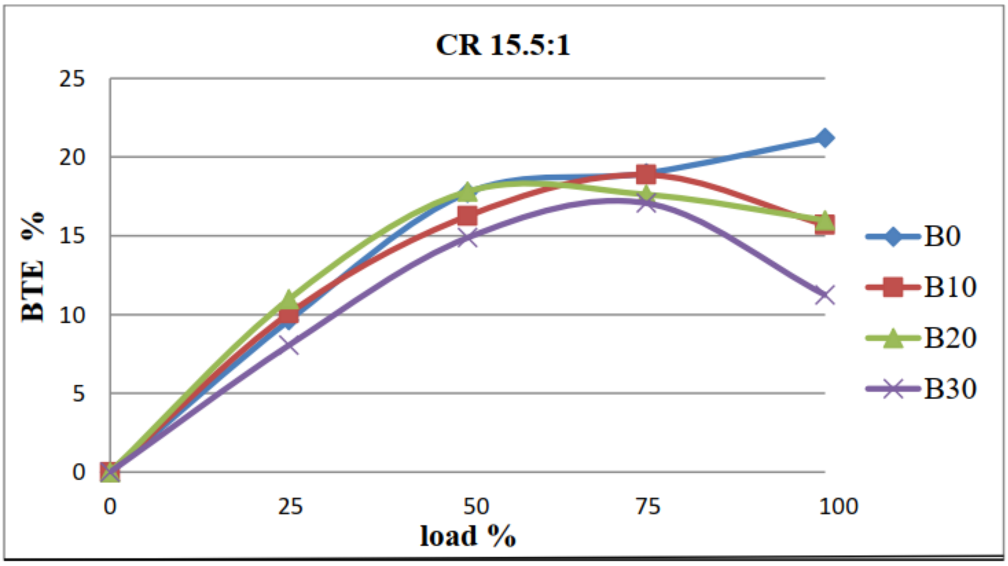

Figure 4.2. BTE vs. engine load at different blends and 15.5:1 CR.

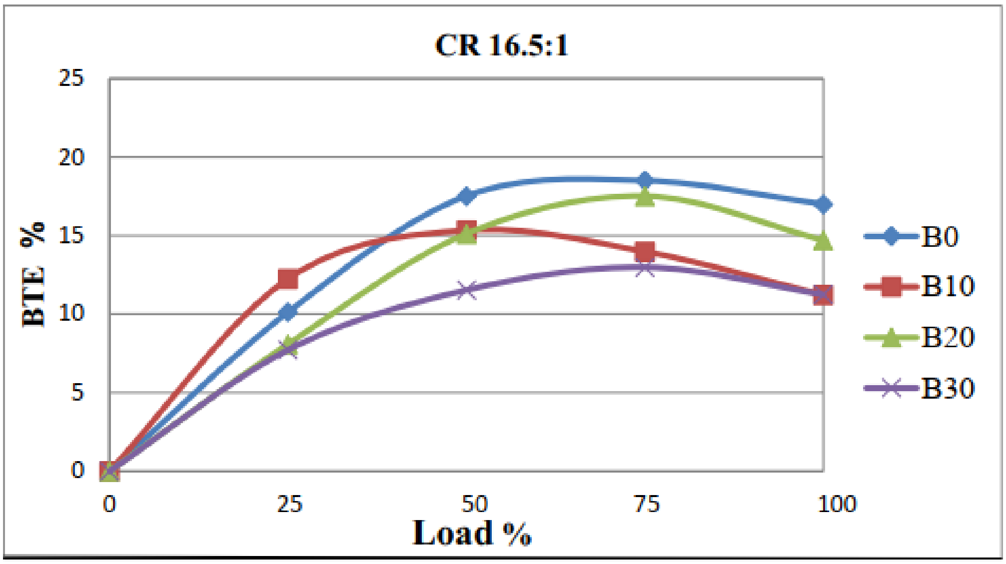

Figure 4.3. BTE vs. engine load at different blends and 16.5:1 CR.

4.3.2. Brake Specific Fuel Consumption

Graphs (4.4, 4.5, and 4.6) show the relation between brake specific fuel consumption and the different engine loads at compression ratio (14.5:1, 15.5:1, and 16.5:1) the trend of graph is with load increasing the consumption of fuels are increased where to overcome the extra load on engine. It can be observed that increasing algae biodiesel caused an increase in fuel consumption. Whereas, as compression ratio is increased due to high requirement on energy where the caloric value is decreased as the biodiesel blend ratio is increased. The change in consumption of fuel is calculated on the base of caloric value for biodiesel and diesel and on only diesel caloric value at combustion of diesel alone.

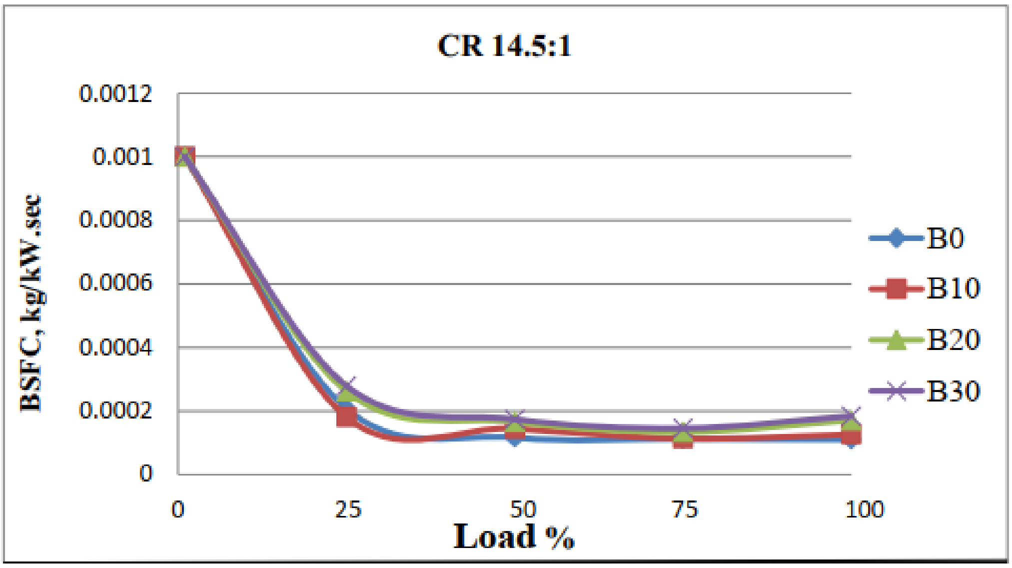

Figure 4.4. BSFC vs. engine load at different blends and 14.5:1 CR.

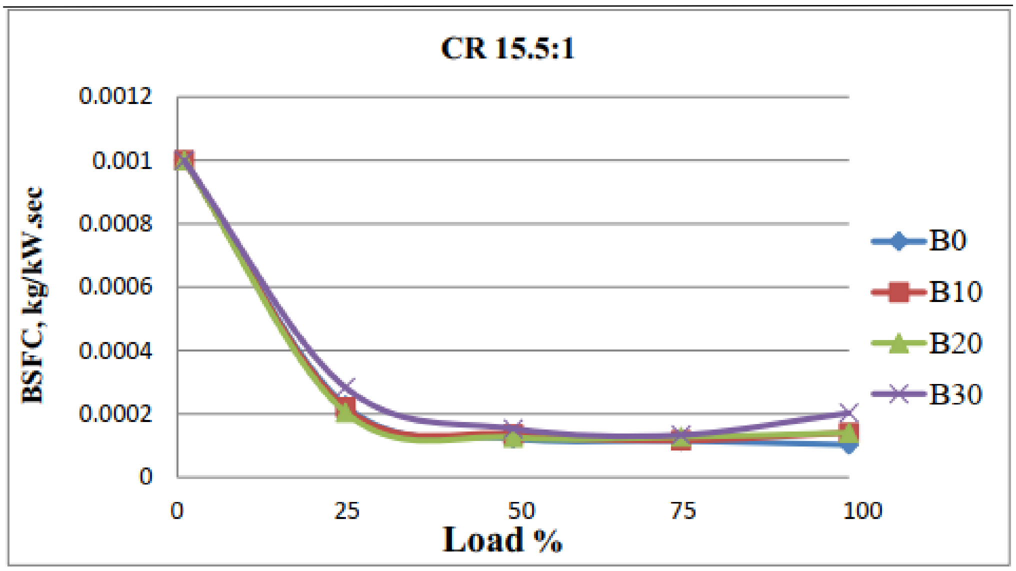

Figure 4.5. BSFC vs. engine load at different blends and 15.5:1 CR.

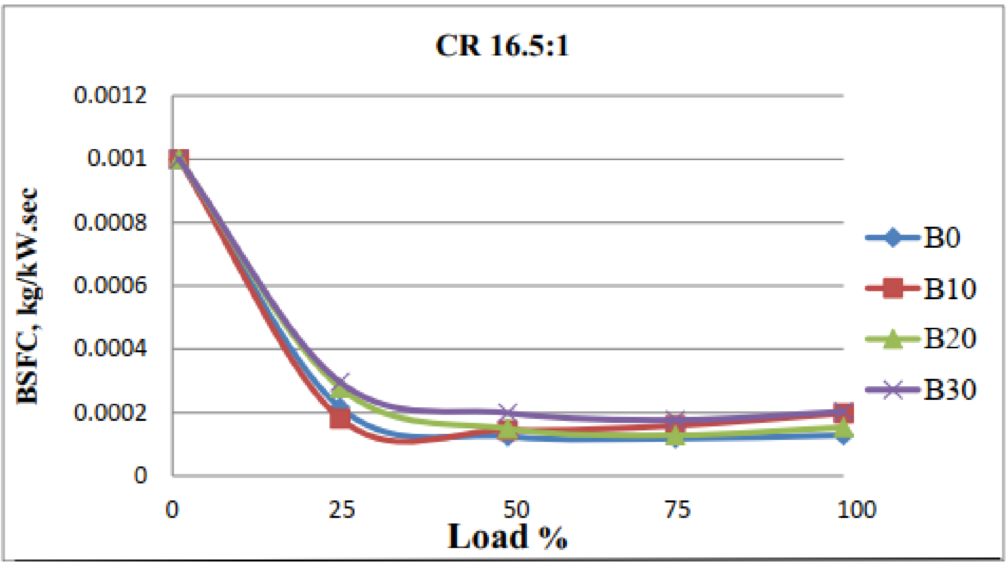

Figure 4.6. BSFC vs. engine load at different blends and 16.5:1 CR.

4.3.3. Volumetric Efficiency

The relation between volumetric efficiency and varied loads at different compression ratios is presented in figures (4.7, and 4.8, and 4.9). In diesel engines, air is a dominant factor to initiate the combustion and complete it. Volumetric efficiency is the most effective and true measure of the amount of air entering the engine combustion chamber. The combustion chamber volume is fixed then volumetric efficiency is proportional directly with actual sucking air. Biofuel has oxygen in its chemical formula and its availability made the volumetric efficiency little changed. At different compression ratio, the volumetric efficiency is increased. As engine load increased the volumetric efficiency decreased. Reasonable fact the increase of fuel pumping in combustion chamber will lead to reduce the sucking air volume.

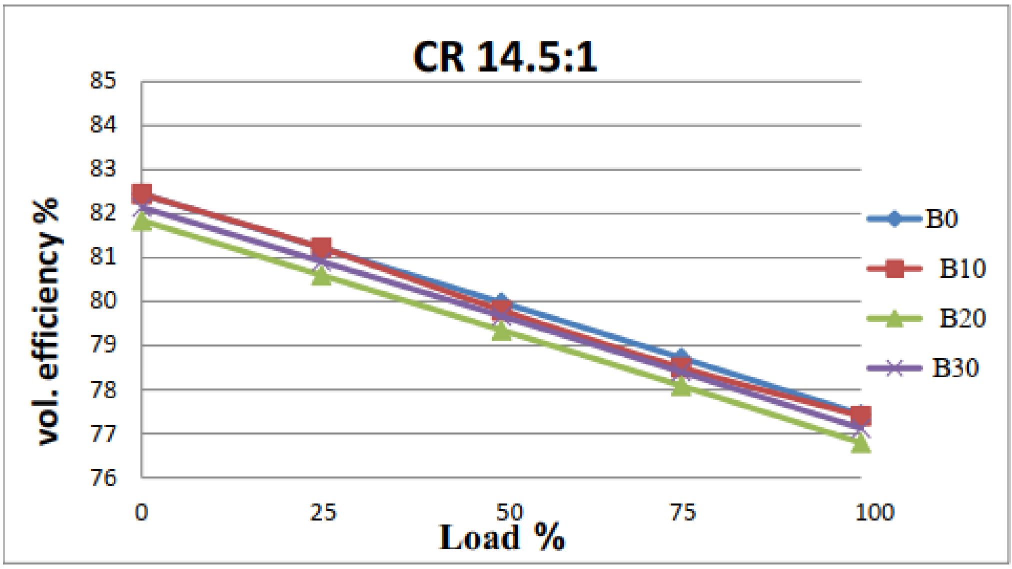

Figure 4.7. The volumetric efficiency vs. engine load at different blends and 14.5:1 CR.

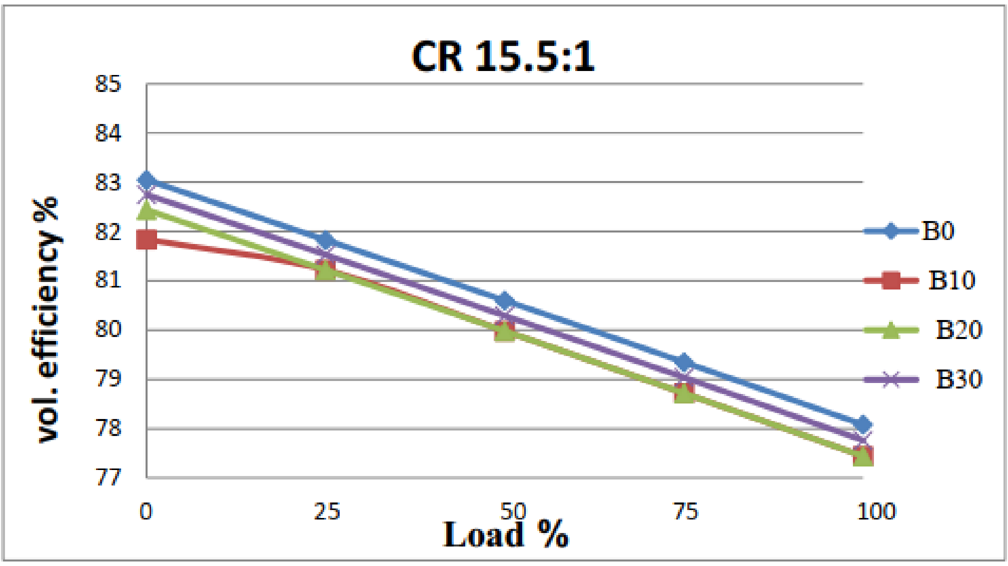

Figure 4.8. The volumetric efficiency vs. engine load at different blends and 15.5:1 CR.

