

MICRO ALGAE CULTIVATION FOR BIODIESEL PRODUCTION AND ENGINE STUDIES

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

by

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SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC | 12B Status by UGC | Approved by AICTE

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **K. Kabilan (391500059)** and **B. Sathish Kumar (39150118)** who carried out the project entitled **“MICRO ALGAE CULTIVATION FOR BIODIESEL PRODUCTION AND ENGINE STUDIES”** under our supervision from November 2022 to April 2023.

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ABSTRACT

The CI engine was utilizing fuel blend of plain diesel and Bi-fuel (Micro algae, 90 percent, and Cotton Seed oil, 10 percent). This is the formula for the current study: 80% diesel, 20% bi-fuel (made of 90% microalgae), and 10% cotton seed oil. The research includes this bi-fuel diesel concoction. The blend was produced in accordance with the American Type Culture Cultivation (ATCC) standards. The traits fall within the recommended limits. A vertical, water-cooled, four-stroke diesel engine with one cylinder was used for the tests. In this article, the impacts of microalgae oil biodiesel on engine performance, combustion, and emissions are assessed in relation to the B20, B15, B10, and B05 Bi-fuel, which contains cotton seed oil and microalgae. The investigation results show that the B10 blend is more efficient than other biodiesel blends. It gives an overall better emission characteristic, better fuel economy, and better efficiency. B05 blend is not considered because of its low cylinder pressure which may stall the engine while running.

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LIST OF ABBREVIATIONS

BTE	BRAKE THERMAL EFFICIENCY
SFC	SPECIFIC FUEL CONSUMPTION
RME	RAPESEED METHYL ESTER
SME	SOY METHYL ESTER
PME	PALM METHYL ESTER
WCOME	WASTE COOKING OIL METHYL ESTER
AFME	ANIMAL FAT METHYL ESTER
JME	JATROPHA METHYL ESTER
Nox	NITROGEN OXIDE
FAME	FATTY ACID METHYL ESTER
CO ₂	CARBON DIOXIDE
ATCC	AMERICAN TYPE CULTURE COLLECTION
PBR	PHOTOBIOREACTOR
VE	VOLUMETRIC EFFICIENCY
EGT	EXHAUST GAS TEMPERATURE
CO	CARBON MONOXIDE
HC	HYDROCARBON
SO	SMOKE OPACITY
CP	CYLINDER PRESSURE
CA	CRANK ANGLE
NHRR	NET HEAT RELEASE RATE

CHAPTER 1

INTRODUCTION

1.1 HISTORY AND BACKGROUND:

The Industrial Revolution of the 18th and 19th centuries, which resulted in the creation of the internal combustion engine, is responsible for the modern engine we use today. The first internal combustion engine, a tiny gas-powered engine, was created by French engineer Etienne Lenoir in the early 1800s. The first useful internal combustion engine was not created until the late 1800s by the German engineer Nikolaus Otto because it was not very efficient. Otto's engine utilized a four-stroke cycle, which is still the foundation of the majority of contemporary engines. Intake, compression, combustion, and exhaust are the four strokes that make up the four-stroke cycle. The engine transforms fuel into mechanical energy by using a piston that oscillates inside a cylinder. Karl Benz created the Benz Patent-Motorwagen, the first practical automobile, in 1885 using an internal combustion engine. The Wright Brothers made the first successful powered flight in 1903 as engines first started to be employed in aircraft in the early 1900s. Air travel underwent a revolution as a result of the jet engine's development in the 1930s and 1940s, making it quicker and more effective. Diesel engine development in the middle of the 20th century resulted in higher efficiency and less fuel use. Diesel engines are frequently employed in power generators, ships, and heavy-duty vehicles like trucks and buses. Focus has recently been placed on creating ecologically friendly and more efficient engines, like hybrid and electric models. To cut back on fuel use and pollutants, these engines combine a number of different technologies.

1.2 Introduction of Biodiesel and Its Generations:

Biofuels are made from organic matter and are typically divided into two categories: (i) primary biofuels like landfill gas, firewood, wood chips and pellets; (ii) secondary biofuels like bioethanol, butanol, biodiesel and hydrogen. The first generation of biofuels includes biodiesel created chemically from rapeseed, soybeans, sunflower, palm, coconut, and animal fats, as well as bioethanol/butanol

produced by fermentation of starch from wheat, barley, corn, potatoes, sugarcane, and sugar beetroot (Amaro, Macedo, and Malcata 2012). The production of bioethanol, bio-butanol, and/or syndiesel from lignocellulosic materials including straw, wood, and grass are categorised as second-generation biofuels, as are the production of bioethanol and biodiesel from *Jatropha*, cassava, and *Miscanthus* (Maity et al. 2014). The first generation of biofuel production systems have significant economic and environmental drawbacks, as well as increased pressure on farmland needed for food production to feed the ever-increasing global population, which is predicted to reach 7.2 billion people in 2050.(de Vries et al. 2010) The primary disadvantages of the second generation of biofuel production are the need for a sizable cultivation area and the woody parts of plants that do not compete with food production. The drawbacks of first- and second-generation biofuels can be overcome by considering microalgae, which can generate substantial amounts of biomass and subsequently biofuels on considerably smaller areas (Schenk et al. 2008). Biodiesel is a form of sustainable biofuel manufactured from vegetable oils, animal fats, or recycled cooking oils. Transesterification is a chemical process that includes reacting the feedstock with an alcohol (typically methanol) and a catalyst (such as sodium hydroxide) to form methyl ester, which is the major component of biodiesel. Here are the many forms of biodiesel and how they are produced (Schenk et al. 2008).

First Generation of Biodiesel:

- Rapeseed methyl ester (RME): A biodiesel feedstock derived from rapeseed oil, which is the most popular feedstock in Europe.
- Soy methyl ester (SME): A methyl ester derived from soybean oil, the most prevalent feedstock for biodiesel in the United States.
- Palm methyl ester (PME): A biodiesel feedstock derived from palm oil, which is the most popular feedstock in Asia.

Second Generation of Biodiesel:

- Waste cooking oil methyl ester (WCOME): This product is made from recycled cooking oil, which is a by-product of restaurants, households, and food producers.
- Animal fat methyl ester (AFME): A by-product of the meat industry made from animal fats such as tallow and lard.
- Jatropha methyl ester (JME): This product is derived from jatropha oil, a non-edible oilseed that may be farmed on marginal soil.

Third Generation of Biodiesel:

- Algal methyl ester (AME): Made from oil derived from algae, which can thrive in a variety of water conditions and generate a large amount of oil.

Biodiesel is a sustainable energy source that can assist to reduce NO_x emissions and the "carbon content" of the atmosphere. Because the carbon in the fuel was taken from the atmosphere by the plant feedstock, it contributes less to global warming (Sims et al. 2010). Furthermore, biodiesel creates less air pollutants such as NO_x, carbon monoxide, and carbon dioxide than diesel derived from fossil fuels. According to a 1998 study conducted by the USDA and the US DOE, using pure biodiesel in urban buses results in a significant reduction in the life cycle emissions of total particulate matter around 32%, carbon monoxide around 35%, and sulphur oxides around 8% when compared to the life cycle emissions of petroleum diesel (Dragone et al. 2010).

1.2.1 Biodiesel Production:

Biodiesel production from microalgae involves two main processes: biomass production and lipid extraction. The biomass production process includes cultivation and harvesting of microalgae, while the lipid extraction process involves the conversion of lipids into biodiesel (Gebremariam and Marchetti 2018).

Biomass Production:

Biomass production is the process of mass cultivation of microalgae. The cultivation procedure includes giving the microalgae with the nutrients, light, and carbon dioxide they require to flourish. To optimize microalgae development and avoid contamination, culture conditions must be continuously monitored. Microalgae may be grown in a variety of ways, including open ponds, closed photobioreactors, and hybrid systems. Open ponds are the most basic and cost-effective approach, although they are prone to pollution and produce less than closed systems. Closed photobioreactors are more costly, but they provide better control over growing conditions and higher yield (Aransiola et al. 2014).

Lipid Extraction:

After producing biomass, the microalgae biomass must be treated to extract the lipids, which are then turned into biodiesel. The following processes are involved in lipid extraction, which is a vital phase in the process:

- Cell disruption: Microalgae cell walls are strong and must be broken down in order for the lipids to be released. Mechanical, chemical, or enzymatic approaches can be used to disturb cells.
- Lipid extraction: After cell disintegration, the lipids must be removed from the cell debris. Lipid extraction can be accomplished using solvent extraction or mechanical extraction methods such as pressing or grinding.
- Lipid purification: The collected lipids may include contaminants that must be eliminated before being converted to biodiesel. Techniques such as centrifugation or chromatography can be used to purify lipids.

Once the lipids have been removed and purified, they may be turned into biodiesel by a process known as transesterification. (Rezania et al. 2019)

Transesterification or alcoholysis (typically metanalysis) is the traditional process for producing biodiesel, in which triglycerides react with alcohols (typically methanol) in the presence of a catalyst, either homogeneous or heterogeneous, as a reaction promoter, to produce fatty acid alkyl esters [typically fatty acid methyl esters (FAME)] (Lee et al. 2015). Transesterification is a series of reversible, sequential events in which triglycerides are

transformed to diglycerides, monoglycerides, and eventually glycerine (also known as glycerol) Biodiesel is typically created using a single-step transesterification process catalysed by alkali catalysts. However, depending on the FFA and commonly known as esterification, preceding the transesterification process may be necessary the presence of a catalyst speeds up the reaction, increasing the yield of the product. Various catalysts are employed in the transesterification process for biodiesel synthesis. As previously stated, the catalysts utilised in the transesterification process are crucial to the group. According to recent review papers, they may be grouped into four key groups: homogeneous catalysts, heterogeneous catalysts, biocatalysts, and nano catalysts (Rizwanul Fattah et al. 2020).

1.3 Introduction of Algae's:

Algae are part of a diverse category that includes a large variety of organisms. Several species that can be used as a source of raw materials to make biofuel. On a large scale, algae may often be cultivated using inorganic materials like carbon dioxide (CO₂), light energy, and nutrients like Nitrogen (N) and phosphorus (P) (N). Since the beginning of time, algae have utilized in their capacity as producers of food for humans and animals. Additionally, they exhibit superb bioactivities and metabolite secretion They are mostly investigated for the application of fertilizer, wastewater treatment, and greenhouse gas, antibiotics, and nutraceuticals a mitigating factor. Recently, there has been a conversion of converting microalgae biomass into various biofuels, including biodiesel, bioethanol, biohydrogen, and bio-oil that may one day help with today's problems energy shortage (J. Singh and Saxena 2015). Important characteristics of microalgae cells include high growth less water is needed, there is a high biomass production rate, and They are a great feedstock since they have room to grow macroalgae for making biofuels Despite significant research efforts on microalgae, its commercial use is still lacking. difficulty choosing an appropriate farming system makes it uneconomical. Various techniques for gathering biomass. Open ponds are used in large industrial growth systems to grow microalgae with a variety of techniques. Water, nutrients, and microalgae cells are

moved about using a paddle wheel. While being in continual contact with the environment. Nevertheless, closed methods like PBRs of different designs are chosen to reduce the contamination concerns and simplifying parameter control for greater productivity (Venu, Subramani, and Raju 2019).

1.3.1 Types of Microalgae's and composition:

Different crops that have readily available sugars and starches are included in first generation biofuels, including canola, wheat, sugarcane, palm, and corn starch. They require highly advanced conversion methods in order to be converted into biofuels. They immediately compete with crops grown for human consumption, so their utility as a source for biofuel is constrained. Lignocellulosic biomass is primarily referred to as the second generation of biofuels (Deshmukh, Kumar, and Bala 2019). It predominantly consists of cellulose, hemicellulose, and lignin, with minor levels of extractives. Because lignocellulose is difficult for humans to digest, unlike carbohydrates or starches, its use does not pose a danger to the global food supply (Mata, Martins, and Caetano 2010). Their primary benefits are quick growth cycles, high output rates, and little to no fertiliser requirements, which result in an expedited return on investment. Algae is used to produce third generation biofuels. Finally, algae are used to produce third generation biofuels. Algae are a particularly promising type of biomass since these species are known to produce much more biomass and lipids (López-González et al. 2014). They can be grown without taking up soil, do not compete with food crops, use less energy than other feedstock during the conversion process, have a flexible water demand (salt and wastewater to give nutrients), use CO₂-rich flue gas as a carbon source, and have a wide product range (López-González et al. 2014).

1.3.2 Algae Biodiesel and Its Requirements:

The production of biodiesel from microalgae involves multiple steps, but oil extraction requires special consideration due to its intricate and energy-intensive nature (Halim, Danquah, and Webley 2012).

Specific extraction procedures are used to remove the components of interest from the various components that each microalgae cell contains.

The capacity to scale up the production of microalgal biodiesel depends on the selection of the right extraction technique (Rakopoulos, Rakopoulos, and Giakoumis 2015). One more downstream processing stage in the creation of biodiesel is the conversion of extracted lipid into biodiesel, which occurs in the presence of a catalyst. The thermo-physical characteristics of the biodiesel produced determine its quality; these characteristics are crucial for its use as a diesel engine fuel (Mubarak, Shaija, and Suchithra 2015). While some research focused solely on extraction-related activities, others examined the impact of fatty acid profiles on biodiesel characteristics and the viability of producing biodiesel on a wide scale (Chen et al. 2018). Additionally, a summary of experiments involving the direct conversion of biomass into biodiesel has been provided. Additionally, the characteristics of microalgae biodiesel and a comparison to first- and second- generation biodiesel have been provided. Finally, research on the performance and emission characteristics of microalgal biodiesel has been compiled (Chen et al. 2018).

Biodiesel is an alternative fuel that is created by processing biological materials like leftover cooking oil, animal fats, and edible and non-edible oils. In some regions, in addition to being a fuel for transportation, biodiesel is also used to produce energy in engines and turbines. These independent studies have conclusively established that biodiesel does not endanger human health while dramatically reducing practically all allowable emissions (Rouhany and Montgomery 2019). When utilised in a conventional diesel engine, biodiesel greatly lowers the number of unburned hydrocarbons, carbon monoxide, and particulate matter because it contains neither sulphur nor aromatics. According to U.S. Department of Energy research, the production and use of biodiesel resulted in carbon dioxide emissions that were 78.5% lower than those from petroleum diesel. Furthermore, biodiesel has a positive energy balance (B. R. Singh and Onkar 2006).