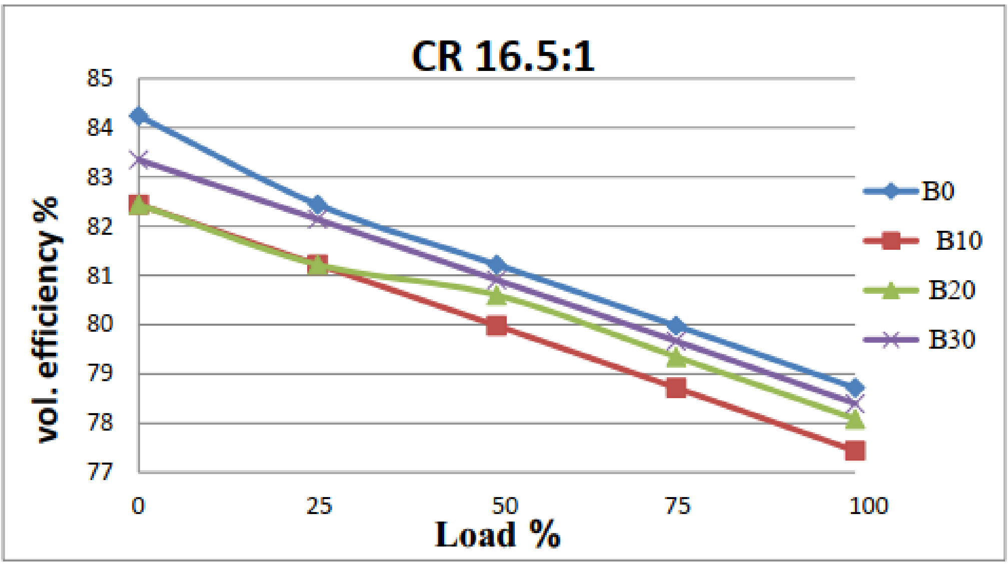

Figure 4.9. The volumetric efficiency vs. engine load at different blends and 16.5:1 CR.

4.3.4. Air / Fuel Ratio

The figures 4.10, 4.11, and 4.12 possess the relation between the A/f ratio and different load ratio at three compression ratios named 14.5:1, 15.5:1, and 16.5:1. It's observed that this ratio decreased with load for three compression ratios due to increase in fuel consumption and marginally decreased in sucking air. The A/F ratio is increasing as compression ratio is increasing. While the algae biofuel is increased in diesel-biodiesel blends, the A/F ratio is decreased because of decreased in quantity of sucking air by engine and increasing in fuel consumption due to biodiesel low caloric value.

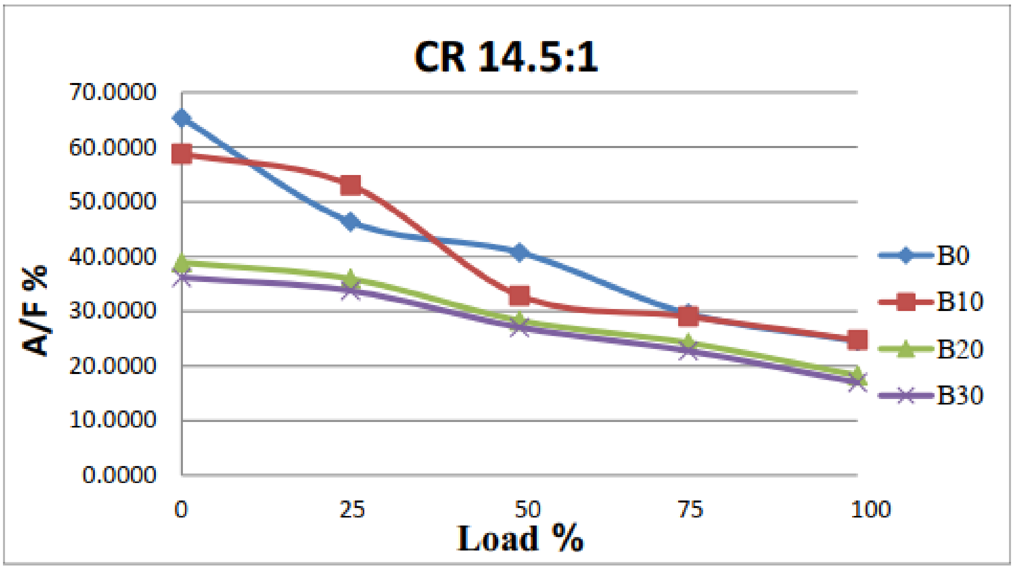

Figure 4.10. The Air/ Fuel vs. engine load at different blends and 14.5:1 CR.

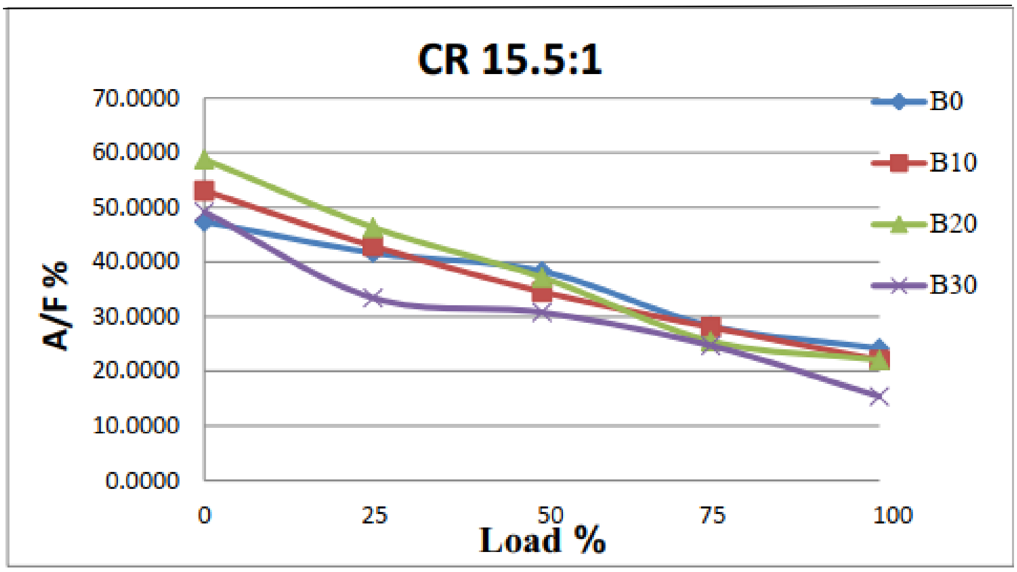

Figure 4.11. The Air/ Fuel vs. engine load at different blends and 15.5:1 CR.

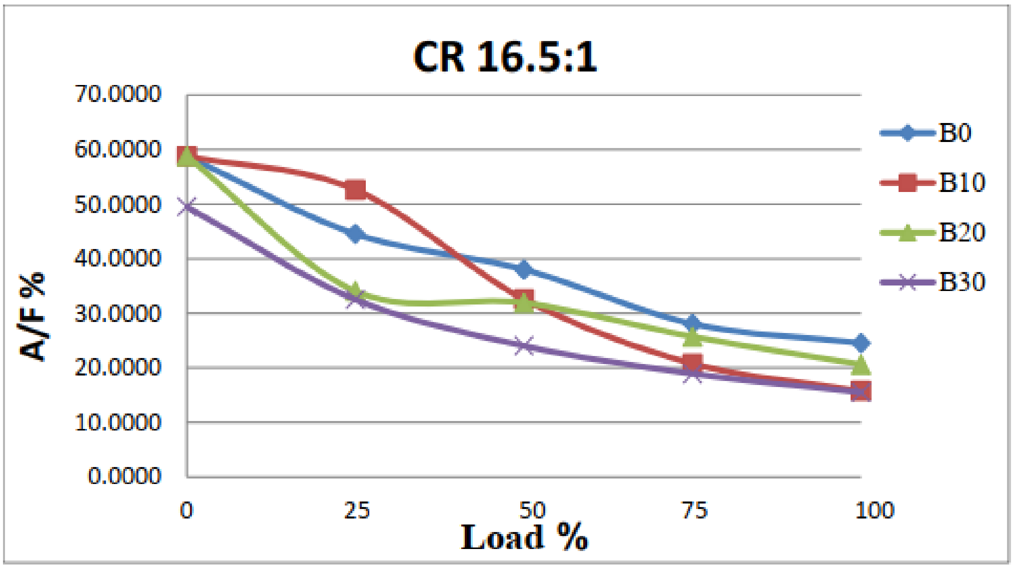

Figure 4.12. The Air/ Fuel vs. engine load at different blends and 16.5:1 CR.

4.3.5. Exhaust Gas Temperature

The exhaust temperature is the sensor of combustion process. It indicates the much of burning fuel, availability of air, and the emission constituent's formation specially NO_X. The amount of heat lost is indicated by exhaust temperature. Figures 4.13, 4.14, and 4.15 illustrate the exhaust temperature of engine with loads at varied compression ratios. The exhaust temperature increased with load increment as a result to increasing to fuel combustion. The increment of biodiesel in blends led to decrease in the exhaust temperature due to the caloric values decreasing of blends. The effect oxygen contained in biodiesel does not appear clearly. As compression ratio is increased, the exhaust temperature is increased as well. This logical behavior appeared as a result to increase the fuel combustion where the chamber is increased.

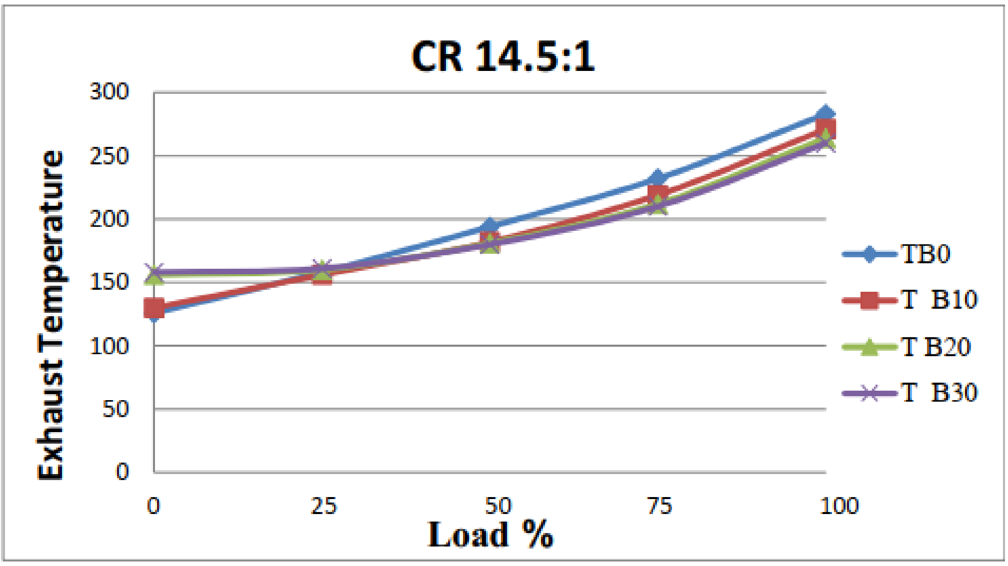

Figure 4.13. The exhaust temperature vs. engine load at different blends and 14.5:1 CR.

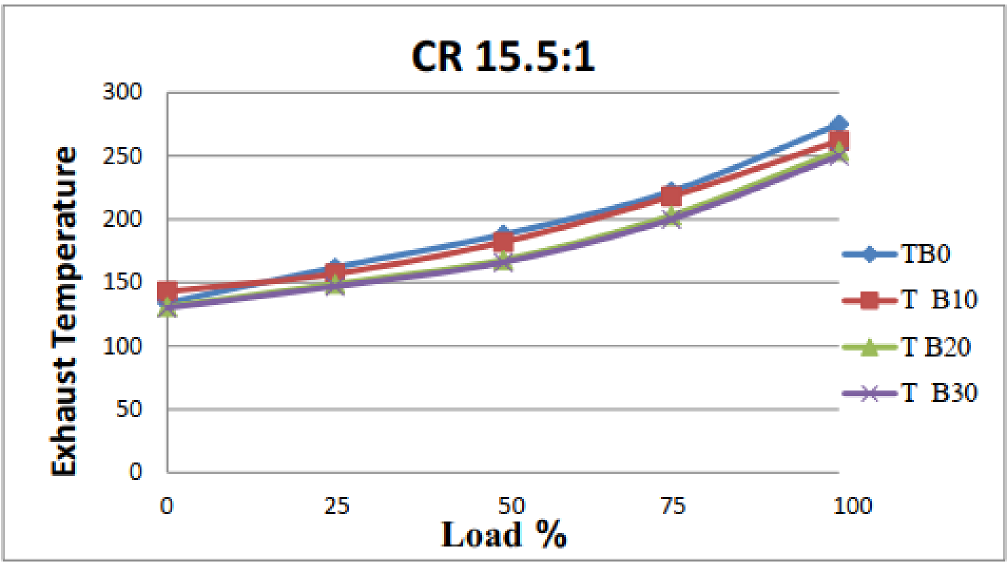

Figure 4.14. The exhaust temperature vs. engine load at different blends and 15.5:1 CR.

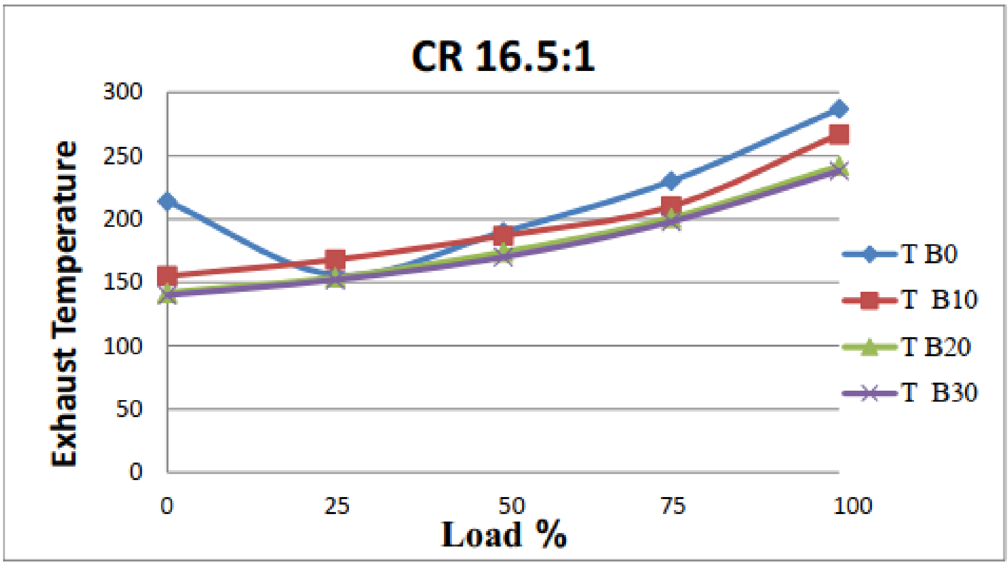

Figure 4.15. Exhaust temperature vs. engine load at different blends and 16.5:1 CR.

4.4. EXHAUST GAS EMISSION CONSTITUENTS OF DIESEL ENGINE FUELED BY ALGAE BIODIESEL

4.4.1. Carbon Monoxide

Figures 4.16, 4.17, and 4.18 show the relation between monoxide and engine load at variable compression ratios. The trend of mono oxide carbon decreases with load and then increases at full load. The formation of CO is related to the combustion process. Complete combustion of fuel led to the forming of CO_2. Normally, CO formation happens at idle speed. When the load increases the main formation is CO_2 and the formation of CO is retarded. With compression ratio increasing, the monoxide carbon is increased. The adding of biofuel led to decrease the CO marginally. The main reason that stands behind this decrease is: biodiesel has low carbon in its chemical formula. In addition, biodiesel has oxygen in its structure which leads to enhance the combustion and form CO_2 more than CO. The addition of biodiesel enhanced the combustion and limited prevent CO making. Enough oxygen gave the chance to form CO_2 more than monoxide.

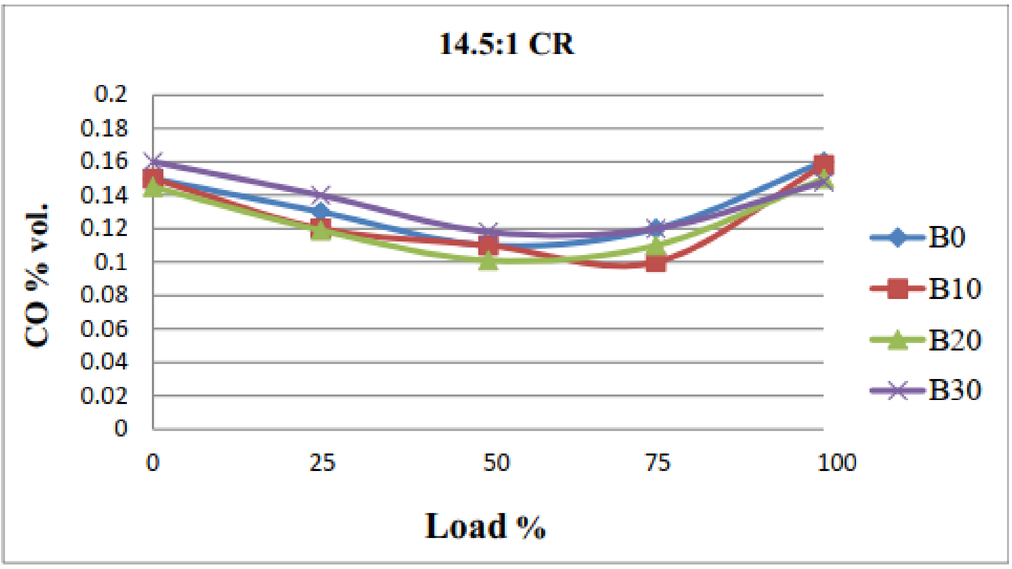

Figure 4.16. Carbon monoxide vs. engine load at different blends and 14.5:1 CR.

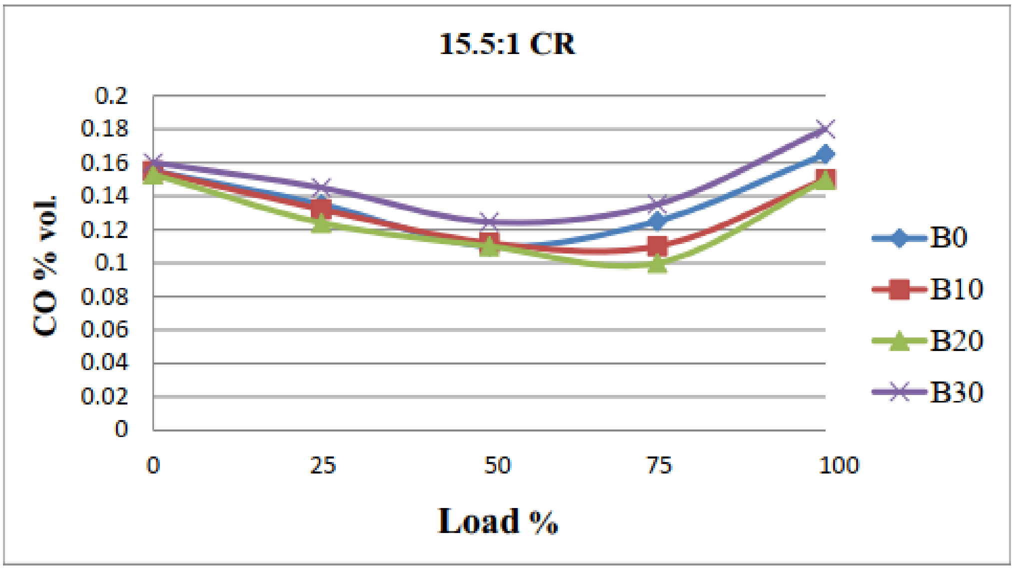

Figure 4.17. Carbon monoxide vs. engine load at different blends and 15.5:1 CR.

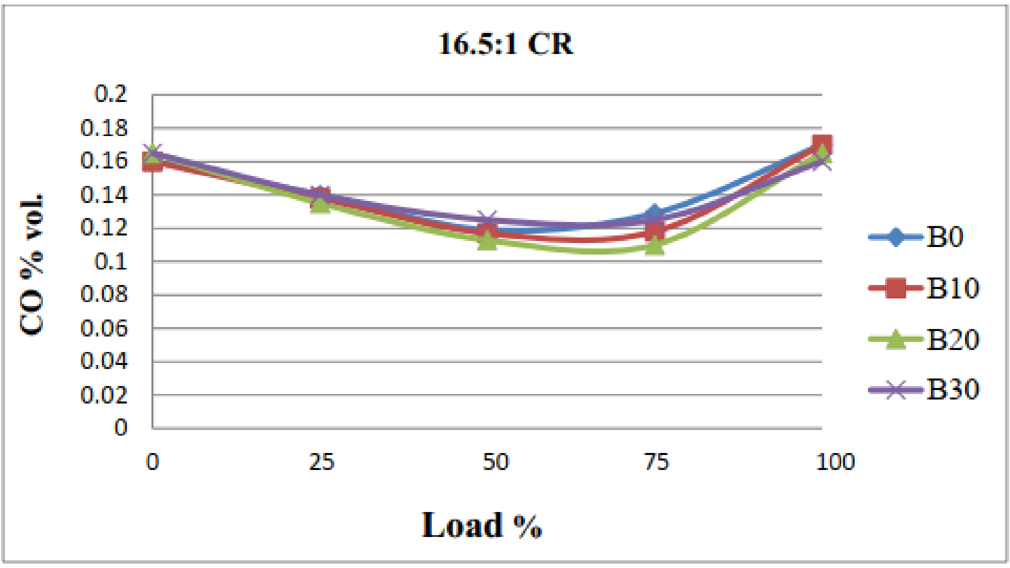

Figure 4.18. Carbon monoxide vs. engine load at different blends and 16.5:1 CR.

4.4.2. Unburned Hydrocarbon

The unburned carbon constituents are plotted against engine loads at figure 4.19, 4.20, and 421 for compression ratio 14.5:1, 15.5:1, and 16.5:1 respectively. It can be observed that unburned hydrocarbons are increased with the increment of compression ratio due to increase the chamber size and increase the mass burning fuel. As in carbon monoxide state, the unburned hydrocarbon is unstable chemical chains such as acetone, CH_4, or acetylene appears as the combustion in combustion chamber incomplete to form CO_2. The addition of biodiesel increased the unburned hydrocarbon marginally. A non-uniform trend yields as a formation behavior. B10 is little changed as compared with B0.

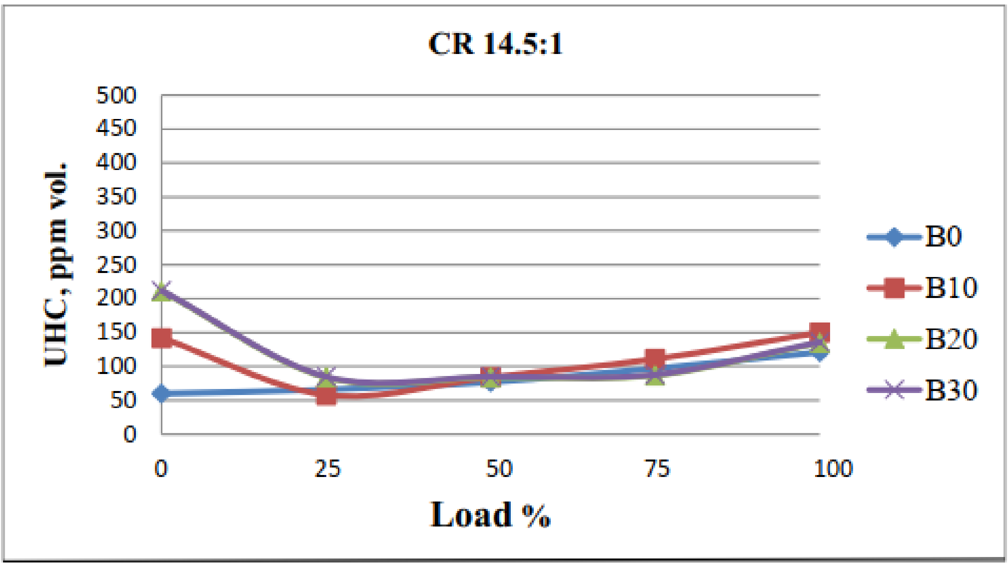

Figure 4.19. Unburned hydrocarbon vs. engine load at different blends and 14.5:1 CR.

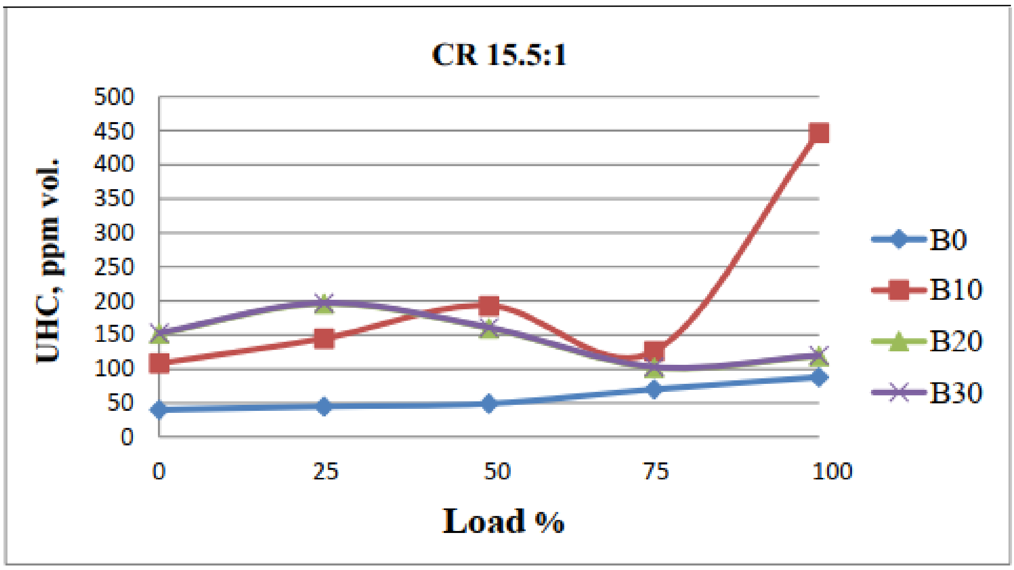

Figure 4.20. Unburned hydrocarbon vs. engine load at different blends and 15.5:1 CR.

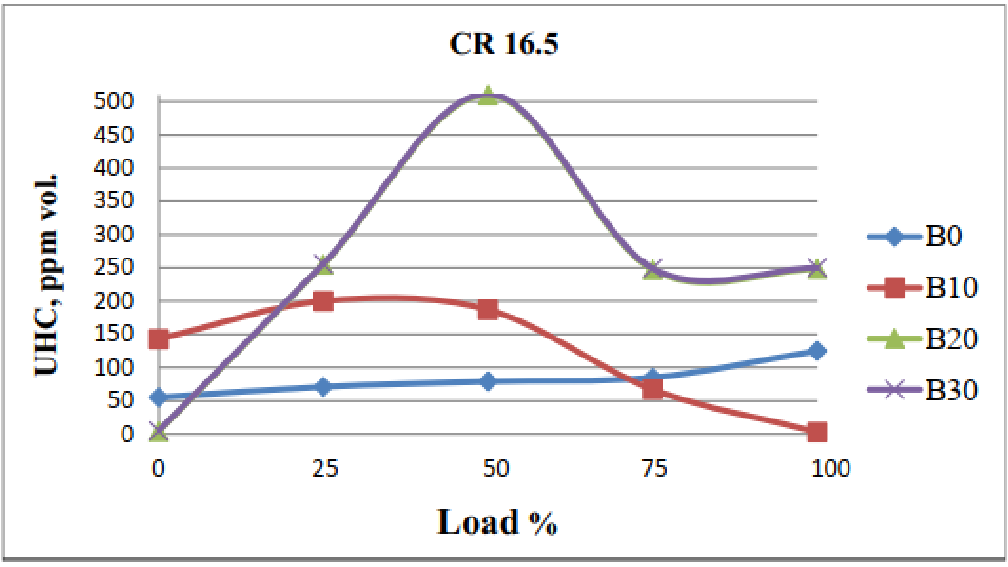

Figure 4.21. Unburned hydrocarbon vs. engine load at different blends and 16.5:1 CR.

4.4.3. Carbon Dioxide

The main positive change in hydrocarbon emission formation because of algae biodiesel adding to diesel is clearly appearing in carbon dioxide CO_2. Figures 4.22, 4.23, and 4.24 presented the relations between CO_2 and engine load at 14.4 compression ratio, 15.5:1, and 16.5:1. CO_2 is the main hydrocarbon emission and appears in combustion equation of any hydrocarbon fuels including as well as the diesel fuel. At compression ratio 14.5:1 and 15.5:1 can be noticed between 2.5% to 4% reduction in CO_2 emission in mean while its 8% to 10% at compression ratio 16.5:1. High compression ratio made the effect of biodiesel adding more influence on the CO_2 formation. Normally CO_2 increased with loads and compression ratios increment as shown in figures 4.22 to 4.24.