1.3.3 Microalgae Cultivation and Factors Influencing:

There are various microalgae growing methods, each having advantages and cons. The cultivation technique used is determined by criteria such as the strain sought, the kind of water available, the size of production, and the availability of

resources. Here are some of the most prevalent microalgae growing methods (Zhuang et al. 2018).

i. Open Ponds:

Open ponds are the most basic and widely used form of microalgae culture. These ponds, which may range in size from a few square metres to many hectares, can be sunk into the earth or erected above ground. Open ponds use natural sunlight as a source of energy for photosynthesis and require just minimum infrastructure, making them relatively inexpensive. Open ponds, on the other hand, are susceptible to contamination from other microorganisms, need a substantial quantity of water and area, and have low production when compared to other farming methods.

ii. Photobioreactors:

Photobioreactors are closed systems that provide more exact control of the growing environment, such as light intensity, temperature, and nutrient availability. Simple plastic bags to more complicated tubular or flat-panel reactors are examples of these systems. Photobioreactors are more productive than open ponds, need less water, and are less prone to pollution. They are, however, more expensive to create and run, as well as requiring more upkeep than open ponds.

iii. Hybrid Systems:

Hybrid systems combine the benefits of open ponds with photobioreactors by growing algae in open ponds and then moving them to photobioreactors for final culture. This approach lowers photobioreactor costs while boosting production and lowering contamination hazards.

iv. Wastewater Treatment:

Microalgae may be grown with wastewater as a fertilizer source. This technology has the benefit of lowering the cost of fertilizer inputs as well as wastewater treatment. However, the wastewater quality must be closely checked to ensure that it does not include dangerous chemicals that might infect the algae.

v. Aquaponics:

An aquaponics system combines fish farming with microalgae cultivation. The fish feed nutrients to the algae, and the algae assist the fish clean the water. This technology has the advantage of producing both food and fuel in an environmentally friendly manner. It does, however, need more equipment and skill than other methods and may not be appropriate for large-scale manufacturing.

Microalgae species were chosen based on productivity, ease of adherence to support medium, cell shape and size, amount of extracellular polymeric substance (EPS), value of by-products, and anti-bacterial capacity, among other factors. The high productivity of microalgae and the high value of their byproducts are significant factors to consider when selecting a species for biomass production. Microalgae's high adhesion potential offers value to attached microalgae farming. Microalgae attachment is facilitated by cell shape/size and EPS production (Zhuang et al. 2018).

CHAPTER 2

LITERATURE SURVEY

2.1 Biodiesel Blends:

The production of biofuels, their properties, and their efficiency in diesel engines have all been the subject of several studies in the past. Although there have been numerous researches on the creation of biodiesel from rice bran oil, there have only been a small number on the impacts of employing microalgae oil biodiesel blends on internal combustion engines' performance, combustion, and emission characteristics.

That is a perceptive finding. Due to its high productivity, cheap cost, and potential for sequestering carbon dioxide (CO₂), biodiesel made from microalgae has been recognized as a prospective replacement for petroleum- based diesel. But as you pointed out, there haven't been many research on how using microalgae oil biodiesel blends in internal combustion engines affects the engines' performance, combustion, and emission characteristics.

The 10% and 20% biodiesel blends were developed, according on the research of Avinash Kumar and Rupesh Kumar Tripathi. The number of fatty acids has a big effect on obliques. The B10, B20, B40, and B50 biodiesel blends were chemically and physically equivalent to diesel oil. Investigated were the performance characteristics and exhaust emissions of a diesel engine using a combination of biodiesel and diesel fuel (Kumar et al. 2020).

A study conducted by Wang et al. (2018) investigated the combustion and emissions characteristics of a microalgae oil biodiesel blend (B20) in a single-cylinder diesel engine. The results showed that B20 had similar combustion characteristics to petroleum-based diesel, but with lower emissions of particulate matter, carbon monoxide, and unburned hydrocarbons.

Another study by Silva et al. (2019) investigated the performance and emissions characteristics of a microalgae oil biodiesel blend (B30) in a diesel engine. The results showed that B30 had similar engine performance to petroleum-based diesel, but with lower emissions of nitrogen oxides and particulate matter.

2.2 Algae Cultivation and Harvesting:

According to their research, Converti, A., Casazza, A. A., Ortiz, E. Y., Perego, P., and Del Borghi, A. (2009) With a view to their potential use as novel raw materials for the synthesis of biodiesel, the current work's goal was to investigate the effects of temperature and nitrogen concentration on the lipid content of *Nannochloropsis oculata* and *Chlorella vulgaris*. Various lipid extraction techniques were also researched. Gravimetric and gas chromatographic methods were used to analyse the extracted lipids quantitatively and qualitatively in order to determine whether they matched the requirements for biodiesel as defined by European standards (Converti et al. 2009).

Yang, J., Xu, M., Zhang, X., Hu, Q., Sommerfeld, M., and Chen, Y (2011). The two most crucial microalgal factors, algal growth rate and lipid content, both have a detrimental effect on the water footprint of the synthesis of microalgae biodiesel. That instance, decreasing the water footprint can be achieved by boosting growth rate and fat content. Growth rate and lipid content are in contradiction, though, because lipid accumulation is likely to accompany nutritional shortage, which happens when growth rate slows (Goldberg and Cohen, 2006).

According to Xin Bei Tan, Man Kee Lam, Yoshimitsu Uemura, Jun Wei Lim, Chung Yiin Wong, and Keat Lee's (2018) research Due to their rapid development and capacity to produce significant amounts of lipid inside of their cells, aquatic microorganisms (especially microalgae) have recently

been raised for cultivation with the goal of producing biodiesel. The biggest obstacles to creating renewable microalgae biodiesel, nevertheless, are energy development and the cost-effectiveness of microalgae cultivation systems. Since they can sustain microalgae development, wastewater or organic compost have recently been used as the growing medium. Both the microalgae production system and method are crucial because they unquestionably influence the final microalgae biomass and lipid yield (Tan et al. 2018).

In 2019, Victor Okoro, Ulugbek Azimov, Jose Munoz, Hector H. Hernandez, and Anh N. Phan The effectiveness of growing microalgae in photobioreactors under varied growth circumstances and the harvesting efficiency of different flocculants on four chosen microalgae species/strains were both thoroughly examined. Analysis was done on the biomass output, lipid productivity, and economic effects of microalgae cultivation and flocculation. Carbon dioxide and light intensity were discovered to be important elements. To achieve low cost and high productivity of algal biomass and lipid accumulation, photobioreactor design must be optimised effectively, and researchers must learn more about how different microalgae species respond to varied growth circumstances (Okoro et al. 2019).

2.3 Algae Biodiesel:

According to Wahlen, B. D., Willis, R. M., and Seefeldt (2011)'s study Due to their high lipid output and flexibility for growing on poor soil, microalgae have been recognised as a viable feedstock for biodiesel. The complexity of extracting the lipids from the microalgae using organic solvents and then transesterifying the extracts to produce biodiesel is one of the difficulties in employing microalgae to produce biodiesel (Wahlen, Willis, and Seefeldt 2011).

The authors Mata, T. M., Martins, A. A., and Caetano (2010) refer to in comparison to other accessible biodiesel feedstocks, the most popular microalgae species for biodiesel synthesis are provided, along with a summary of their primary benefits. In order to provide an overview of the present level of development of algal cultivation systems (photo-bioreactors and open ponds), several elements related to the design of microalgae production units are described (Mata, Martins, and Caetano 2010).

Hannon, M., Gimpel, J., Tran, M., Rasala, B., & Mayfield (2010) make an effort to clarify the main obstacles to the production of algal biofuels at a large scale with the goal of sharpening the scientific community's emphasis on these issues and bringing algal biofuels closer to becoming a reality (Hannon et al. 2010).

According to Chisti, Y. (2007), biodiesel made from oil crops has the potential to replace petroleum fuels as a renewable and carbon-neutral fuel source. Unfortunately, the demand for transportation fuels cannot practically be met by biodiesel produced from waste cooking oil, oil crops, or animal fat. As seen below, microalgae seem to be the sole source of renewable biodiesel that can satisfy the demand for transport fuels on a worldwide scale. Microalgae use sunlight to make oils, just like plants do, but they do so more effectively than agricultural plants. Many microalgae have oil production rates that are far higher than those of the best oil crops (Chisti 2007).

According to research by Nazia Hossain, T. M. I. Mahlia, and R. Saidur from 2019, microalgae have been tested as a potential feedstock for biofuel generation due to their high energy content, rapid growth rate, low- cost culture methods, notable capacity for CO₂ fixation, and the synergistic effects of microalgal biofuel combined with nano-additive applications. This work has studied the applications of many nano-additives, including nano- particles, nano-tubes, nano-sheets, nano-droplets, and other nano- structures, to promote microalgae growth and biofuel production (Hossain, Mahlia, and Saidur 2019).

CHAPTER 3

AIM AND SCOPE

3.1 Aim:

- Investigation is led on B20 biodiesel because of its good balance of cost, less emissions, cold-weather performance and equipment compatibility.
- To prepare a blend of micro algae biodiesel and diesel by the process of transesterification with 20% biodiesel and 80% diesel.
- To perform engine test on CI ENGINE by adding Cao nanoparticles to B20 blend.
- To check the reduction of NO_x emissions.
- Optimizing the result and analysis of the test

3.2 Scope:

Biodiesel is considered to be an alternate fuel, plays a major role in the reduction of pollutant particles suspended into atmosphere on emission. It also solves fossil fuels demand by providing a sustainable solution. This research work provides a solution for using high viscous blends in unmodified diesel engines. Also, to provide common rail direct injection for the most efficient way of functioning of the diesel engine.

CHAPTER 4

MATERIALS AND METHODS

4.1. Methodology:

To manufacture the mixtures, ingredients such as alcohol, fuel, ATCC 616 medium salts, distilled water, and cotton seed oil are required. Algae are employed in this particular operation as the oil, much like how methanol is used as the process's alcohol. This chapter describes the specific supplies required, the techniques applied, the instrument specifications, operational concepts, and experimental procedures by which the research was carried out. Fig. 4.1 provides an illustration of the comprehensive experimental approach suggested for the study.

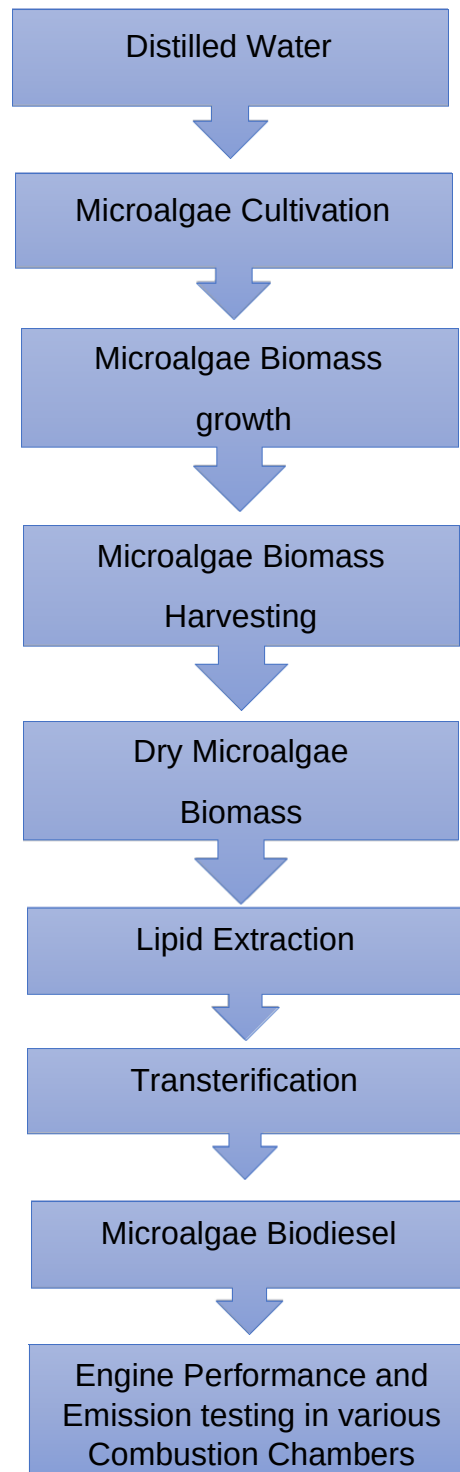


Fig. 4.1 FLOW CHART OF BIODIESEL PREPARATION

4.2 Algae Cultivation and Harvesting (Materials used):

Distilled water is combined in a proportional amount with ATCC medium 616 ions (American Type Culture Cultivation). After 30 minutes of heating, the medium-added water is transferred into a glass container for cooling. After cooling, the nano or chlorella particles are put to the medium with the added water. To produce microalgae, these spores are given to the substrate together with water. The farmed microalgae also develop into microalgae biomass.



Fig. 4.2 Microalgae Biomass Harvesting

4.2.1 ATCC MEDIUM 616:

The Salt Mixture used for producing Green Microalgae Cultivation is listed below in the given fig.4.3

American Type Culture Collection MEDIUM 616	TRACE METAL MIX
NaNO_3 (Sodium Nitrate)	H_2BO_3 (Dihydrogen borate)
K_2HPO_4 (Dipotassium phosphate)	$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ (Manganese chloride)
$\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (magnesium sulphate heptahydrate)	$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (Zinc sulfate heptahydrate)
$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (Calcium chloride dihydrate)	$\text{NaMoO}_4 \cdot 2\text{H}_2\text{O}$ (Sodium molybdate dihydrate)
Citric Acid	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (Copper Sulfate)
Ferric ammonium citrate	$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ (Cobalt nitrate hexahydrate)
EDTA (disodium salt) or edetic acid	Distilled water
Na_2CO_3 (sodium carbonate)	

Fig. 4.3 ATCC MEDIUM

4.2.2. Photobioreactor and its challenges:

Lack of in-depth knowledge of photobioreactor hydrodynamic and mass transfer processes is a major barrier to photobioreactor-based microalgal mass culture. Photobioreactors can be made of acrylic glass, can be flat or tubular, serpentine or manifold, and can be helical. The materials used to construct the flat-plate bioreactor are clear, flat, and very light-absorbing. High photosynthetic efficiency, algal immobilization appropriateness, high biomass output, ease of cleaning, flexibility, and little hydrodynamic stress on cells are all benefits. Tubular photobioreactors are made of glass or plastic tubes and can be horizontal, vertical, nearly horizontal, conical, or inclined. Algal cultures are re-circulated in these devices using a pump or an airlift system. In general, it is economical and perfect for outdoor settings with high biomass productivities. Photobioreactors with vertical columns are portable and easy to operate. Due to correct mixing, there is a high mass transfer of nutrients to cells. Additionally, there is a relatively high scalability, low shear stress, low energy consumption, sterilising capabilities of the chamber to prevent contamination, ease of tempering, and minimal photoinhibition and oxidation.