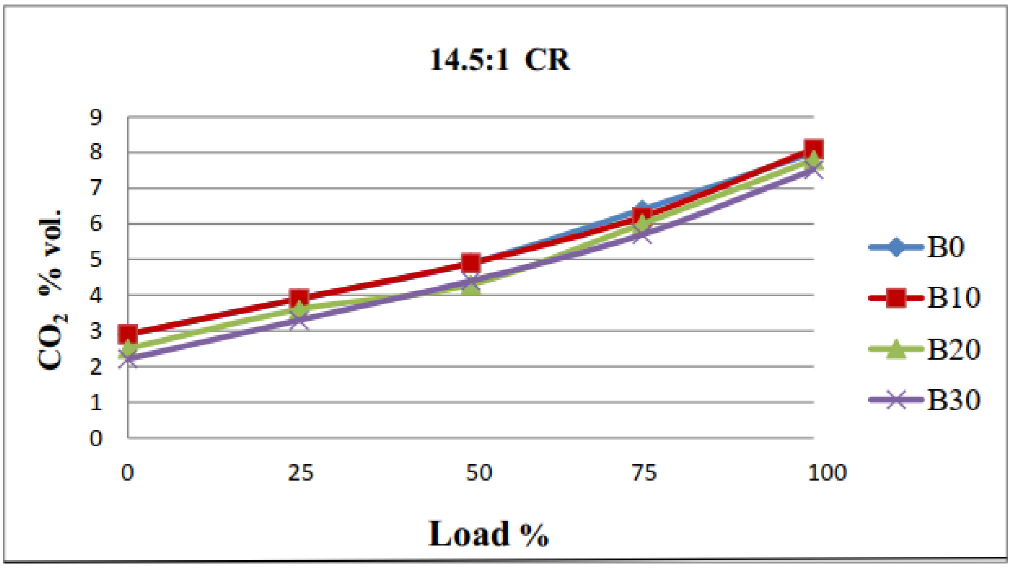

Figure 4.22. The CO_2 vs. engine load at different blends and 14.5:1 CR.

Figure 4.23. The CO_2 vs. engine load at different blends and 15.5:1 CR.

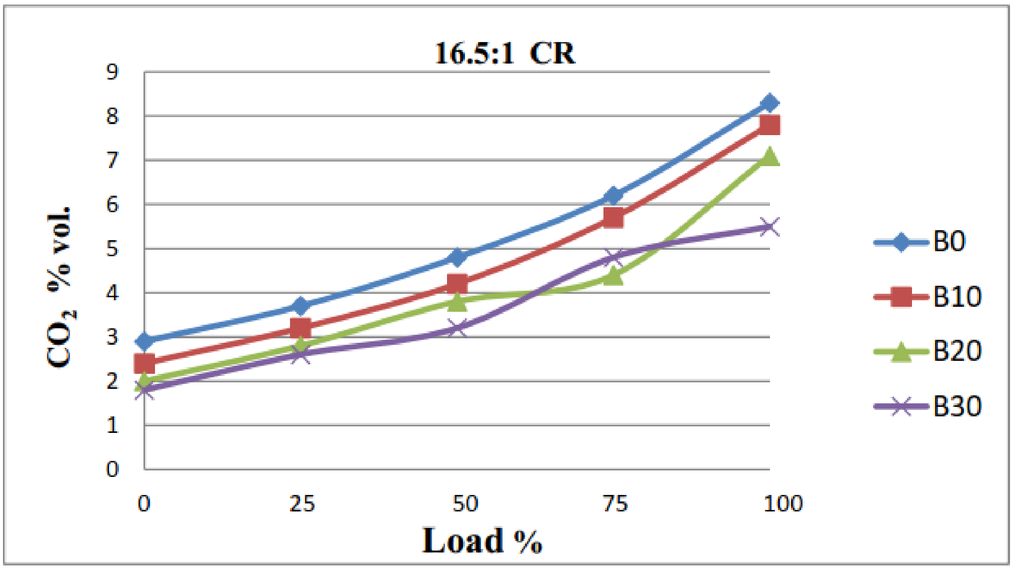

Figure 4.24. The CO_2 vs. engine load at different blends and 16.5:1 CR.

4.4.4. Nitrogen Oxides

The formation of nitrogen oxides or NO_X (NO, NO_2) depends on amount of air and the temperature of combustion chamber. Figure 4.25 shows the variation of NO_X with load at compression ratio 14.5:1, while fig (4.26 and 4.27) gives the NO_X vs. load at CR = 15.5:1 and 16.5:1 respectively. The blending of diesel with biodiesel from Algae oil caused sensible reduction in NO_X emission as a result to reduction in combustion chamber and not raise highly. Air decreased as well because biodiesel oxygen.

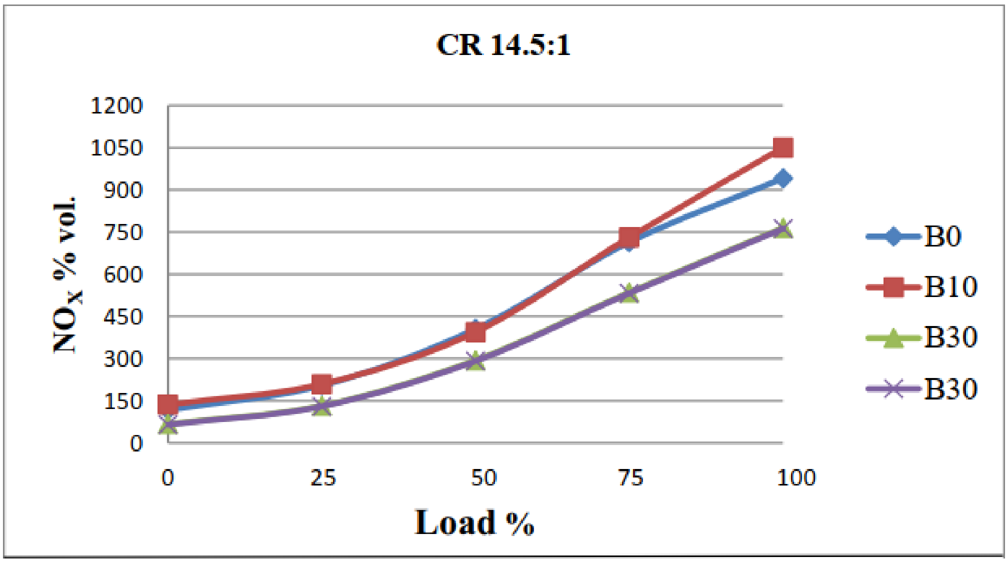

Figure 4.25. The NO_X vs. engine load at different blends and 14.5:1 CR.

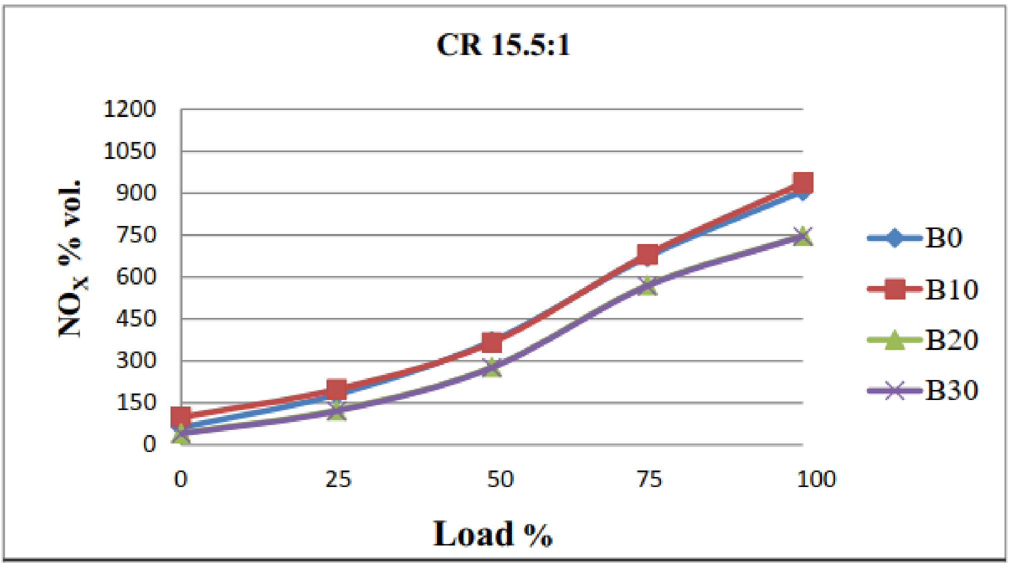

Figure 4.26. The NO_X vs. engine load at different blends and 15.5:1 CR.

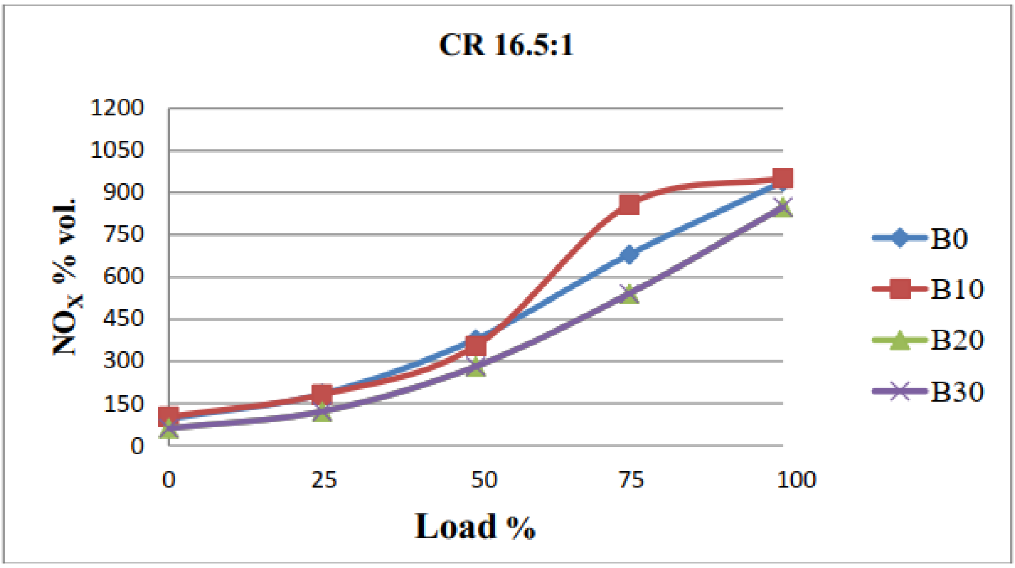

Figure 4.27. The NO_X vs. engine load at different blends and 16.5:1 CR.

4.5. ADDING OF NANO IRON OXIDE PARTICLE

The studying of mixing biodiesel with diesel showed that B20 is the optimum blend between all blends that adopted for experimental investigation. Depending on this point the adding of nano has been happened to this blend only at three doses 25, 50, and 75 ppm. the discussion of results as following:

4.5.1. Brake Thermal Efficiency

It can be observed that the adding of nano iron oxide led to sensible enhancement in the brake thermal efficiency. The high conductivity of nano iron oxide caused high improvement in brake efficiency by providing a surface to heat transfer of combustion. The reduction in fuel consumption and an increase in brake power gave an increase in brake thermal efficiency.

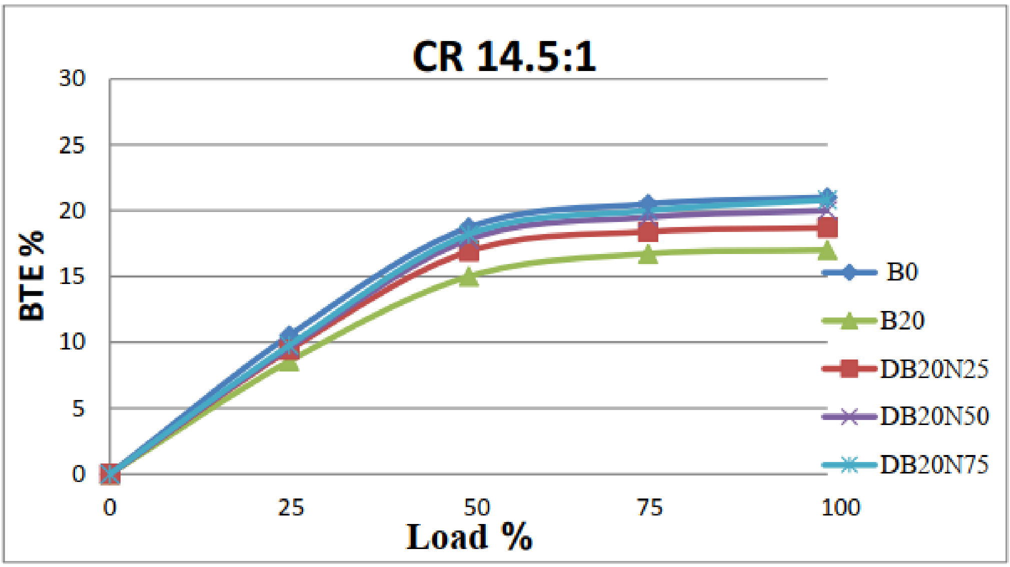

Figure 4.28. Presents the BTE at different nano dose as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

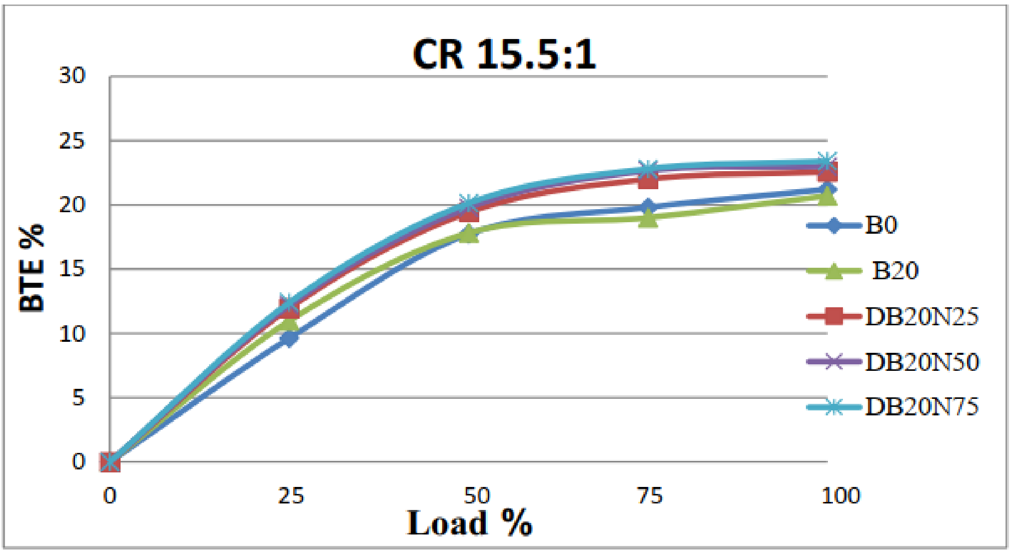

Figure 4.29. Presents the BTE at different nano dose as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

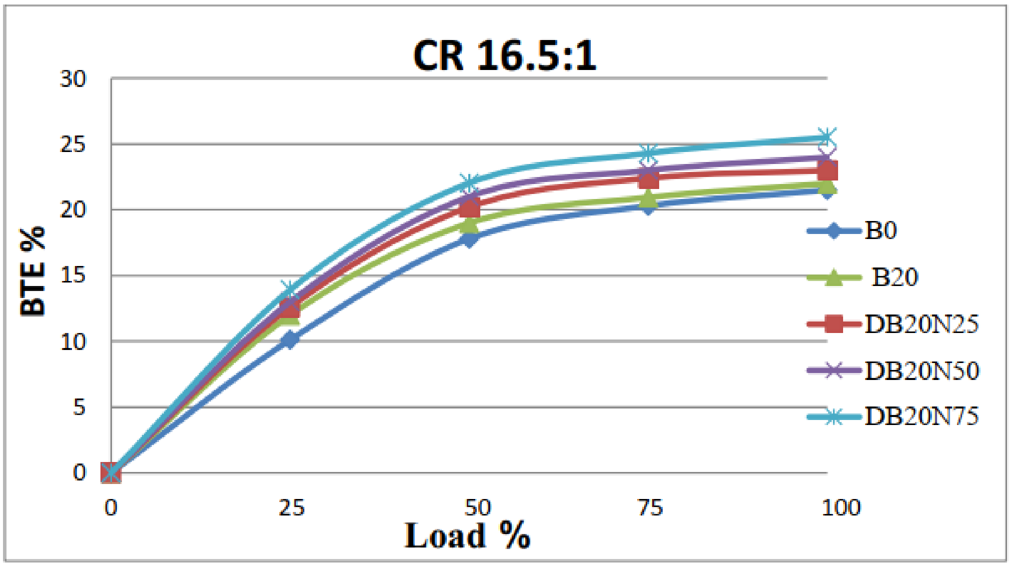

Figure 4.30. Shows the variation in BTE at different nano dose as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

Figure 4.29 and figure 4.30 represented the same trend of variation in BTE with load at diesel, B20, DB20N25, DB20N50, and DB20N75 of blends and compression ratio 15.5:1 and 16.5:1. Normally, brake efficiency increases due to compression ratio increment. On other hand, there is a sensible changed and same behavior for nano iron oxide by enhancing the combustion and brake power efficiency as well as. Same observations were noticed in the results of [58,59].

4.5.2. The Brake Specific Fuel Consumption

Figures 4.31 to 4.33 show the variation of BSFC against the engine load. At base line fuel – diesel- and blends of 20% biodiesel with 80 % diesel named B20 and the B20 blends with iron oxide Nano particles at 25, 50, and 75 respectively. It can be observed that B20 increased the consumption of specific fuel due to low caloric value of algae biodiesel as compared with diesel. The addition of Nano showed improvement in BSFC along with increment in Nano concentration in the blends. Best results can be recorded at full load where the adding of 75 ppm of Nano iron oxide led to sensible enhancement in consumption of fuel to produce engine brake power i.e., more energy from less fuel after adding the nano. Generally, the Nano particle addition led to efficient combustion as compared with combustion of fuel without Nano iron oxide. Same observations were noticed in the results of [58,59].

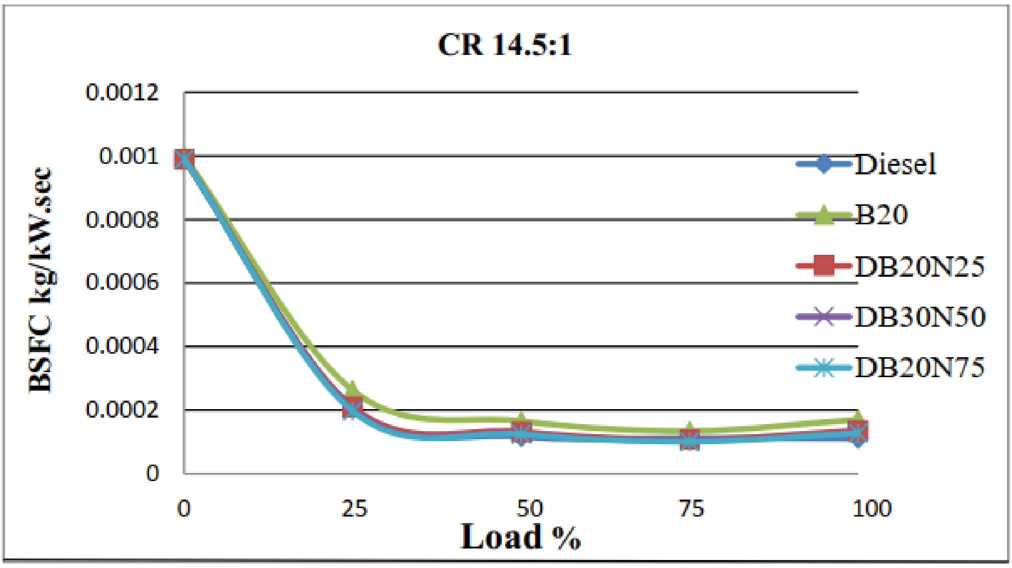

Figure 4.31. Illustrates the variation in BSFC at different nano dose as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

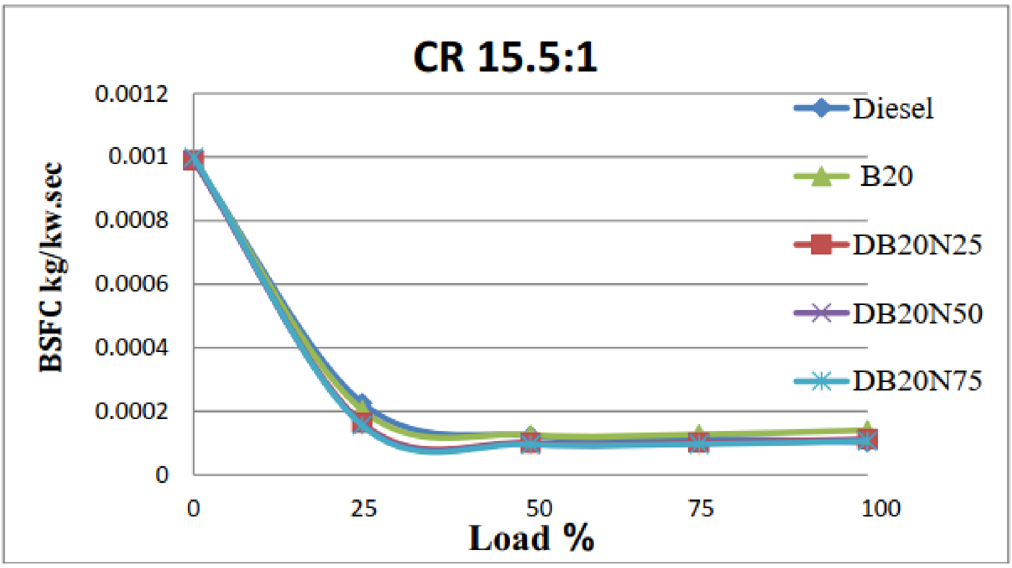

Figure 4.32. Represents the BSFC at different Nano dose as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

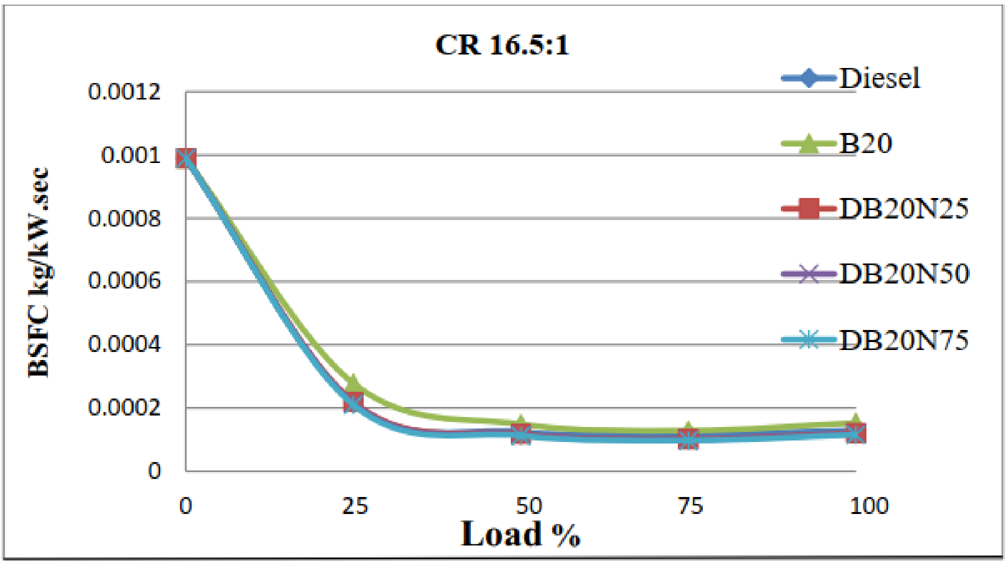

Figure 4.33. Shows the variation in BSFC at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.5.3. The Volumetric Efficiency

The effect of adding Nano iron oxide particle to blend of B20 is studied. Figures 4.34 to 4.436 give the changing of volumetric efficiency at different loads, compression ratios and Nano doses. The adding of Nano led to margin improves the volumetric efficiency as compared to volumetric efficiency at B20. The improvement in combustion process inside the combustion chamber which increases the engine sucking pressure at intake stroke. Volumetric efficiency has the same trend as compression ratio and engine loads changing. Volumetric efficiency increased by 1% to 2% at full load and 16.5:1 compression ratio.

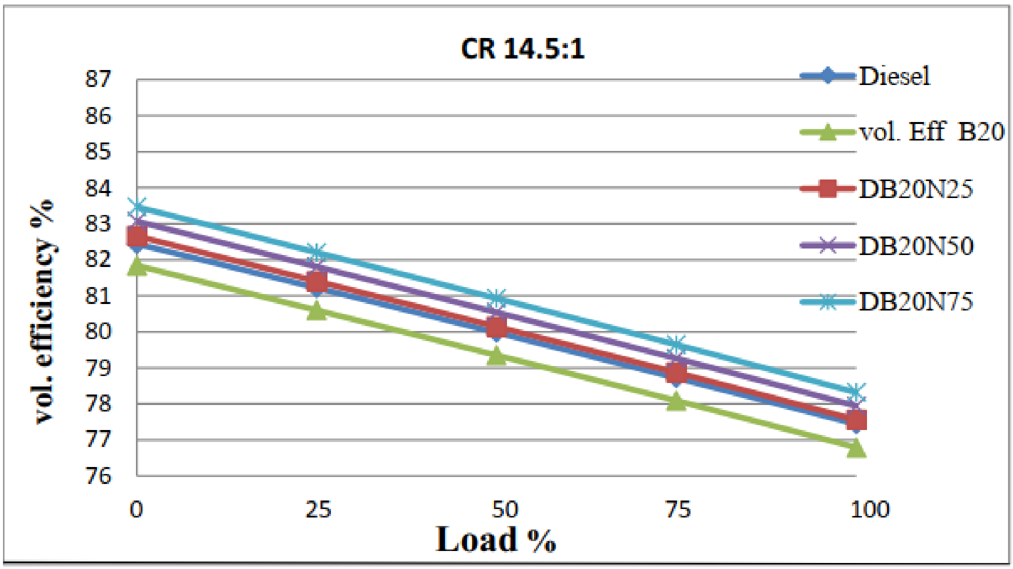

Figure 4.34. Gives the variation volumetric efficiency at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

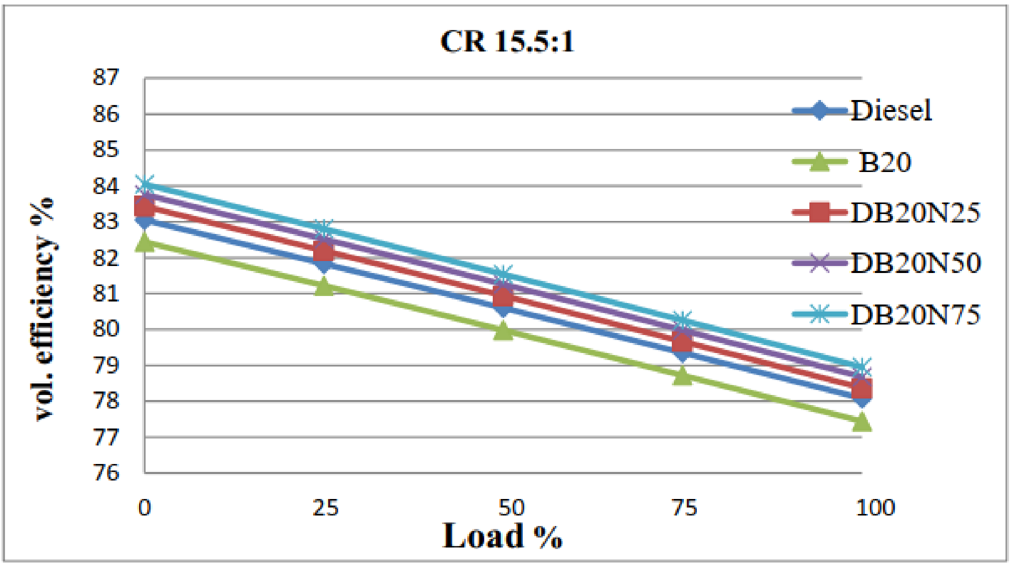

Figure 4.35. Presents the changed of volumetric efficiency at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

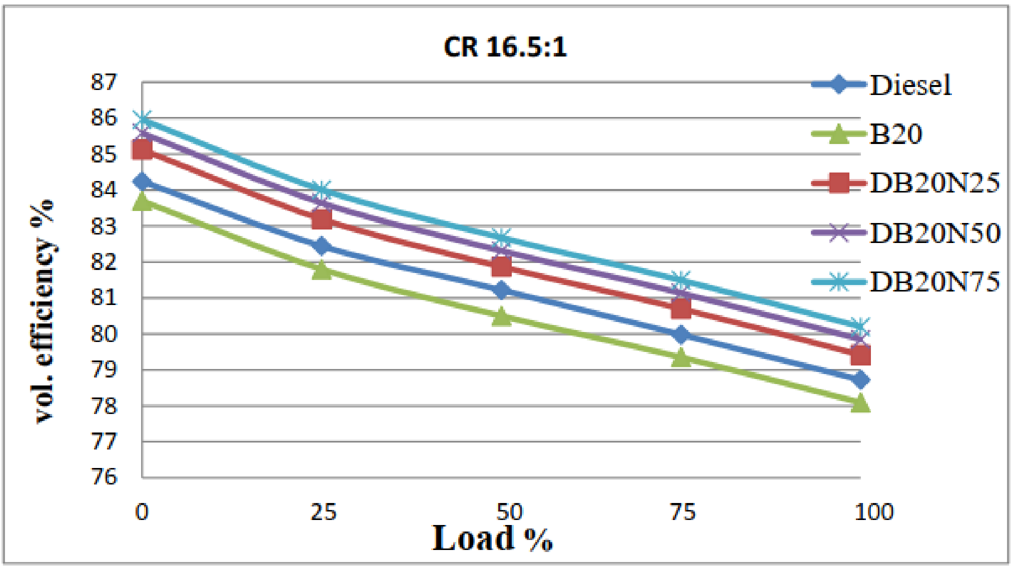

Figure 4.36. Poses the variation of volumetric efficiency at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.5.4. The A/F Ratio

The tests of air /fuel ratio are carried out at different load and compression ratio. The results of adding 25 ppm, 50 ppm, and 75 ppm Nano iron oxides are compared with neat diesel and B20 results. Basic thermodynamic concepts showed that A/F is decreased with load increment due to decreasing in sucked air and increased of fuel with increment of load. The A/F is increased with compression ratio increments as a result of the increment in combustion chamber increasing. Furthermore, the adding of Nano particles gave more A/F ratio which means improved in the combustion process itself. Figures 4.37 to 4.39 demonstrated the behavior of A/F at different load, compression ratio, and blends ratios.