A photobioreactor is a particular kind of bioreactor that is used to grow phototrophs, like microalgae, in a closed system that forbids direct material contact between the culture and its surroundings. A photobioreactor (PBR) is any cultivation tool used to cultivate photoautotrophic organisms with the use of artificial or natural light to promote photosynthesis. As a result of the system's provision of a closed, strictly regulated environment for the culture's growth, the system generates a single strain, contamination-free microalgae culture. For two to three weeks, the microalgae were grown in the photobioreactor using artificial light and continuous air delivery.



Fig.4.4. Photobioreactor

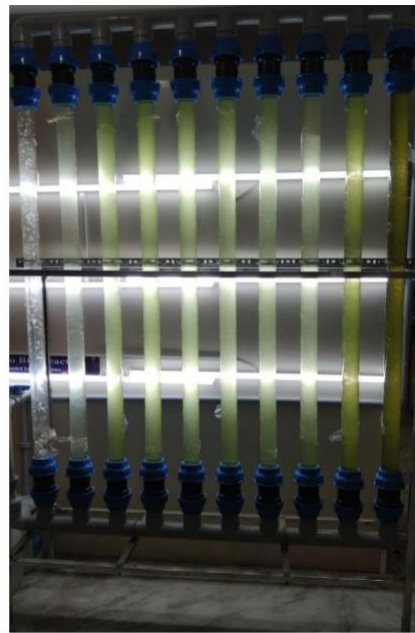


Fig. 4.5 Photobioreactor in algae growth

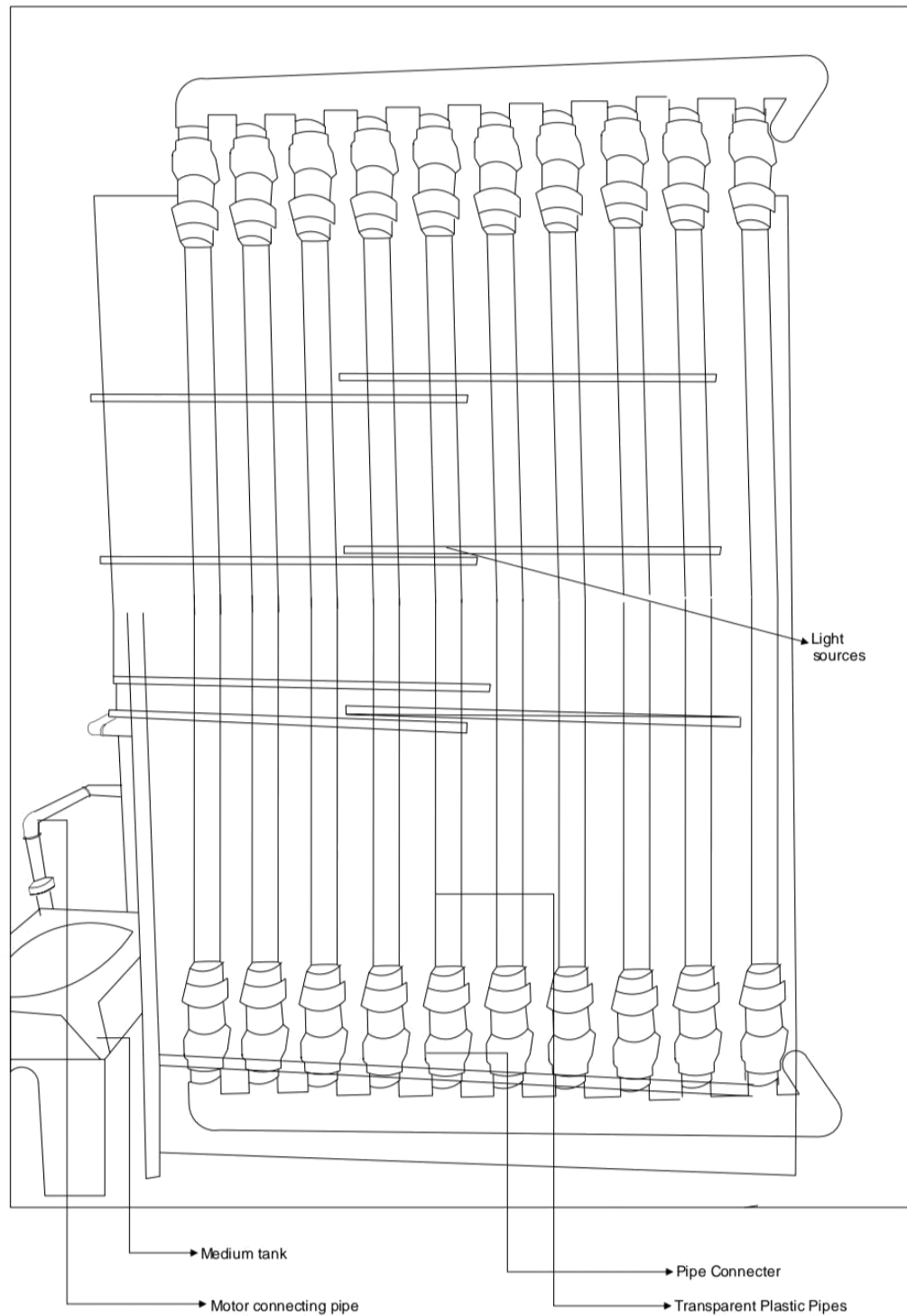


Fig 4.6 cad design photobioreactor

Microalgae are often produced under controlled circumstances in a closed vessel or chamber known as a photobioreactor. Transparent materials, like glass or plastic, are frequently used to create the chamber, allowing light to pass through and reach the microalgae inside. The light source can be adjusted to offer the ideal level of light for microalgae growth and can be either artificial or natural, like sunlight. In order to maintain adequate mixing and exposure to light, the microalgae are often cultured in a liquid media, such as water or a nutrient-rich solution, and are constantly stirred. To keep the microalgae growing in the best conditions possible, the temperature and pH of the medium are also adjusted.

The microalgae can be removed from the photobioreactor after they reach the proper growth stage and processed for use in a variety of processes. Numerous sectors, including those producing food and feed, cosmetics, biofuels, and medications, use microalgae. In conclusion, a photobioreactor is a crucial instrument for the development of microalgae and may be used to sustainably and environmentally-friendly produce high-quality biomass for a variety of applications.

4.2.3. FILTRATION:

The Cultivated Nano Chloropsis Micro Algae is further Filtered by means of filter paper. The filtered algae are allowed to get dry. Afterwards, they all have been scrapped from the filter paper for further process



Fig. 4.7 Filtered nano chlorosis

4.3 Lipid Extraction:

The technique of extracting lipids, or fats, from biological materials such as microalgae is known as lipid extraction. Lipids are essential because they can be turned into biodiesel, a renewable and environmentally friendly alternative to fossil fuels. Breaking apart the cells of the microalgae to release the lipids is the process of lipid extraction. This can be accomplished using a variety of techniques, including mechanical disruption, chemical extraction, or a combination of the two. After the lipids are removed, they can be converted into biodiesel via a transesterification step. This entails reacting the lipids with an alcohol and a catalyst to form fatty acid methyl esters (FAMES), the primary component of biodiesel. The extraction of lipids is an important stage in the synthesis of biodiesel from microalgae. The extraction process's efficiency can have an impact on the overall production of biodiesel, as well as the cost and sustainability of the process. As a result, optimizing the lipid extraction process is a critical topic of investigation in the field of microalgae biodiesel manufacturing. lipid extraction from wet algal biomass consists of disrupting/damaging the algal cell walls in the solution in which the microalgae were cultivated. These techniques can be grouped into organic solvent- based and solvent-free approaches.

Table 4.1 Extraction lipids process

Process	Method
Disrupt cell methods	Ultrasound High-pressure homogenization Pressing Ball mill Microwave Osmotic shock Enzymatic breakdown
Dry process	Solar drying Spray drying Freeze drying
Particle size reduction	Milling Pressing
Extraction lipids methods	Organic solvents Super critic fluid Sohxlet Disrupt cell methods using solvents
Removal of cellular debris	Filtration Centrifugation
Removal of solvents	Distillation Vacuum evaporation Adsorption column

4.3.1. Soxhlet process:

Soxhlet extraction is a popular technique for extracting lipids from a variety of biological materials, including microalgae. It makes use of a Soxhlet extractor, which is a specialized glassware device made up of a round-bottom flask, a thimble, a reflux condenser, and a heating mantle. In the instance of microalgae lipid extraction, the wet algal biomass is put in a thimble and then placed in the Soxhlet extractor. The round-bottom flask is filled with a solvent, such as chloroform, methanol, or hexane, and heated to boiling. The vapor of the solvent rises through the thimble, removes the lipids from the algal biomass, and condenses on the reflux condenser. The condensed solvent is then drained back into the round-bottom flask and heated again to repeat the extraction process.

This cycle of solvent extraction, condensation, and reboiling is repeated for many hours, or until the appropriate lipid extraction efficiency is obtained. Following the completion of the extraction, the solvent is evaporated to yield the crude lipid extract, which may subsequently be refined and converted into biodiesel. Soxhlet extraction is a dependable and efficient method for extracting lipids from microalgae biomass, although it is time-consuming and requires a substantial volume of solvent. As a result, researchers are investigating more efficient and ecologically friendly techniques of lipid extraction. Figure 4.7 is about The Soxhlet extraction method guarantees that the sample matrix is in close contact with the extraction solvent. This approach can be used to isolate and concentrate organics that are water-insoluble or somewhat water-soluble in preparation for a variety of chromatographic methods.



Fig. 4.8 Soxhlet extraction process

4.3.2. Distillation Process:

Distillation is a typical separation process for purifying liquids based on boiling point differences. Distillation is frequently used to purify crude biodiesel derived from the transesterification process in the context of biodiesel synthesis from microalgae. The crude biodiesel is often heated in a distillation column, which is a tall cylindrical cylinder with many trays or plates. The mixture is heated until it starts to boil, at which point the vapour rises through the column. The vapour cools and condenses on the trays as it rises, and is collected as a purer liquid. Fig 4.8 denotes Liquids having lower boiling points condense at higher levels in the column, whereas those with higher boiling points condense at lower levels. This enables for the separation of distinct components in crude biodiesel, such as glycerol, methanol, and unreacted fatty acids, which have different boiling points than the biodiesel itself. Distillation may be an effective method for purifying crude biodiesel and removing contaminants, but it is also energy-intensive and requires specialised equipment. Alternative purification technologies, including as membrane filtering and adsorption, have been examined as potential substitutes for distillation in biodiesel synthesis.

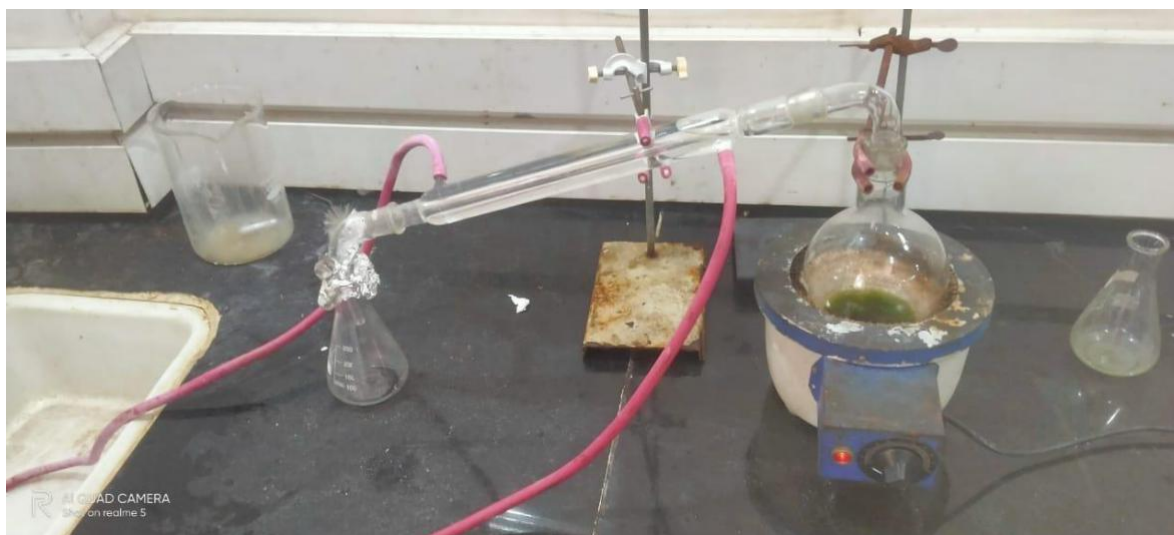


Fig. 4.9 Distillation process

4.4 Transterification:

Transesterification is a chemical process that is extensively used to produce biodiesel from a variety of feedstocks, including microalgae. It entails converting triglycerides, the major component of fats and oils, into fatty acid methyl esters (FAMES), the main component of biodiesel. The reaction of triglycerides with an alcohol, generally methanol, in the presence of a catalyst such as sodium or potassium hydroxide is known as transesterification. The reaction generates FAMES, glycerol, and a few additional byproducts. Typically, the reaction is carried out in a batch or continuous reactor vessel, with mixing to ensure that the reactants are thoroughly reacted. Temperature, pressure, catalyst concentration, and the molar ratio of alcohol to oil are all parameters that can impact the transesterification process. These variables can have an impact on the reaction rate, yield, and quality of the produced biodiesel. After the reaction is finished, the liquid is normally allowed to settle to allow the glycerol and other byproducts to separate from the biodiesel. The crude biodiesel is then refined further using methods such as washing, drying, and distillation to eliminate contaminants and increase the end product's quality. Transesterification of fats and oils is the most common process for creating methyl esters, according to the reaction at par. Triglycerides are transesterified batch-by-batch or continuously in multistep reactors with excess methanol and an alkaline catalyst like sodium methylate or potassium hydroxide at atmospheric pressure and a temperature of around 60-70°C. fig.4.9 reacts The mild reaction conditions need the removal of free fatty acids from the oil by refining or pre- esterification prior to transesterification in order to prevent the production of soap, which the alkaline catalyst encourages. The mixture is allowed time to settle when the reaction is finished. leading methyl ester. The bottom layer of glycerin is taken off after the top layer has been cleaned to eliminate any entrained glycerin. processed after that. The extra methanol is collected, purified, and recycled in a rectifying column. The same distillation equipment that was used for the fatty acid distillation may also be used to purify or fractionate the generated methyl esters into smaller slices or even individual components(Baskar et al. 2019).

4.4.1. Transesterification for Biodiesel Conversion

Transesterification is the chemical process through which vegetable oils, animal fats, and other feedstocks are converted into biodiesel. Triglycerides in the feedstock are reacted with an alcohol, often methanol or ethanol, in the presence of a catalyst such as sodium or potassium hydroxide. The transesterification procedure produces fatty acid methyl esters (FAMES), which are the primary components of biodiesel, as well as glycerol, a useful byproduct. Typically, the reaction is carried out in a batch or continuous reactor vessel, with mixing to ensure that the reactants are thoroughly reacted. Several parameters can impact the transesterification process, including the kind and concentration of catalyst employed, the molar ratio of alcohol to oil, reaction temperature and duration, and the presence of contaminants such as water or free fatty acids. Overall, transesterification is a crucial stage in the manufacture of biodiesel from a range of feedstocks, including microalgae, and optimizing it may have a substantial influence on the process's efficiency and costs.



Fig. 4.10 Transterification Process

4.5 Properties of biodiesel

Biodiesel is an environmentally friendly alternative fuel made from vegetable oils, animal fats, or recycled cooking oil. It has comparable qualities to petroleum-based diesel fuel, however there are notable distinctions due to its differing chemical makeup. Biodiesel has the following key properties:

Density: Because biodiesel has a lower density than petroleum fuel, the energy content per unit volume might be affected.

Viscosity: Because biodiesel has a higher viscosity than petroleum diesel, its flow via fuel injectors and pumps might be affected.

Flash point: Because biodiesel has a greater flash point than petroleum diesel, it is safer to handle and store.

Cetane number: Biodiesel has a higher cetane number than petroleum diesel, indicating that it has a better ignition and combustion quality.

Sulphur content: Biodiesel has almost little sulphur, which minimises sulphur oxide (SO_x) and particulate matter emissions.

Lubricity: Because biodiesel is more lubricious than petroleum diesel, it helps minimize engine wear and lengthen engine life.

Oxygen content: Because biodiesel contains more oxygen than petroleum diesel, it can enhance combustion efficiency and minimize carbon monoxide (CO) and unburned hydrocarbons (HC) emissions.

Cold flow qualities: Biodiesel has poor cold flow properties, which can cause it to thicken and form gels at low temperatures, resulting in fuel filter blockage and engine stalling.

4.5.1. Copper strip corrosion test

The copper strip corrosion test may also be used to assess the corrosiveness of biodiesel fuels to copper. Although biodiesel is known to be more lubricious than petroleum diesel, it may also include small levels of pollutants that may accelerate the corrosion of fuel system components.

The test is carried out in the same manner as for petroleum diesel fuels. A polished copper strip is submerged in a sample of biodiesel fuel at a certain temperature and time. The strip is next examined for apparent corrosion or discoloration. The copper strip corrosion test on biodiesel fuels is frequently performed using the ASTM D130 standard test technique. Biodiesel fuels that fulfil the ASTM D6751 biodiesel criteria may be needed to pass the copper strip corrosion test as well. To perform a copper strip test, a strip of copper is dipped into an algae biodiesel sample of interest at 60 degrees Celsius for three hours. The measured corrosive activity of the sample is then compared to a reference corrosion strip specified in the standard.

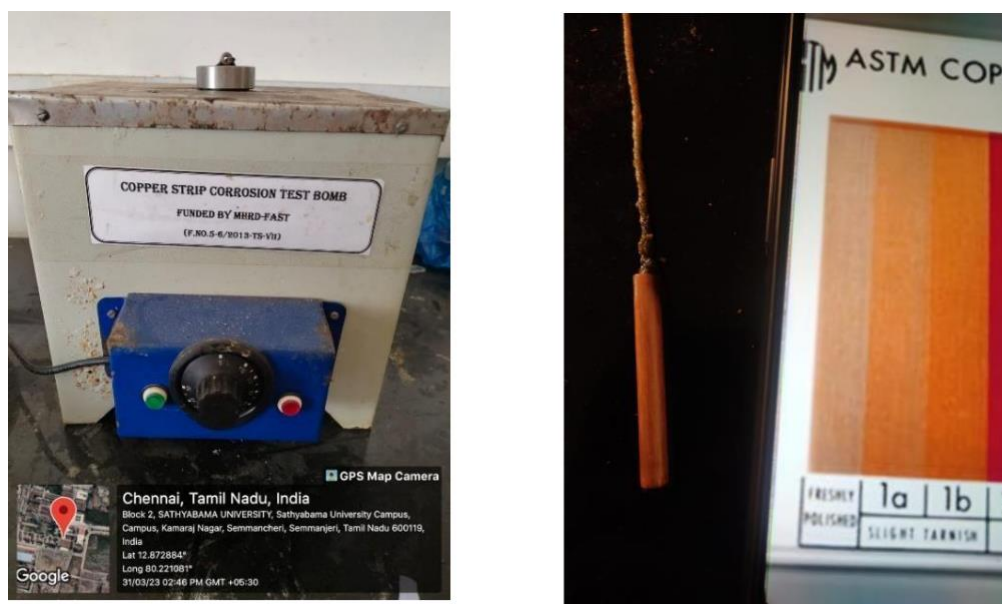


Fig. 4.11 Copper strip test

Corrosion Test: 1b

4.5.2. Moisture air content test

The moisture and air content test for biodiesel is a laboratory test used to assess the presence of moisture and air in biodiesel fuel. Water and air can be harmful to the performance and storage stability of biodiesel because they increase the development of microorganisms, induce fuel deterioration, and lower the fuel's energy content.

The test includes taking a tiny sample of biodiesel fuel and placing it in a test vessel with a defined volume. The sample is then heated to a given temperature and held at that temperature for a set period of time to allow any moisture or air to evaporate. The weight loss of the test vessel before and after heating is used to determine the moisture and air content of the biodiesel fuel. For evaluating the moisture and air content of biodiesel fuels, the ASTM D6304 standard test technique is often employed. The process entails heating the sample to 130°C for 1 hour to eliminate any moisture and air.



Fig. 4.12 Hot air oven

4.5.3. Kinematic viscometer bath

The kinematic viscometer bath is a laboratory apparatus for measuring the viscosity of liquids such as biodiesel fuels. Fuel viscosity is an essential feature since it influences the ability of the fuel to flow and lubricate engine components. The kinematic viscometer bath measures the time it takes a sample of biodiesel fuel to flow through a capillary tube at a certain temperature. The flow time is then used to compute the fuel's kinematic viscosity, which is represented in centistokes (cSt). Using a viscometer bath, the ASTM D445 standard test technique is routinely used to determine the kinematic viscosity of biodiesel fuels. The test technique calls for the use of a glass capillary viscometer and a temperature-controlled bath ranging from 40°C to 100°C.

The kinematic viscometer bath is a crucial tool for ensuring biodiesel fuel purity and performance. It is extensively used in fuel testing facilities and by biodiesel manufacturers to guarantee that their products fulfil the necessary regulations and standards. Kinematic viscosity is an important component in determining the flow resistance of oils.



Fig. 4.13 Kinematic viscometer bath

Viscosity = Time in seconds*0.014

=339*0.014

= 4.746(cSt)

Specific gravity = Sample weight/25

= 36.63 - 15.32/25

= 21.27/25

= 0.8508 kg/m³

4.5.4. Calorimeter test

The calorimeter test is a laboratory method for determining the heat of combustion of a fuel, such as biodiesel. The heat of combustion is a measure of the fuel's energy content and an important parameter for evaluating the fuel's performance in combustion applications. In the calorimeter test, a tiny sample of fuel is burned in a controlled setting and the heat emitted during the combustion process is measured. The heat emitted is measured with a calorimeter, which can be adiabatic or isoperibolic. The adiabatic calorimeter is a closed device that burns the sample in an oxygen environment and measures the temperature rise caused by the combustion. The isoperibolic calorimeter is an open system in which the sample is burnt in an oxygen environment and the heat emitted is transmitted to a water bath around it. The heat emitted during combustion is then calculated by measuring the change in temperature of the water bath. The calorimeter test findings are used to determine the calorific value of the biodiesel fuel, which is stated in joules per gramme (J/g) or British thermal units per pound (BTU/lb). The calorific value of a fuel is a measure of its energy content, and It is used to evaluate the performance of fuel in combustion applications. A calorimeter is a measuring instrument for thermal movement. A calorimeter is a device that detects heat flow during a chemical or physical change. For the first seven minutes, we calibrated the material using a calorimeter test. Then press the red button. After 22 minutes, the final result of the calorimeter test is =2.55.



Fig. 4.14 Calorimeter

4.6 PREPARING FUEL BLENDS:

Because pure diesel emits more pollutants and is a non-renewable non-biodegradable fossil fuel. The transesterification method is used to produce alternative microalgae oil, but this biodiesel cannot be used directly in a compression ignition engine. As a result, biodiesel is mixed with cotton seed oil and gasoline. As a result, the diesel is obtained from the fuel station. Cotton seed oil was purchased from an oil store in Chennai. 1500ml of three mixes are made by combining diesel (80%), microalgae oil, and cotton seed oil biofuel (20%). The components are weighed in a measuring jar, and the blends are made in a bottle using a funnel.

Table 4.2 Properties of blends

PROPERTIES	B20
DENSITY (kg / m ³)	873
Kinematic viscosity	4.746
Specific Gravity	0.8508
Calorific value (kJ/kg)	40100
Calorific value (cal/g)	9,570.40

4.7 ENGINE TESTING AND ANALYSIS:

The engine study is carried out in a single cylinder, four stroke diesel engine that is loaded using an eddy current type dynamometer. The required tools are supplied for measuring combustion pressure and crank angle.

4.7.1 ENGINE DETAILS:

The engine specs utilized to conduct the different tests are listed in the table.

Table 4.3 Engine Specifications

Engine Model	Kirloskar TV1
No of Cylinder	1
No of Strokes	4
Cubic Capacity (liter)	0.661
Rated Speed (rpm)	1500
Power	5.20KW
Power Rating	7 hp
Cylinder Bore(mm)	87.50
Stroke Length(mm)	110.00
Connecting rod length(mm)	234
Compression ratio	17.50
Swept volume	661.45cc
Cooling type	Water cooled
Over all dimensions	Width 2000*length2500*height1500mm.
Dynamometer	Eddy current type water cooled
Software	Engine Soft

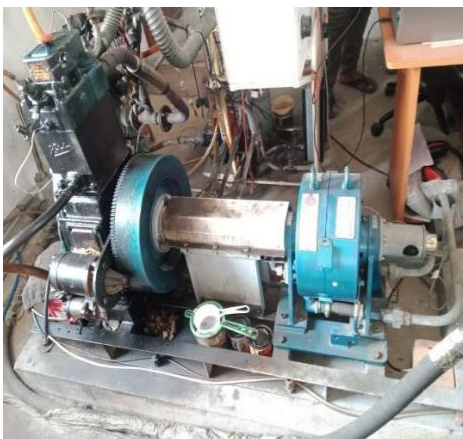


Fig 4.15. Engine front view



Fig 4.16. Engine back view

CHAPTER 5

RESULTS

After preparing four test batches with different mixes. The samples are added one at a time to the fuel tank while the engine is running. Efficiency and different emission performance metrics are measured by altering the loads.

5.1 PERFORMANCE GRAPHS

5.1.1 Brake Thermal Efficiency

The engine's temperature and the applied load both affect Brake Thermal Efficiency. The performance of the engine is enhanced by an increase in affect Brake Thermal Efficiency. It is the most crucial factor to consider when assessing the engine's efficiency.

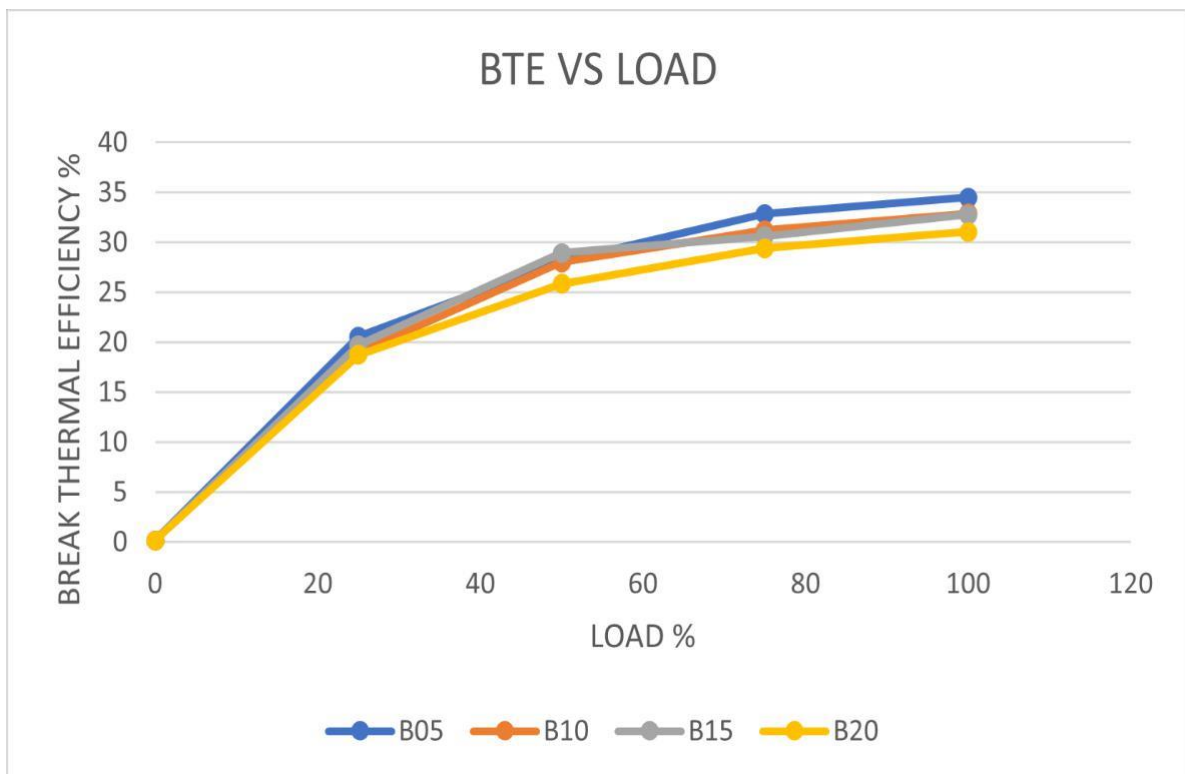


Fig. 5.1 BTE vs Load

In every case when there is a mixture of fuels, the brake thermal efficiency (BTE) decreases as the load rises. However, the heat loss diminishes as the load rises. As the ester concentration in the mixture rises, the engine's BTE will get better. The graph shows that Blend 3 has the highest BTE, followed by Blend 4 and Blend 2. Contrarily, Blend 1 exhibits the lowest BTE because of its low concentration of bioethanol and low boiling point. Because Blend 3 contains about equal proportions of biodiesel and bioethanol, it has a higher BTE.