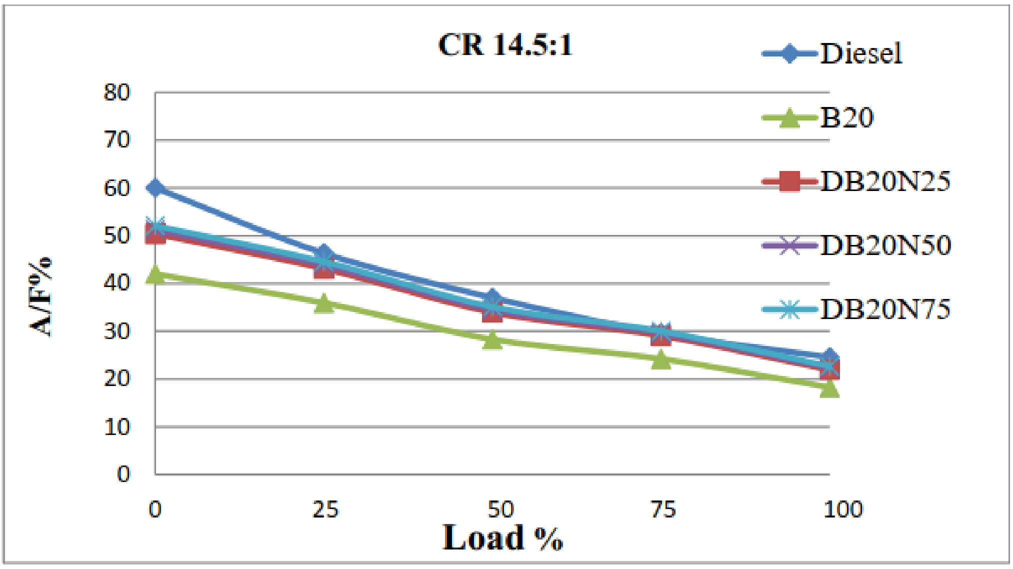

Figure 4.37. Poses the variation of A/Fat different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

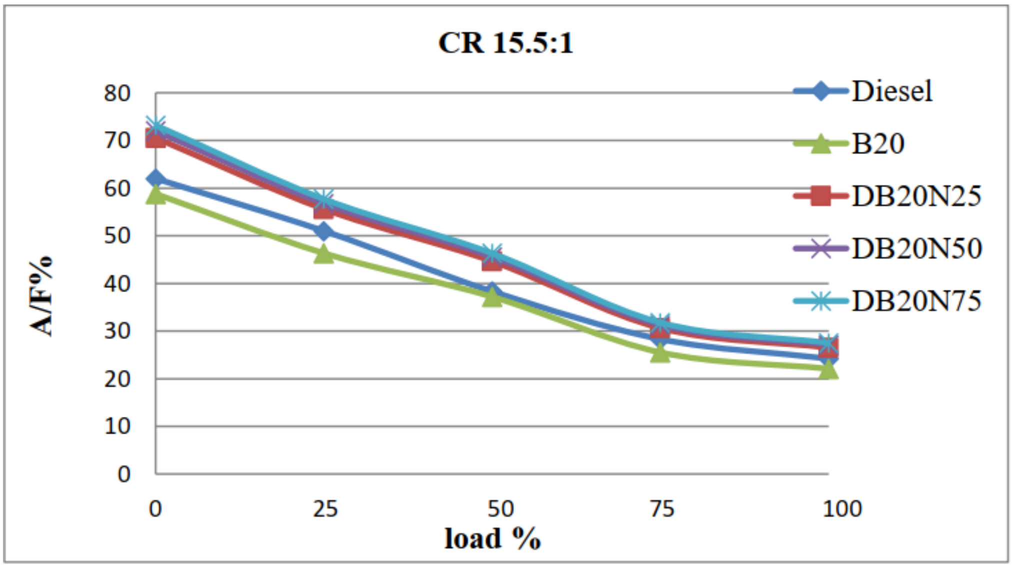

Figure 4.38. Poses the variation of A/F at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

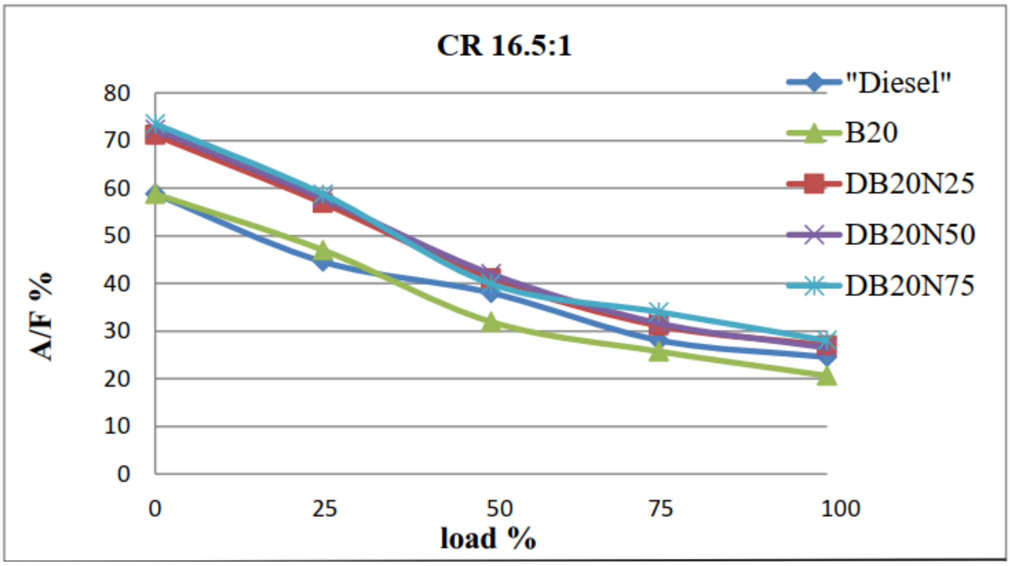

Figure 4.39. Poses the variation of A/F at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.5.5. The Exhaust Temperature

Figures 4.40, 4.41, and 4.42 represent the changing in exhaust temperature with loads and compression ratio, and blends of Nano. Basically, loads caused an increase in exhaust temperature due to an increase in fuel consumption. The increasing compression ratio led to an increase in the exhaust temperature. The increment of Nano caused to increase the temperature of exhaust which happened as a result to high conductivity and combustion improving but this increment not exceeds the same temperature at base line fuel. The B20 caused a decrease in exhaust temperature because of the low caloric value of algae biodiesel. However, Nano particles as active heat conduction raise the exhaust temperature as well.

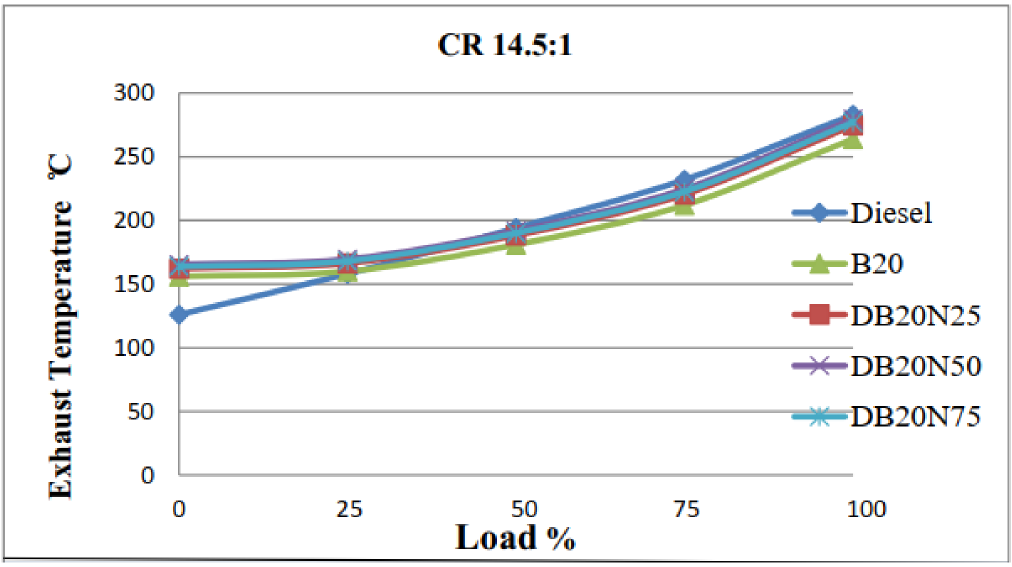

Figure 4.40. Poses the variation exhaust temperature of A/F at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

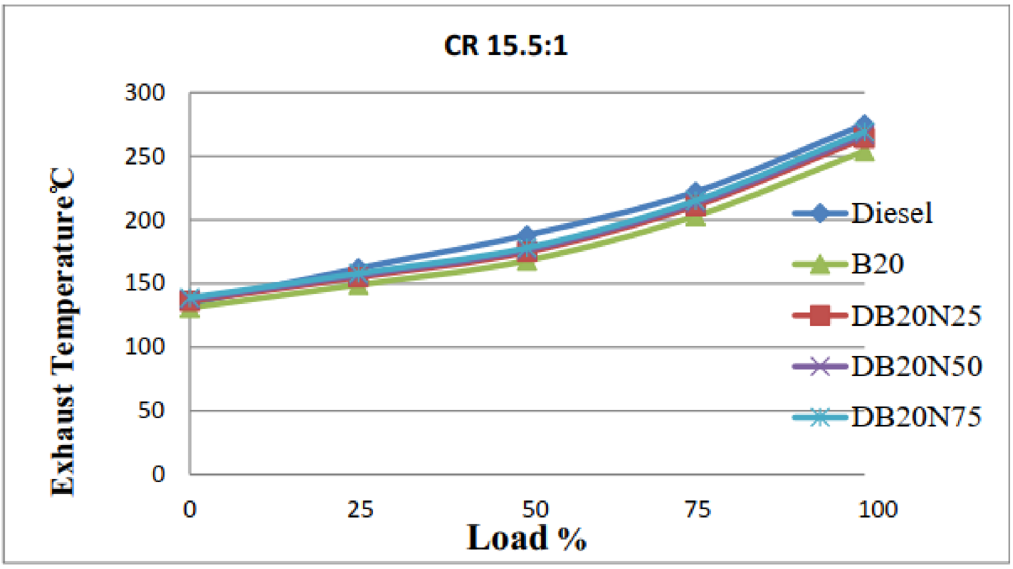

Figure 4.41. Shows the variation of exhaust temperature at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

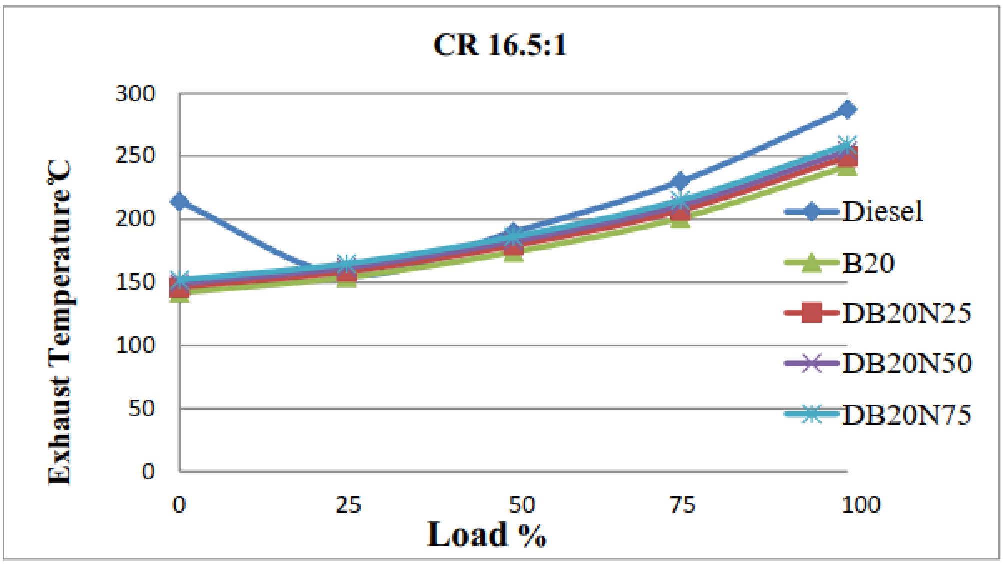

Figure 4.42. Poses the variation of exhaust temperature at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.6. THE EXHAUST EMISSIONS AFTER ADDING THE NANO

The emission of diesel engine is tested at different operating conditions named different load varied from no load up to full load by fixed increments. The engine compression ratio varies to 14.5:1, 15.5:1, and 16.5:1. The compression ignition engine is fuelled by net diesel, blend of 80% net diesel with 20% algae biodiesel named B20, and B20 with different Nano iron oxides 25, 50, and 75 called DB20N25, DB20N50, and DB20N75 respectively. The main exhaust emission constituents are CO, CO_2, UHC, and NO_X. The figures 4.43 to 4.54 represent the variation of CO, CO_2, UHC, and NO_X at different compression ratio, load, and type of fuel subsequently.

4.6.1. The Carbon Monoxide

Figure 4.43 shows the relation between the carbon monoxide percentage and engine load at 14.5:1 compression ratio. Five types of fuel are compared in this graph, named diesel, B20, DB20N25, DB20N50, and DB20N75. It can be observed that Nano enhanced carbon monoxide emissions. Due to the enhancement in combustion, carbon monoxide decreased whereas the Nano improved combustion depending on its conductivity and oxygen availability.