5.1.2 Volumetric efficiency

The volumetric efficiency is a measure of how well gas is compressed in a compressor cylinder. It can be described as the piston displacement divided by the volume of gas actually delivered, with suction temperature and pressure taken into account.

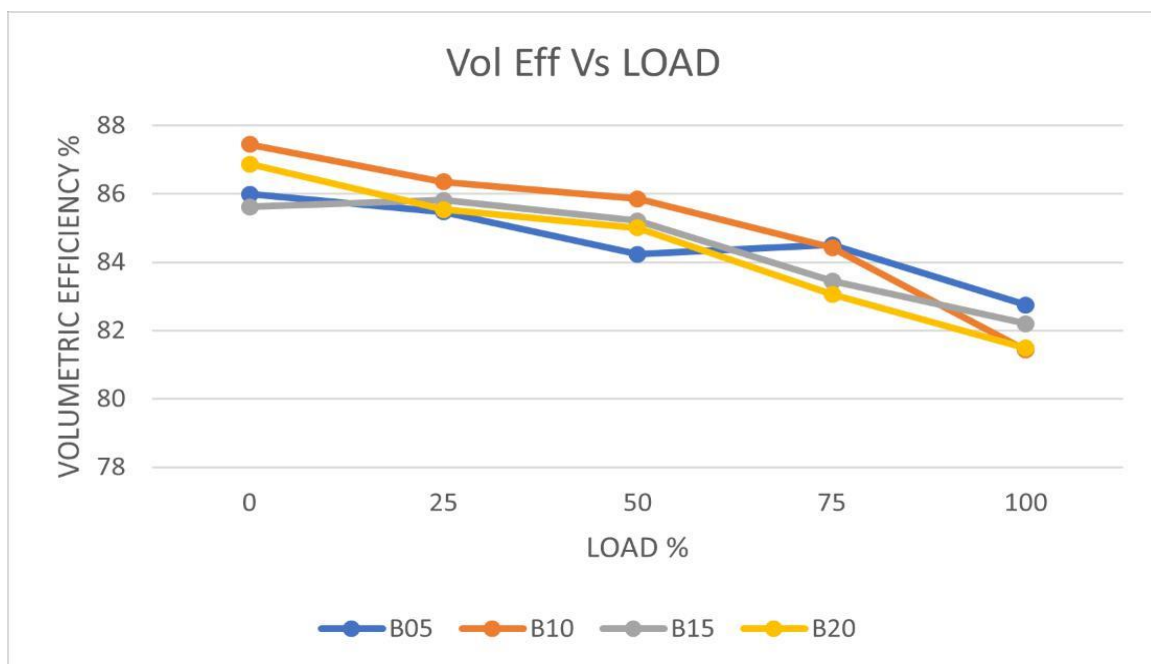


Fig.5.2 VE vs load

It is obvious from the graph that Blends 2 and 3 have the highest volumetric efficiency. The volumetric efficiency of these blends, however, decreases significantly as the load is raised. The volumetric efficiency of Blend 4 is constant between 50% and 75% loading. Blend 1 exhibits nearly comparable volumetric

efficiency at 25%, 50%, and 75% loading, but it has the lowest volumetric efficiency overall.

5.1.3 Exhaust gas temperature

The temperature of the turbine exhaust gases as they exit the turbine unit is known as the exhaust gas temperature (EGT), sometimes known as the turbine outlet temperature (TOT), in a turbine engine. Numerous thermocouples installed in the exhaust stream measure the gas temperature, which is then shown on a flight deck gauge in either degrees Fahrenheit or degrees Celsius. EGT is a measurement of the temperature of the exhaust gases at the exhaust manifold of a piston engine. The temperature of the exhaust gas can be used as a foundation for controlling the fuel/air combination entering the engine because it fluctuates with the ratio of fuel to air entering the cylinders.

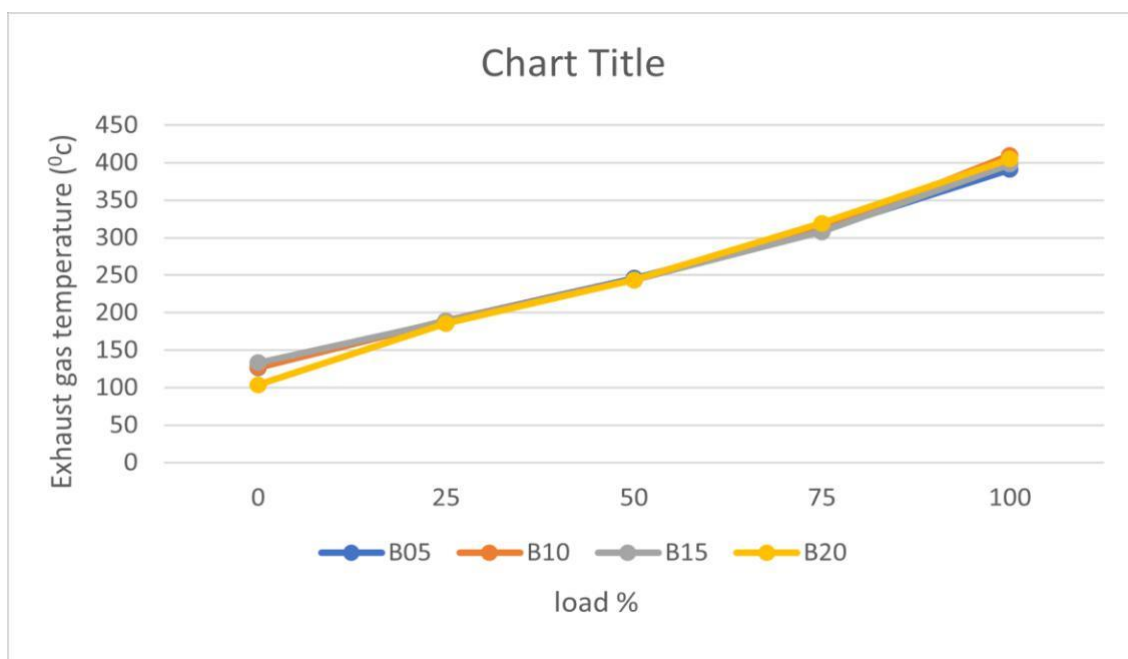


Fig.5.3 EGT vs load

At maximum load, blend 1 has the highest EGT compared to the other blends, and blend 4 has the lowest EGT, as seen in the graph, which shows that as load increases, EGT increases.

5.1.4 Specific fuel consumption

The quantity of fuel used for each unit of thrust produced by an engine is its specific fuel consumption. The particular fuel consumption per kilometer driven fell by more than 30% as a result of improvements in fuel efficiency.

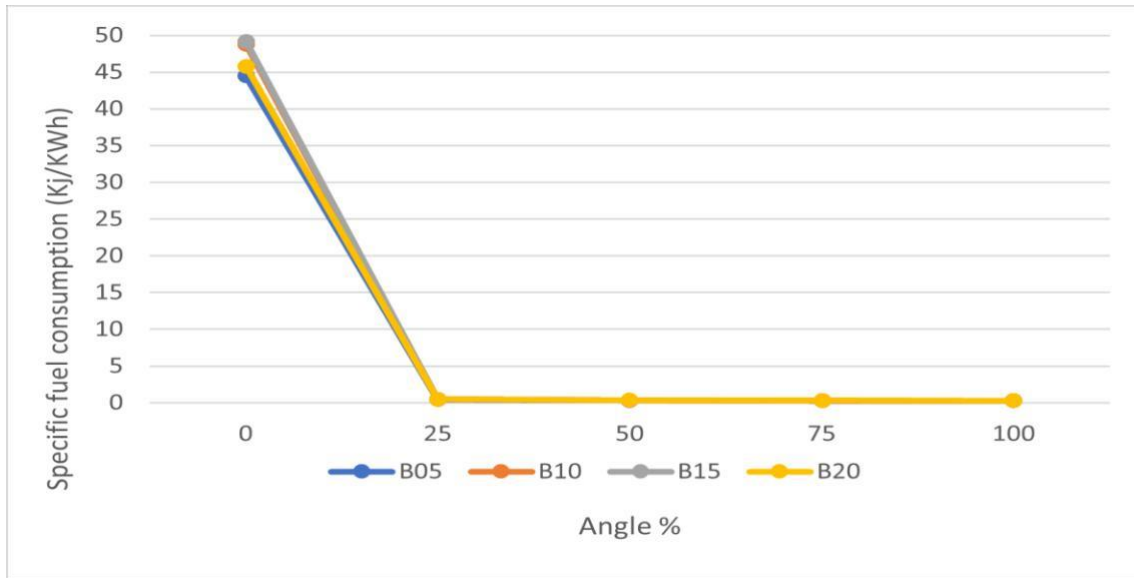


Fig.5.4 SFC vs angle

5.2 EMISSION CHARACTERISTICS

5.2.1 Carbon monoxide

When inhaled in significant amounts, the colourless and odourless gas carbon monoxide (CO) can be very dangerous. All living things may suffer great harm as a result of it. Any item that burns outdoors will release carbon monoxide (CO). Fossil fuel burning and automobile exhaust are the main sources of CO emissions.

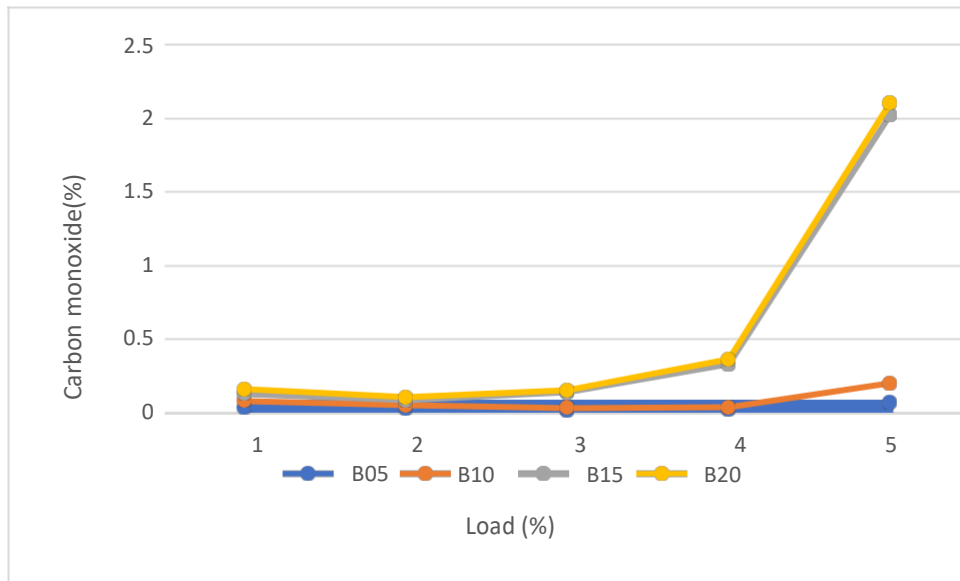


Fig 5.5 CO vs load

In this graph, blend 3 has the lowest CO emission, while blend 4 is roughly the same for all loads except for 100% load. Blend 1 has the largest CO emission at full load, but after that it emits as little CO as diesel.

5.2.2 Carbon Dioxide

CO₂ emissions show that the air and fuel mixture was entirely burnt, proving that there was enough oxygen in the chamber to ignite the fuel injected there. Along with other exhaust gases, CO₂, a primary greenhouse gas, is released into the atmosphere. Its effect on the atmosphere is minimal because plants need CO₂ to grow. However, the main cause of climate change is CO₂ emissions. It is generally accepted that cutting emissions as soon as feasible is essential to preventing the worst effects of climate change. The graph shows that blend4 emits the fewest pollutants at the highest load, all blends emit the fewest pollutants at the lowest load, and mix 1 emits the most pollutants at the lowest load.

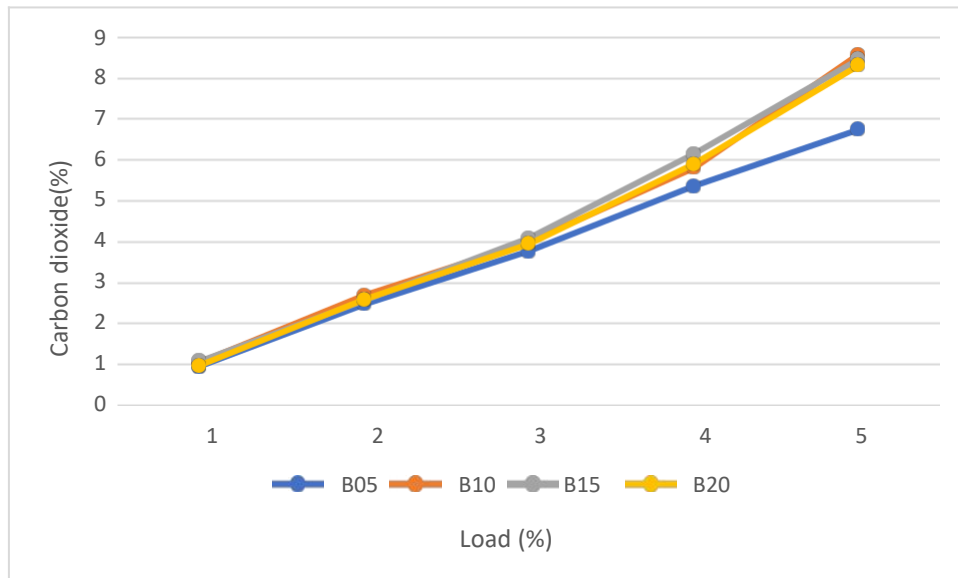


Fig 5.6 CO₂ vs load

5.2.3 Nitrogen Oxide

When fuels are burned at high temperatures, harmful chemicals called nitrogen oxides (NO_x) are created. When fuel is burned, several gases are created, and NO_x is one of them. Numerous types of vehicles, including cars, trucks, and off-road machinery like boats and construction equipment, produce NO_x pollution. NO_x frequently has a brown appearance. Blend 1 has the most NO_x emission in this graph at 100% load compared to other loads, whereas Blend 4 has the lowest NO_x emission at the lowest load.

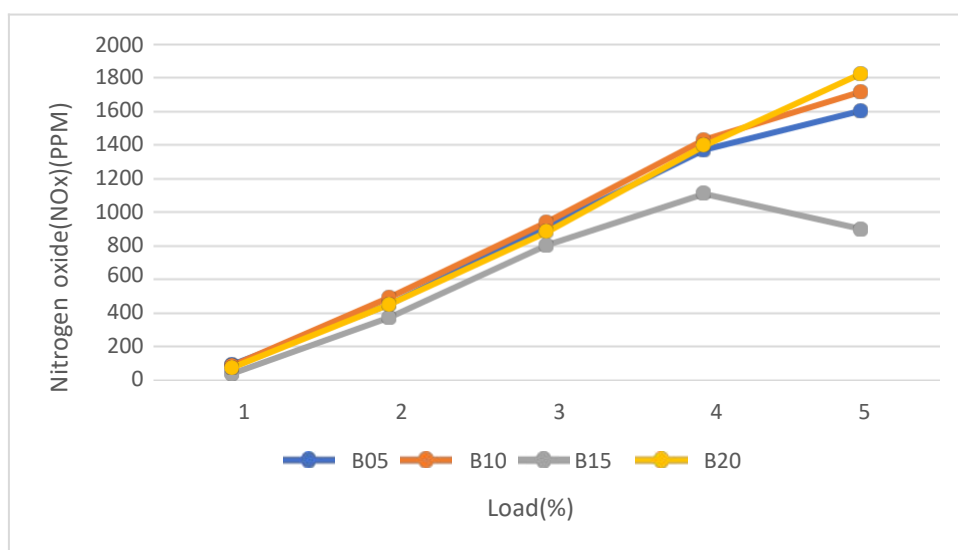


Fig 5.7 NO_x vs load

5.2.4 Hydrocarbon Emission

The main cause of the issue is insufficient fuel combustion in the combustion chamber. Unburned fuel is thus discharged directly into the exhaust system as a result. Compression can be reduced as a result of ignition issues or internal engine faults, which makes the situation worse. Large volumes of hydrocarbons (HC) are released into the atmosphere as a result of improper fuel ignition.

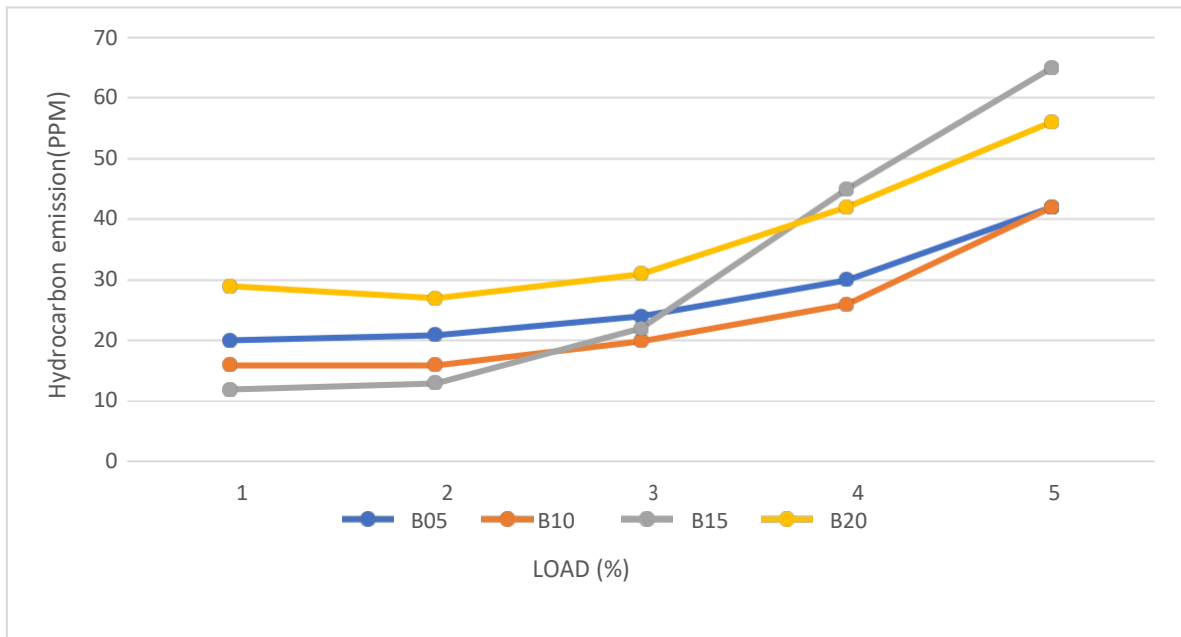


Fig 5.8 HC vs load

According to the graph, blend 4 emits the most HC at maximum load, whereas blend 2 emits the least at maximum load. Blends 1 and 2 emit the most and the least under zero load, respectively.

5.2.5 Smoke Opacity

It is a kind of emission particle that develops when petrol deposits on the cylinder walls of an engine. The gasoline residue that builds up on the cylinder walls of internal combustion engines affects the smoke's transparency. The level of emissions may be measured more easily as a result.

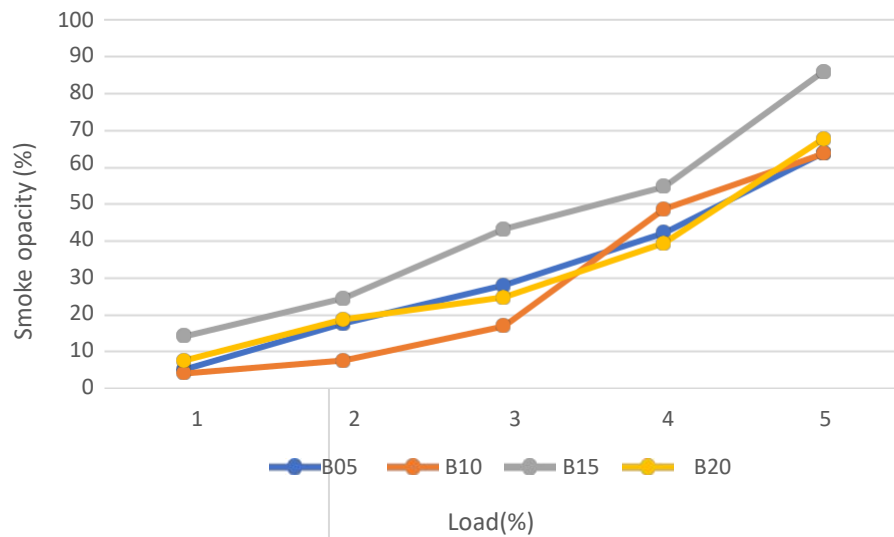


Fig 5.9 SO vs Load

According to the graph, blend 4 has the highest opacity at maximum load, which is hazardous to health. Comparing Blend 4 to other blends, Blend 4 has demonstrated a notable rise at 50%load. The smoke opacity of Blend 1 is the lowest at both 0% and 100% loading.

5.3 Combustion graphs

Therefore, it is clear that the relationship between cylindrical pressure and crank angle increases is inverse.