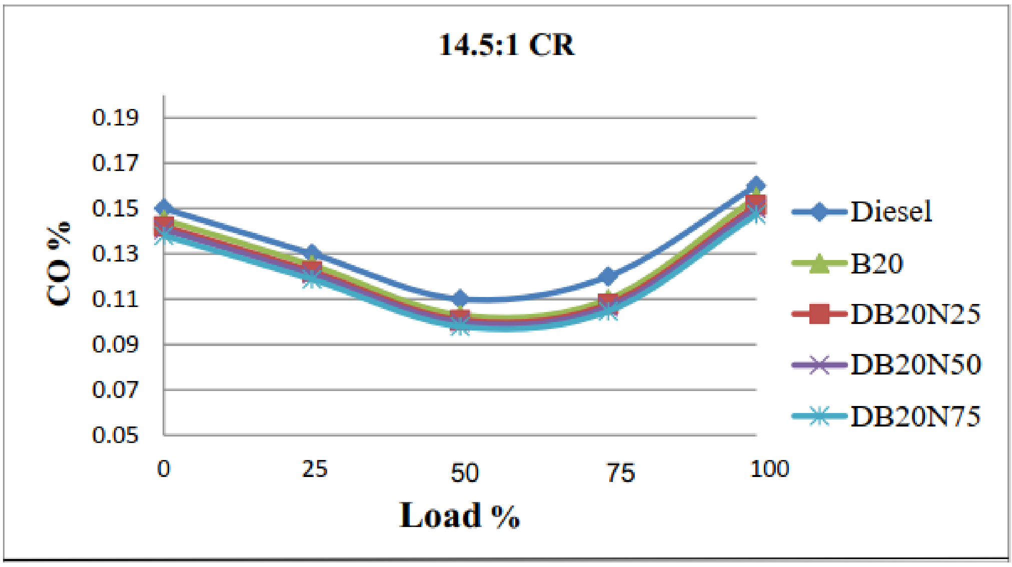

Figure 4.43. Gives the variation of carbon monoxide at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

Figure 4.44 presents the variation of carbon mono oxide at different Nano doses as compared with the neat diesel and blend of 20% biodiesel at 15.5:1 CR. It's noticed that carbon monoxide reduction is increased. The Nano 75 caused more reduction in CO% as compared with DB20N50, DB20N25, and D20 respectively. However, the adding of Nano iron oxide affected the carbon monoxide percentage CO% remarkably. The carbon monoxide reduction scenario is repeated in the diesel engine emissions test at a compression ratio of 16.5:1. This steady decrease indicates the effectiveness of nano iron oxide in the combustion chamber from the improvement of the combustion process as shown in Figure 4.45. Same observations were noticed in the results of [59].

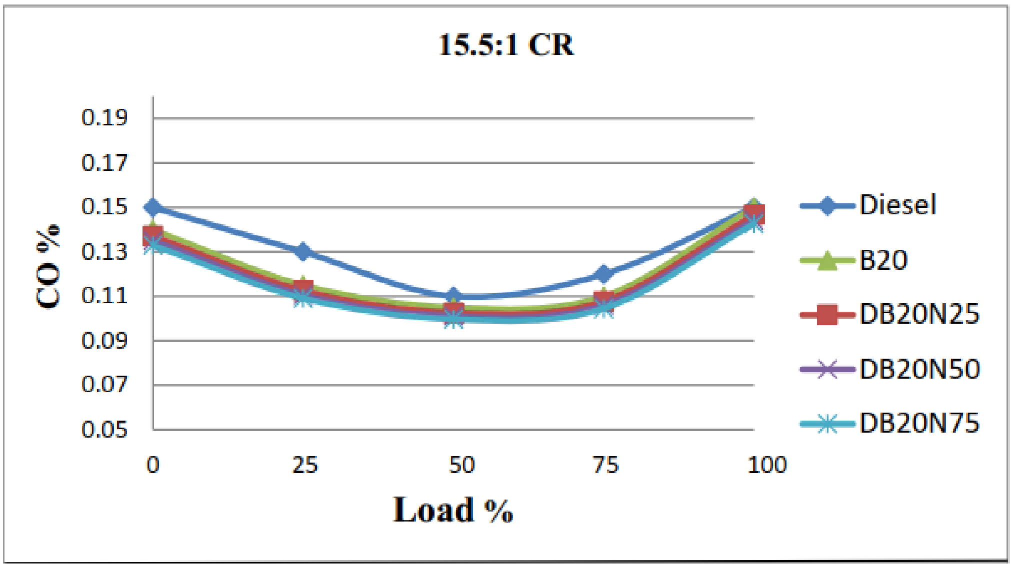

Figure 4.44. Gives the variation of carbon monoxide at different Nano doses as compare with the net diesel and blend of 20% biodiesel at 15.5:1 CR.

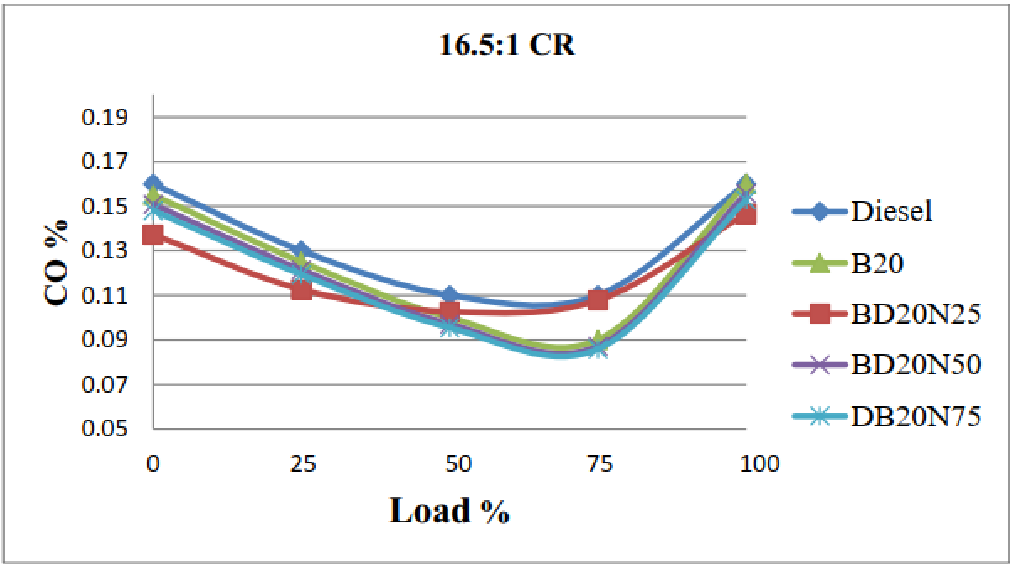

Figure 4.45. Gives the variation of carbon monoxide at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.6.2. The Carbon Dioxide Emission

Figures 4.46, 4.47, and 4.48 show the variations of carbon dioxide that emitted from compression ignition engine at different load and compression ratio 14.5:1, 15.5:1, and 16.5:1 respectively. At each graph the emitted CO_2 at variable type of fuels is plotted and compared. Basically, carbon dioxide is formed because of combustion whatever the fuel leans or rich in the combustion chamber. At idle speed and no load, the formation of carbon monoxide more than carbon dioxide then gradually CO_2 grows with load increment. The adding of biodiesel decreases CO2. The adding of nano with 25, 50, 75 ppm led to more decrease in the emitted CO_2. The mean reason is the availability of oxygen that is freed from Fe_3O_4. Same observations were noticed in the results of [59].

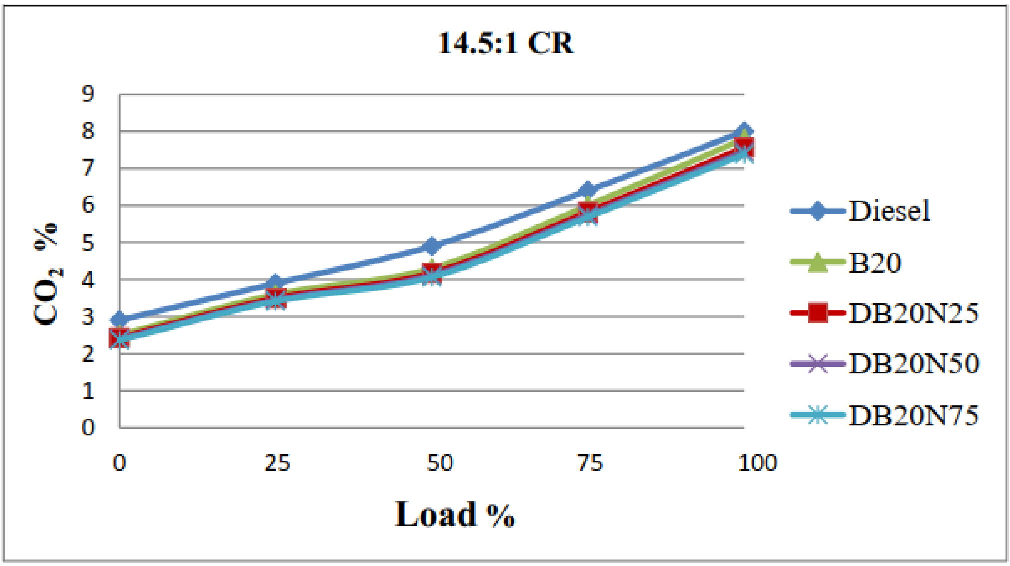

Figure 4.46. Gives the variation of carbon dioxide at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

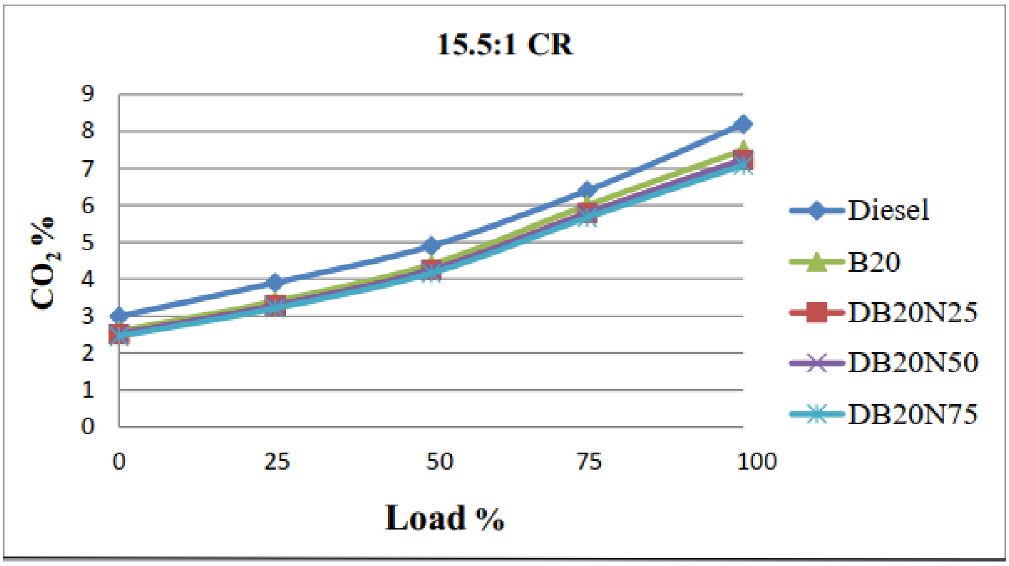

Figure 4.47. Gives the variation of carbon dioxide at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

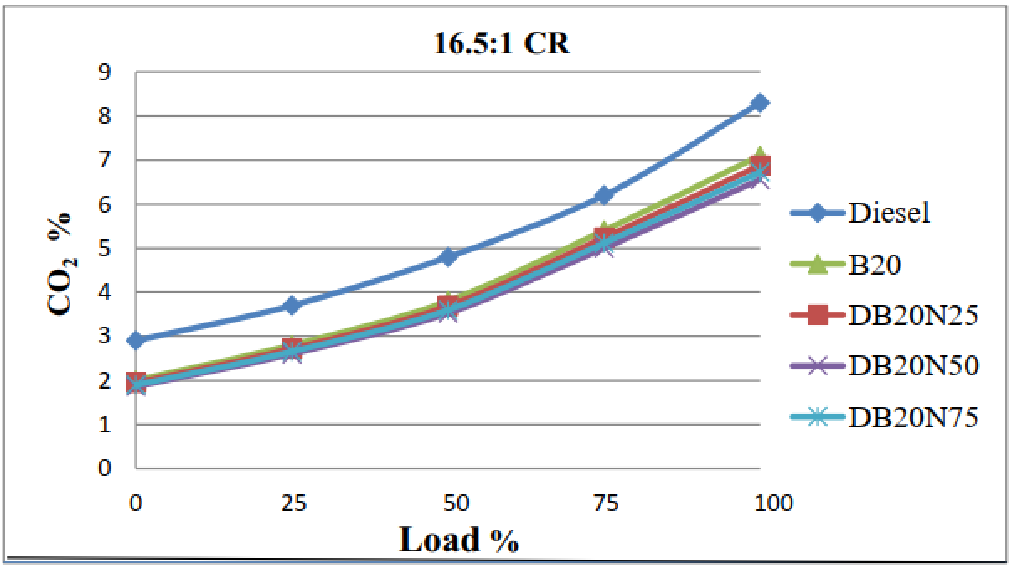

Figure 4.48. Gives the variation of carbon dioxide at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.6.3. The Unburned Hydrocarbon Emission

Unburned hydrocarbons are a series of transition hydrocarbon chemical components formed in combustion chamber under nonstoichiometric. However, unburned hydrocarbons mean the total of hydrocarbons compounds of all classes and molecular weights contained in a gas sample, calculated as if they were in the form of methane. The figures 4.49-4.51 represent the change of unburned hydrocarbon with load at variable compression ratio and blended fuel.

These results showed that the HC is reducing with nano adding increment when compared with B20 and diesel results. It's observed sensible reduction in HC as nano iron oxide increased due to the properties of nano that enhanced the combustion. The pattern is the same where HC starts high at no load then decreases then increase at high load or full load. Obviously, the HC emission varied with compression ratio variation. As CR increases the HC increases too due to increase in amount of hydrocarbon fuel enter the combustion chamber that produces HC. HC decreases with biodiesel adding as well where biodiesel has less carbon atoms as compare with neat diesel. The same results behavior was observed in the results of [59].