5.3.1Crank angle vs Cylinder pressure

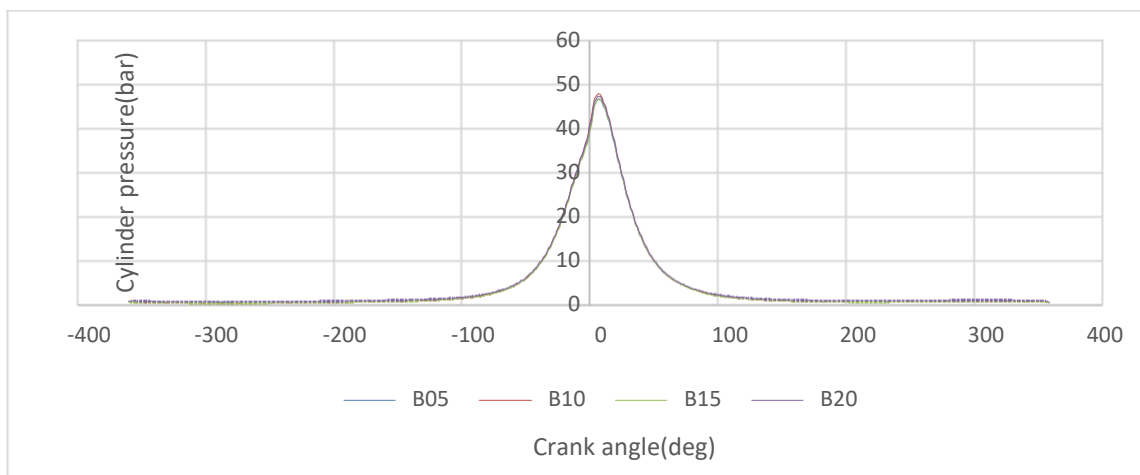


Fig.5.10 Cylinder pressure vs crank angle at 0% load

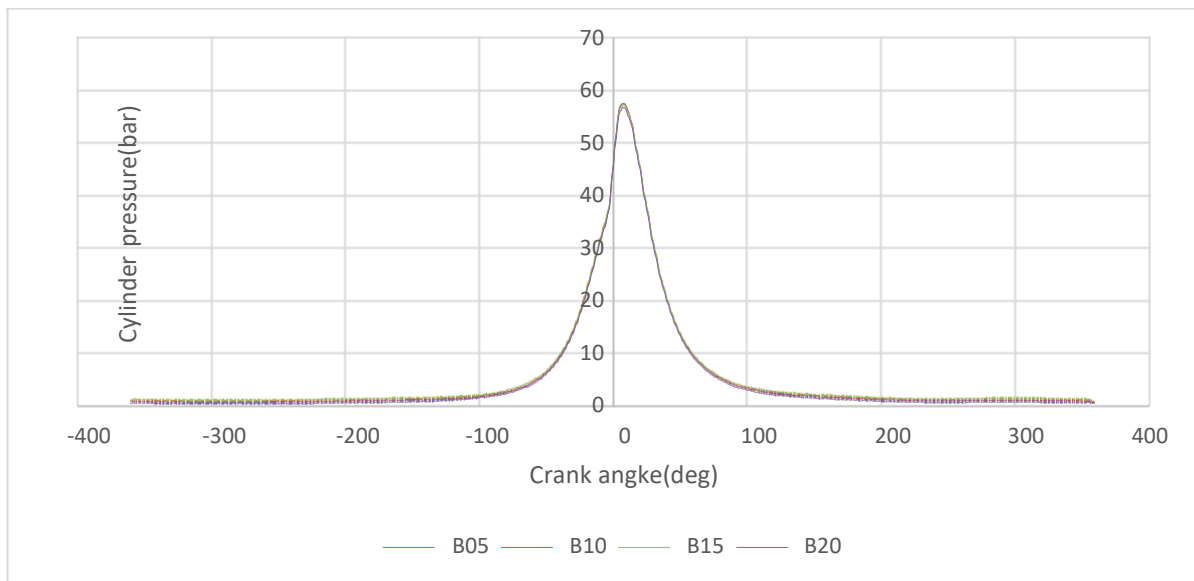


Fig. 5.13 Cylinder pressure vs crank angle at 25%

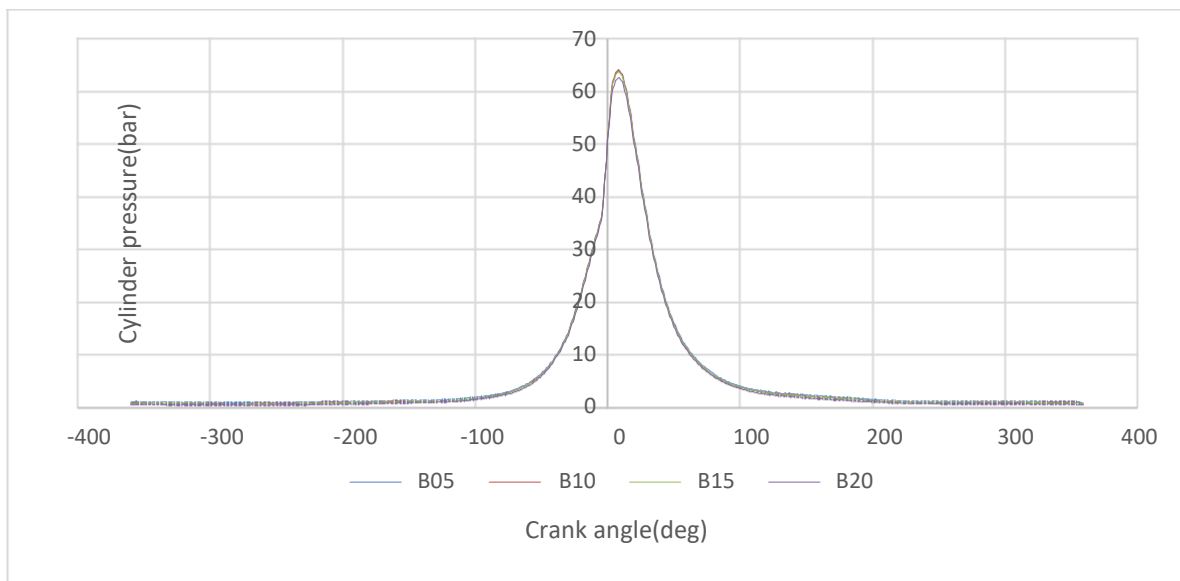


Fig. 5.14 Cylinder pressure vs crank angle at 50%

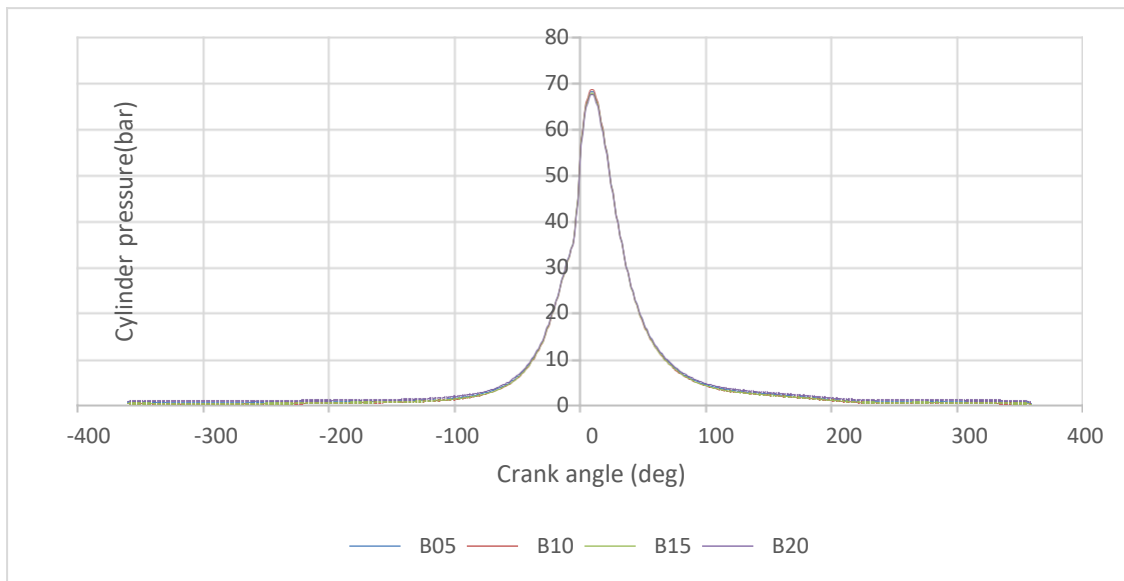


Fig. 5.14 Cylinder pressure vs crank angle at 75%

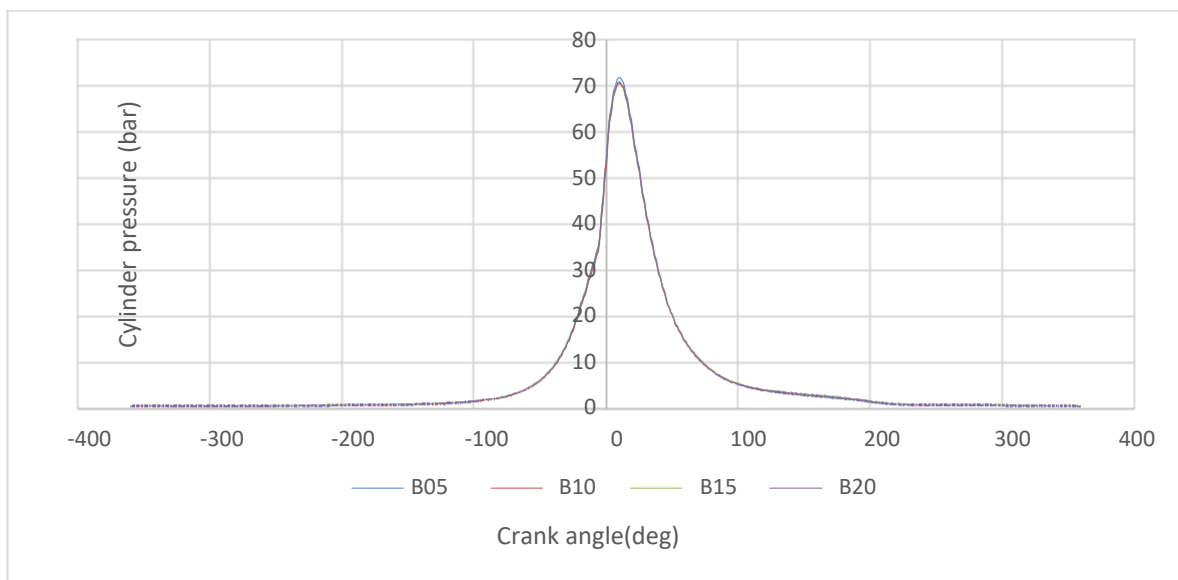


Fig. 5.14 Cylinder pressure vs crank angle at 100%

Table 5.1 Cylinder Pressure Graph Readings

S. no.	Load	Minimum CP	Maximum CP
1	0%	B05	B20
2	25%	B05	B20
3	50%	B05	B20
4	75%	B05	B20
5	100%	B05	B20

We can observe that B20 has maximum load at all loads. B05 and B10 has shown low Cylinder Pressure comparably with other blends B10 Bioethanol has shown significant Cylinder Pressure at all loads variably.

5.3.1 Crank angle vs Net heat release rate

The crank angle affects net heat rate. The following graphs show blend deviations at -100 and -10.