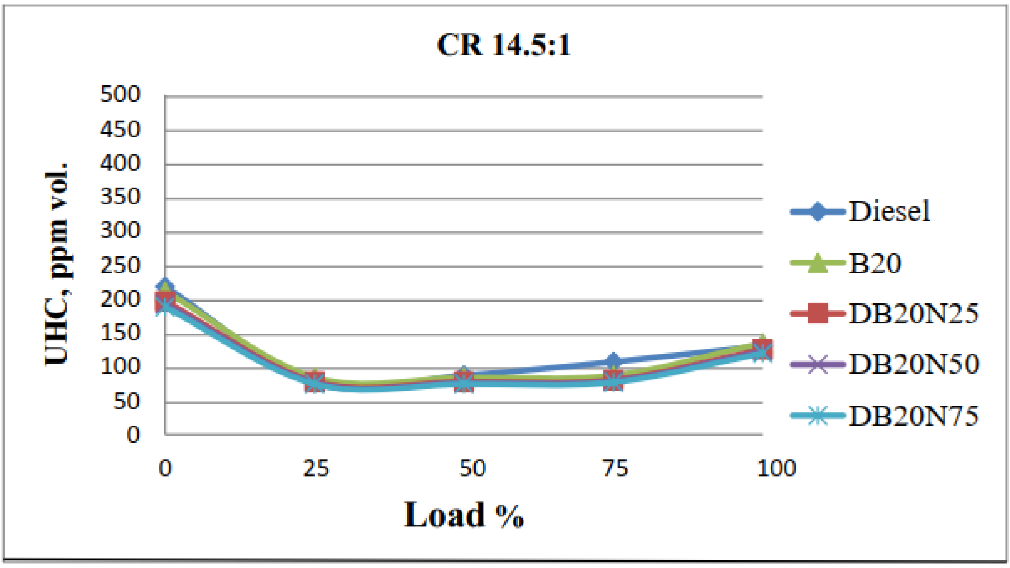

Figure 4.49. Illustrates the variation of unburned hydrocarbon at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

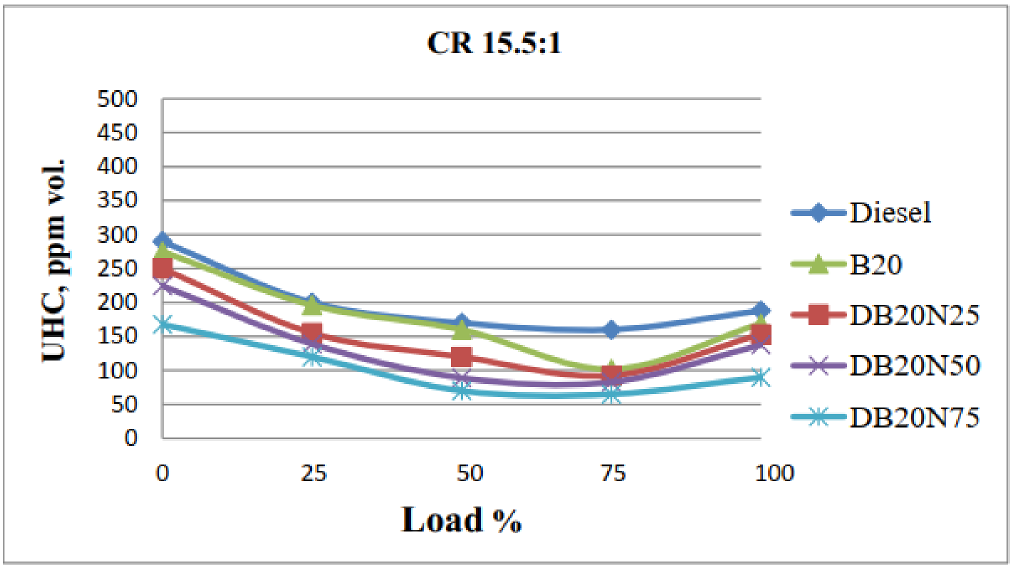

Figure 4.50. Gives the variation of unburned hydrocarbon at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

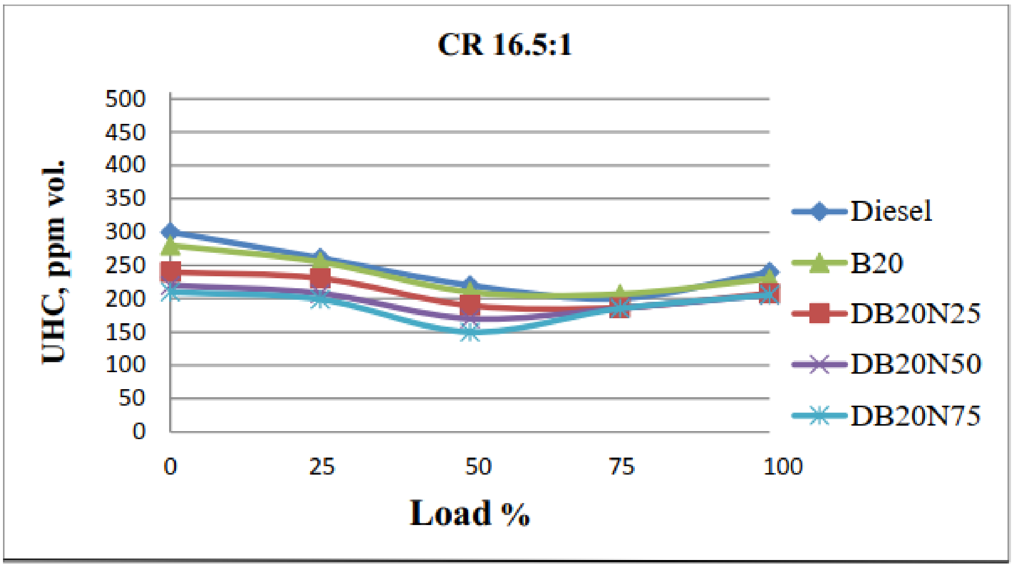

Figure 4.51. Shows the variation of unburned hydrocarbon at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

4.6.4. The Nitrogen Oxides Emission

The formation of nitrogen oxides depends upon the temperature inside combustion chamber and quantity of air there. Nitrogen oxides are like unburned hydrocarbon series of nitrogen components such as NO and NO_2. Those results represented the NO in emitted exhaust as shown in figures 4.52 to 4.54. Naturally, compression ignition engine work on excess air principle which makes us expect high rate of nitrogen oxide formation, but the temperature of formation is another factor affected the NO_X formation. The balance between quantity of air and the formation temperature is given as the final rate of NO_X.

At compression ratio 14.5:1, the rate of NO_X formation is marginally less than 15.5:1 and 16.5:1 respectively as shown in figures 4.52 to 4.54. With increment of loads, the NO_X formation increased due to increase the temperature in combustion chamber. Consequently, the supplementary fuels such as B20 and DB20N25, DB20N50, and DB20N75 the NO_X decreased. The characteristics of nano effected the formation of NO_X by reducing temperature and air where freed oxygen reduced the sucking air. The combustion improvement led to enhanced combustion temperature. The same results behavior was observed in the results of [59].

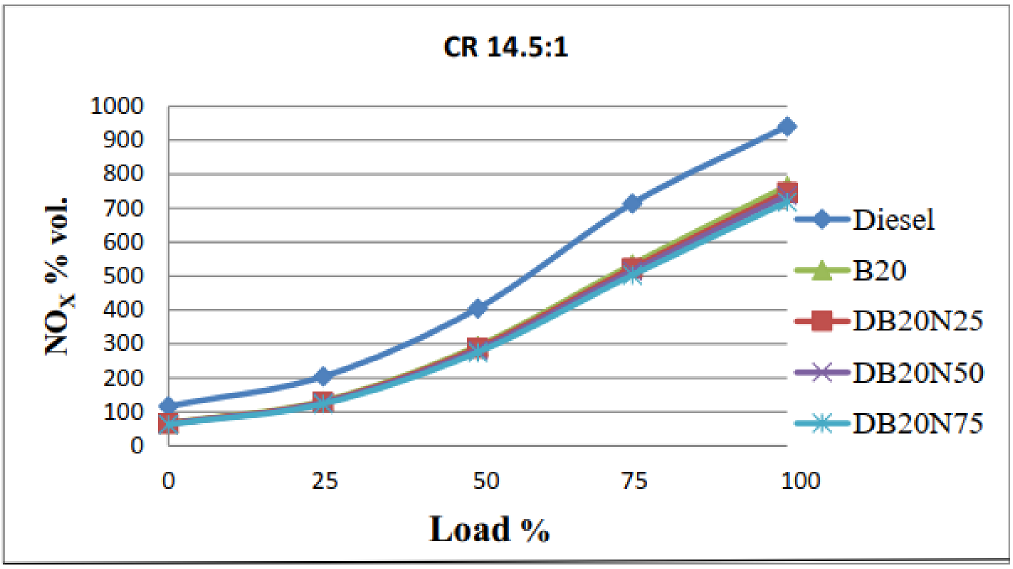

Figure 4.52. Schemes the variation of nitrogen oxides at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 14.5:1 CR.

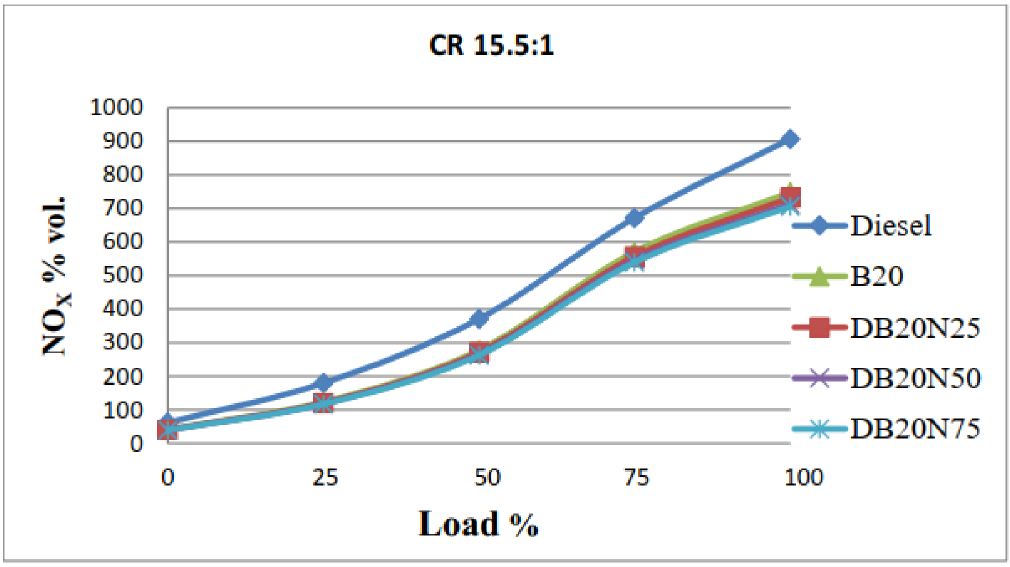

Figure 4.53. Draws the variation of NO_X at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 15.5:1 CR.

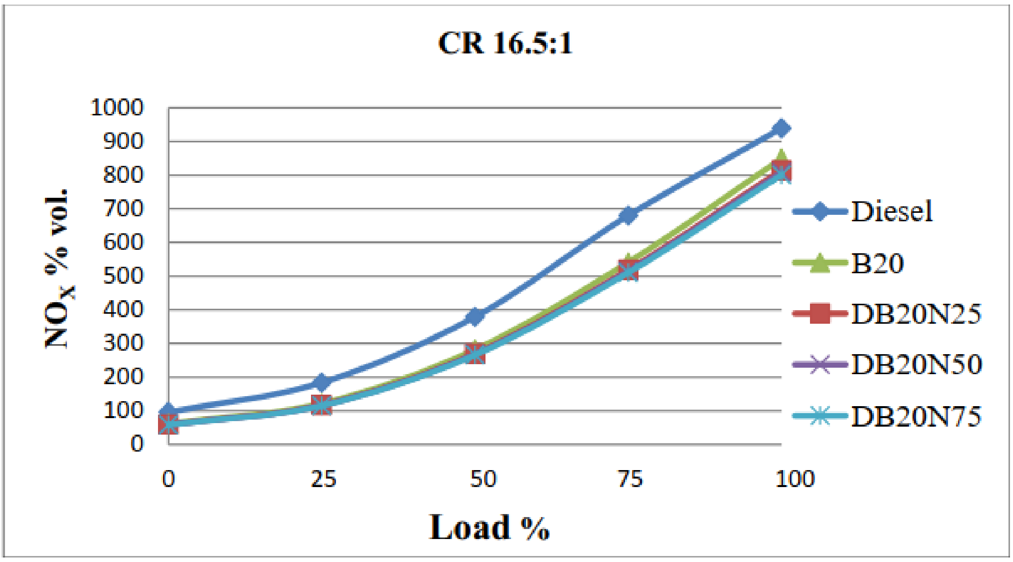

Figure 4.54. Shows the variation of NO_X at different Nano doses as compare with the neat diesel and blend of 20% biodiesel at 16.5:1 CR.

PART 5

CONCLUSIONS

5.1. INTRODUCTION

This chapter pointed out the conclusions of experimental research that achieved by compression ignition engine when it's fueled with different supplementary fuels. Consequently, the three stages of research gave the following conclusions and suggestions for further future work.

5.2. THE RESEARCH CONCLUSIONS

1. Algae are suitable nonedible sources to synthesize biodiesel.
2. Algae biodiesel can be used in compression ignition engines without hardware modifications.
3. Algae biofuel is low cost as compared with another type of biodiesel and with net diesel itself where the synthesize coast cheap.
4. B20 is the best blend between biodiesel and diesel. This optimization appears when thermal performance and exhaust emissions are investigated experimentally.
5. As renewable energy fuel, the Algae biodiesel gave reasonable performance as well as decrease in emission.
6. The adding of nano iron oxide is important to enhance the performance and decrease the emissions constituents.
7. The addition of 75 ppm of nano iron oxides improved the engine performance and exhaust emissions.

5.3. SUGGESTIONS FOR FUTURE WORK

1. Testing a mixing ratio from B40 to B100 to draw a full level of algae biodiesel use in a compression ignition engine.
2. Testing the amount of soot emitted from the engine when adding algae biodiesel to conventional diesel and combustion.
3. Using different Nano particles with concentration ranges from 80 to 100ppm and blending with algae biodiesel.
4. Adding Fe_3O_4-Al_2O_3 Hybrid Nanoparticles at doses (25,50and75ppm) to Algae Biodiesel Fuel and Testing Its Effect on Combustion, Performance, and emission.

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APPENDIX A.

DIESEL FUEL PROPERTIES

DAURA REFINERY
Quality Control Laboratories Department

SAMPLES OF GAS OIL: 6/4/2022

TESTS	First week average	Second week average	Third week average	Fourth average
Density @ 15.0 °C	0.8310	0.8305	0.8329	0.8334
Flash Point (PM) °C	70.0	69.0	69.0	66.0
Viscosity C.st @ 40 °C	2.7	2.6	2.8	2.8
Pour Point °C	-18	-18	-15	-15
Sulfur Content wt. %	1.16	1.17	1.25	1.26
Carbon Residue (RAMS) Bottom (on 10 % Res.)	0.1	0.1	0.1	0.11
Distilled @ 350 °C Vol.%	/	/	/	/
Diesel Index	60.0	60.0	60.0	60.0
Cetane No.	50.0	50.0	50.2	50.1
Calorific Value Kcal /Kg (gross)	10950	10951	10943	10941
Ash wt. %	Nil	Nil	Nil	Nil

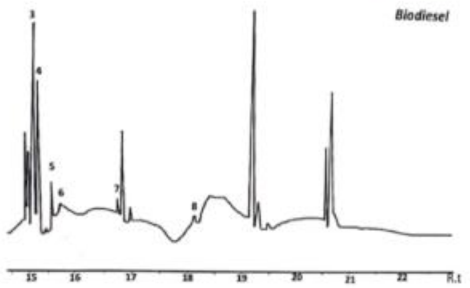
Inaam Mahmood Ali
Analytical lab.Supervisor

Ayad Ahmed Mohammed
Manager of Quality Control Laboratories Dept.

C.C.TO:
- Light oil Products Comm...
- Analytical Section
- File.

APPENDIX B.

THE PROPERTIES OF ALGAE METHYL ESTER



Properties Physical

1	*Chemical formula*		
2	*Density*	0.869	mg/cm³ at 40 C°
3	*Viscosity*	4.98	mm²/sec at 40 C°
4	*Flash Point*	121.65	℃
5	*Cetane Number*	49.85	
6	*Calorific Value*	38.92	MJ/Kg
7	*Surface tension*	0.02924	N/m

3

RESUME

Ali Salam Khaleel AL- GBURI and he graduated primary, elementary, and high school, after that, he started Bachelor at University of Wasit College of Engineering, Department of Mechanical Engineering in 2012. Then in 2020, he started at Karabuk University Mechanical Engineering to complete his M. Sc. education.