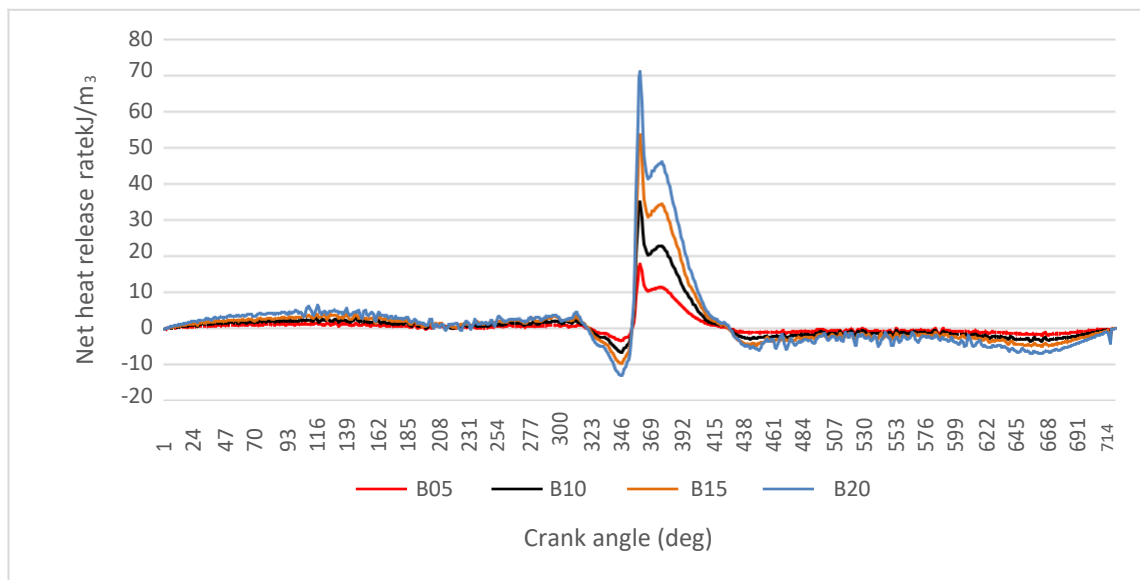


Fig 5.15 Net HR($dQ_n/d\phi$) vs crank angle at 0%

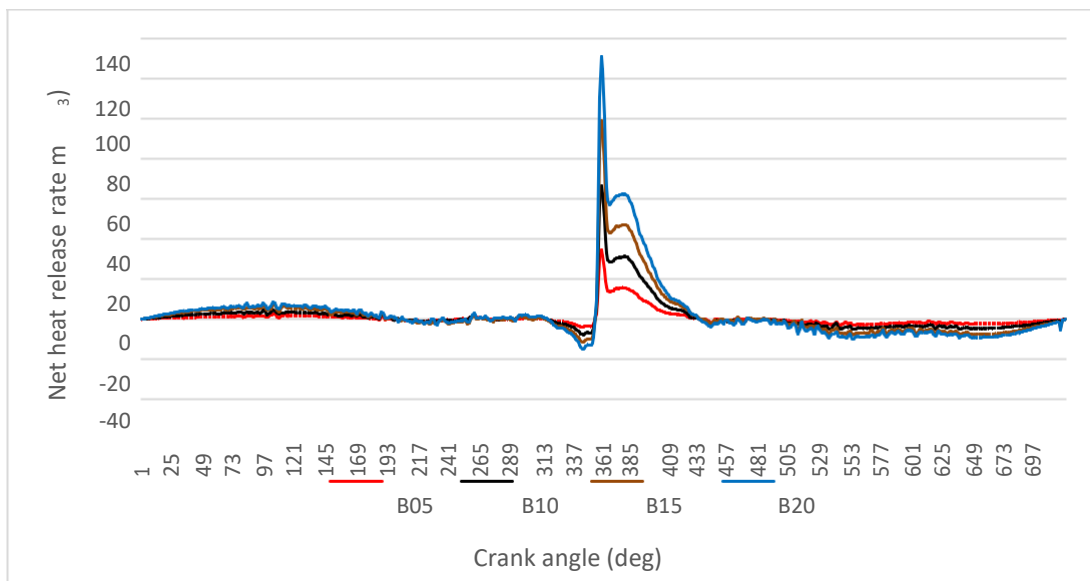


Fig 5.16 Net HR(dQn/dq) vs crank angle at 25%

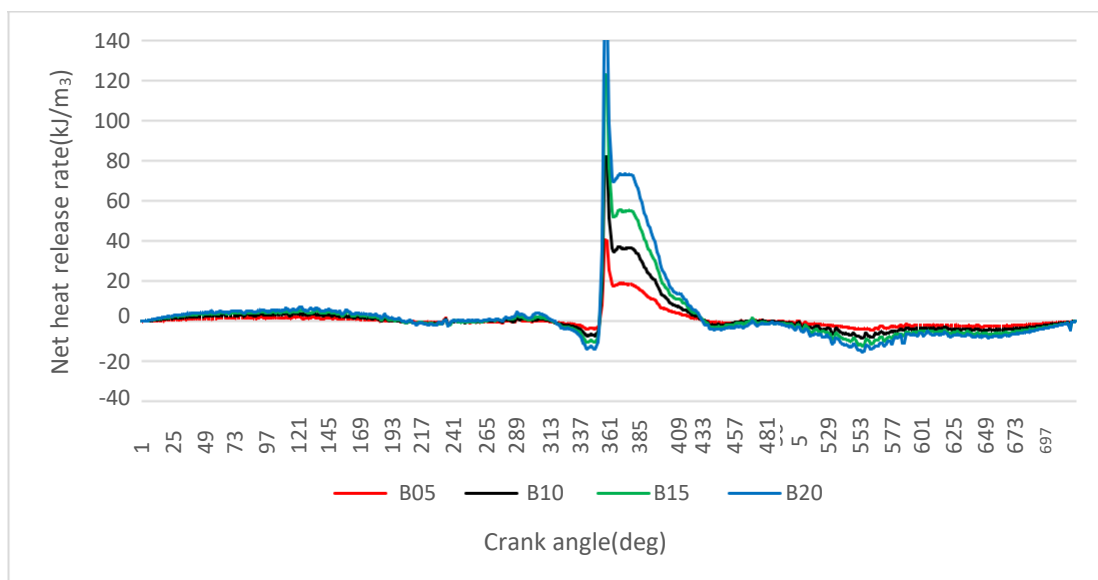


Fig 5.17 Net HR(dQn/dq) vs crank angle at 50%

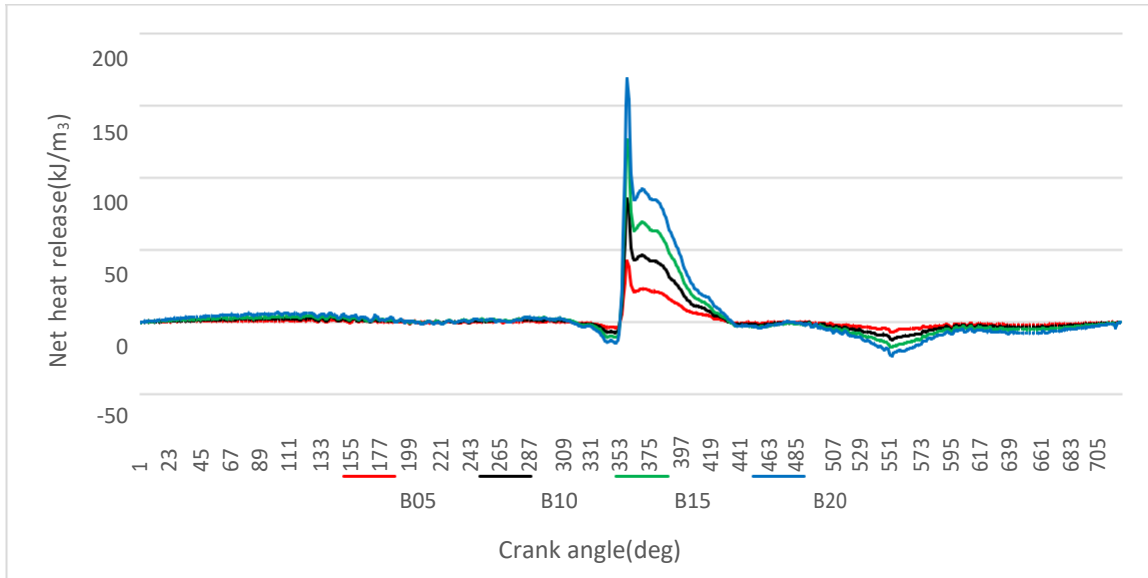


Fig 5.18 Net HR(dQn/dq) vs crank angle at 75%

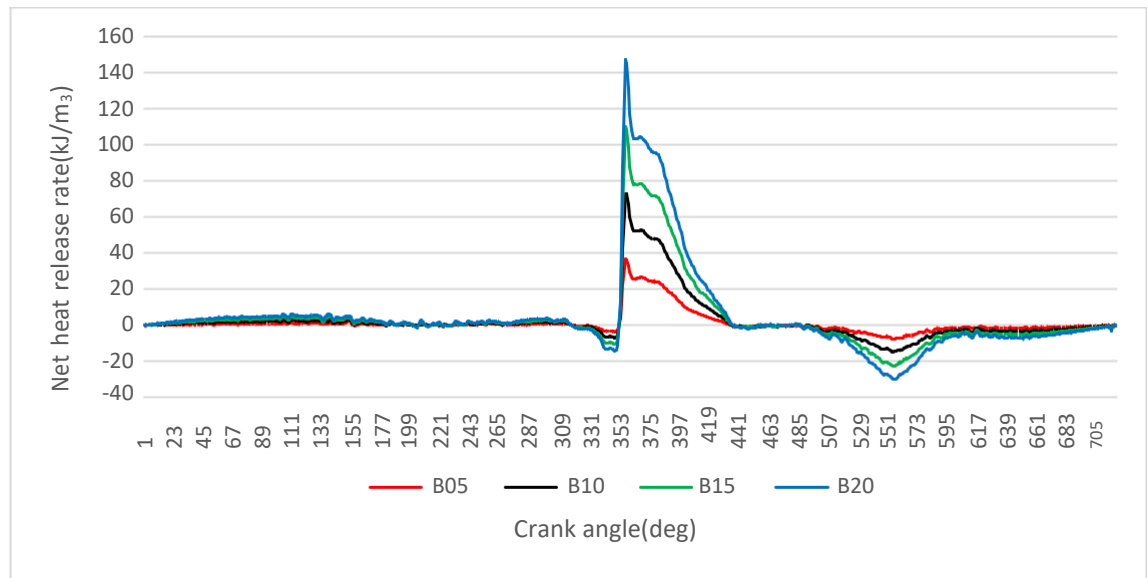


Fig 5.19 Net HR(dQn/dq) vs crank angle at 100%

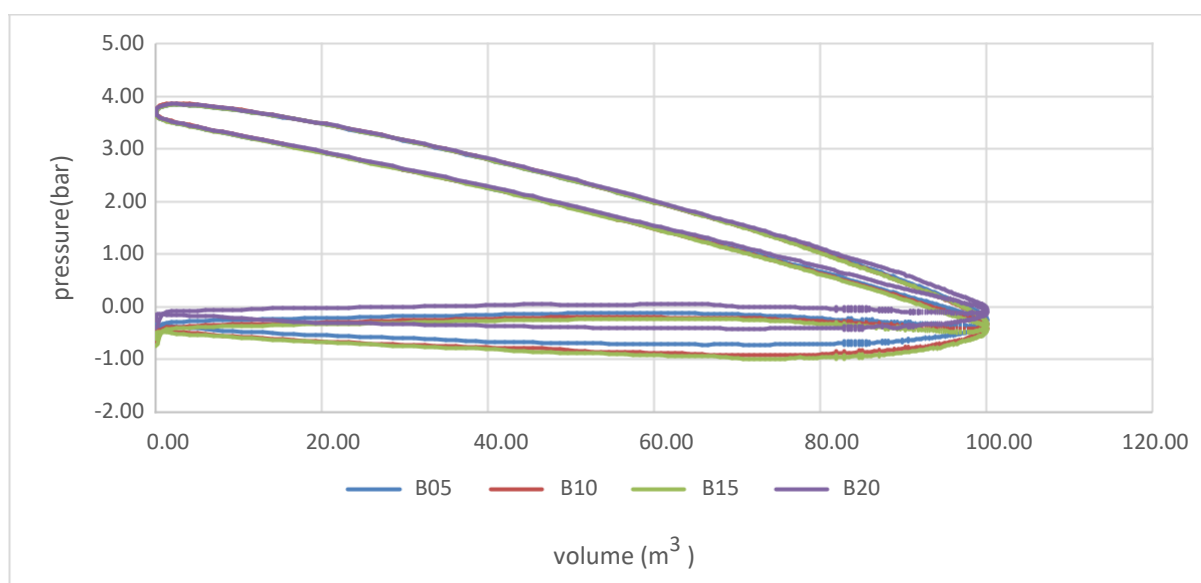
Table 5.2 Net Heat Release Rate Readings

S. no.	load	Minimum NHR	Maximum NHR
1	0%	B05	B20
2	25%	B05	B20
3	50%	B05	B20
4	75%	B05	B20
5	100%	B05	B20

We can observe that B20 has maximum load at all loads. B05 and B10 has shown low NHR comparably with other blends. B05 Bioethanol has shown significant NHR at all loads variably.

5.3.2 Pressure vs volume

Blends have a constant volume, but when a load is applied, a variation in pressure is seen.

**Fig. 5.20 Pressure vs volume at 0% load**

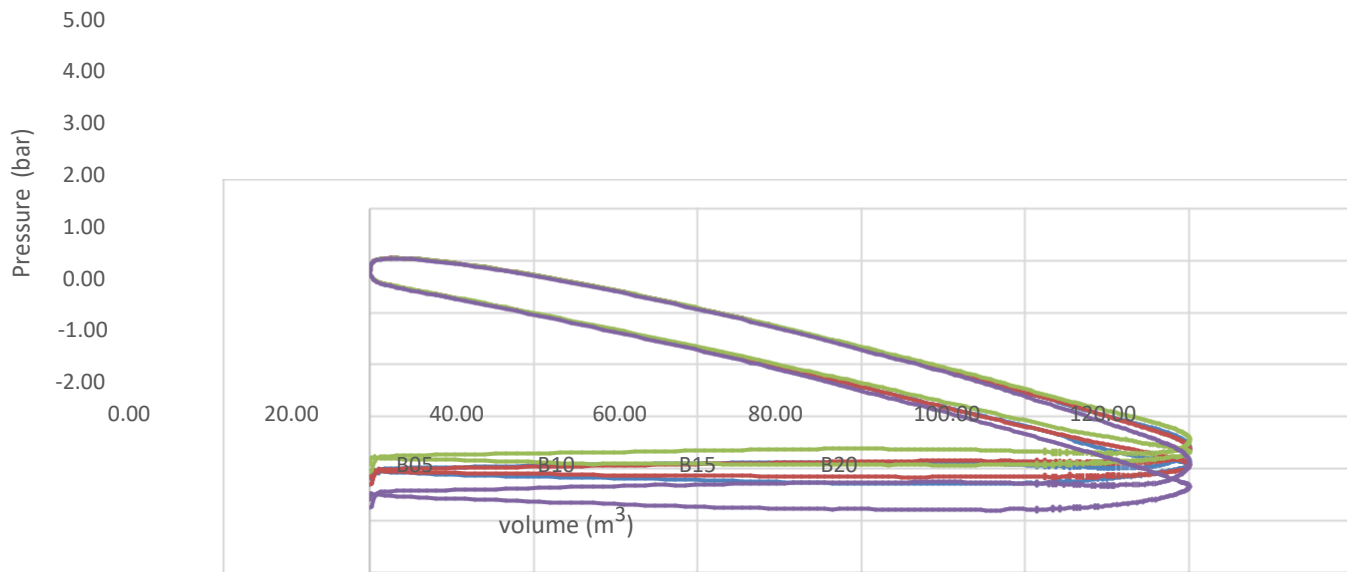


Fig. 5.21 Pressure vs volume at 25% load

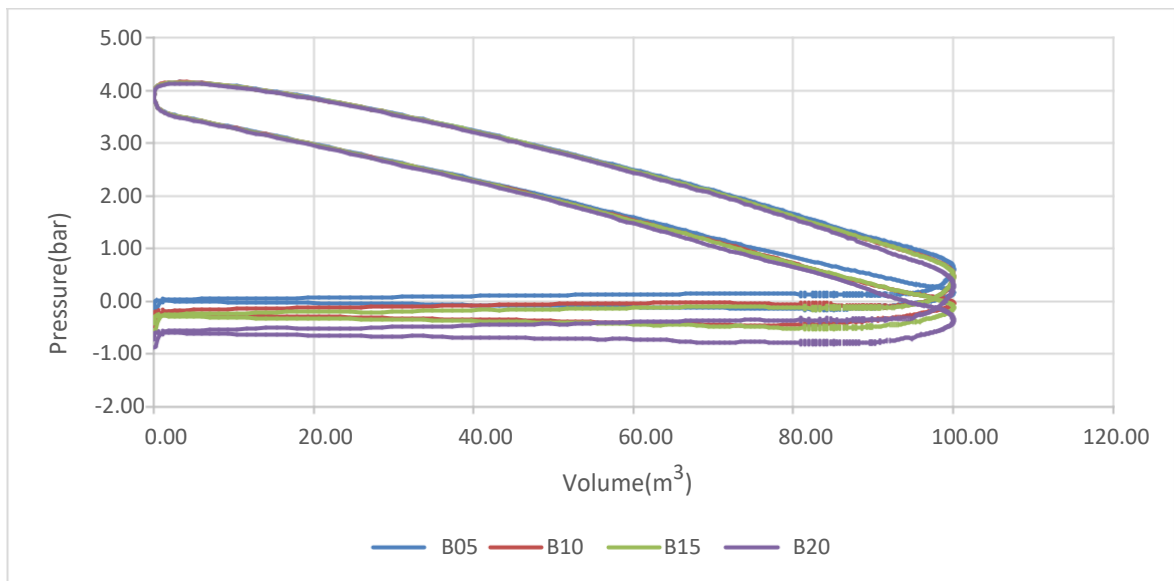


Fig. 5.22 Pressure vs volume at 50% load

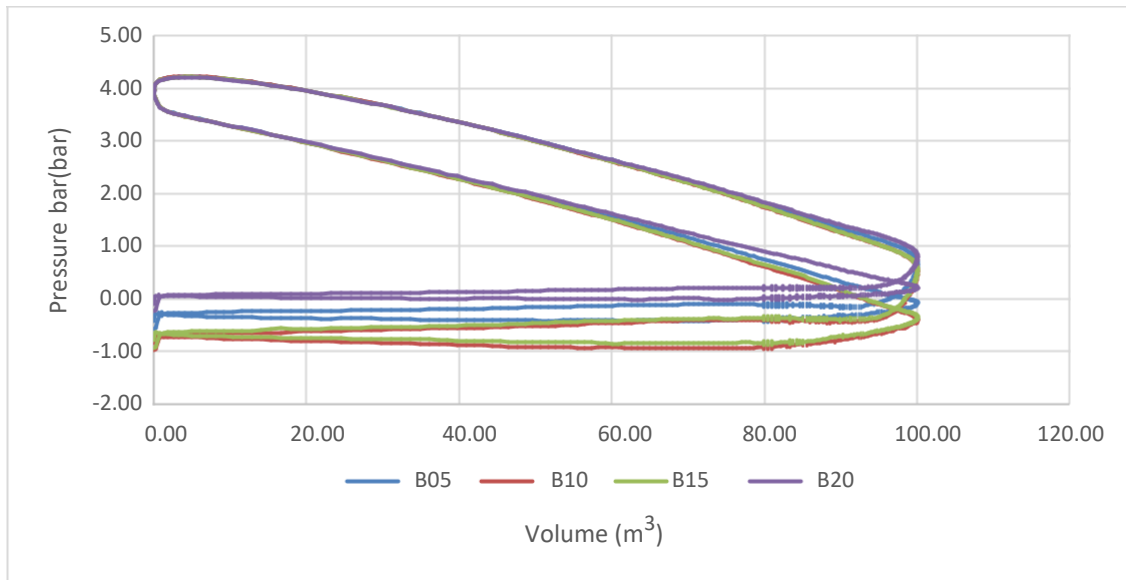


Fig. 5.23 Pressure vs volume at 75% load

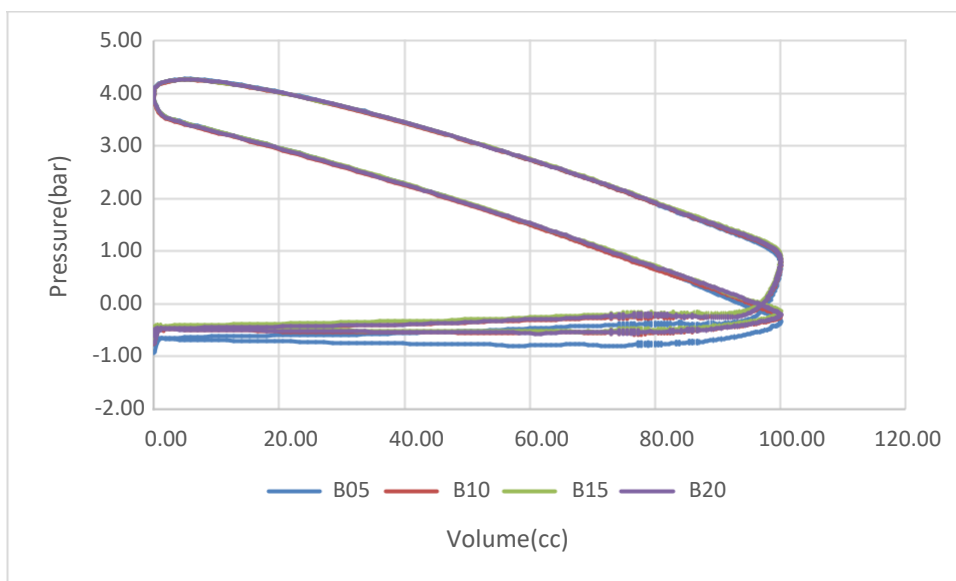


Fig. 5.24 Pressure vs volume at 100% load

Table 5.3 Pressure Graph Readings

S. no.	Load	Minimum pressure	Maximum pressure
1	0%	B15	B20
2	25%	B20	B15
3	50%	B20	B05
4	75%	B15	B20
5	100%	B05	B20

At the load of 0%, 75% and 100% we can observe that the blend B20 is generating maximum pressure. At the load of 25% we can observe that B15 generates maximum pressure. At the load of 50% we can observe that B05 generates maximum pressure compared to other blends. B10 Bioethanol has shown significant pressure at all loads variably.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The Transesterification Process for Micro Algae is done successfully and converted into Methyl Ester. Four Biodiesel samples have been prepared with proper ratios. The four biodiesel samples are tested in Diesel Engine at various loads. The cylinder pressure is less than 100 bar in B05 blend, which results in abnormal combustion. B10 blend generates a pressure of 100 bar with nearby tolerance. Net heat rate is low in B05 blend followed by B10 blend. B10 blend gives significant pressure variation. The emission graph shows that the CO emission is less in B05 blend followed by B10 blend. CO₂ emission is less in B05 blend followed by B20 blend. NO_x emission is less in B15 blend and all the other blends produce high NO_x emission respectively. HC emission is less in B10 blend followed by B05 blend at higher loads. Smoke opacity is less in B10 blend. The Brake Thermal Efficiency is high in B05 blend followed by B10 blend. The volumetric efficiency for B10 blend is high in lower loads and less in higher loads. The Specific Fuel Consumption is low in B05 blend followed by B20 blend. The temperature of the exhaust gas is low in B05 blend followed by B15 blend. Overall analysis shows that the B10 blend is more efficient than other biodiesel blends. It gives a overall better emission characteristics, better fuel economy and better efficiency.

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