

**PRODUCTION OF BIODIESEL AND BIOETHANOL HIGH
PERFORMANCE BLEND FOR 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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(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of M.PRAVEEN REDDY (Reg.No- 39150079) who carried out the project entitled "PRODUCTION OF BIODIESEL AND BIOETHANOL HIGH PERFORMANCE BLEND FOR ENGINE STUDIES" under our supervision.

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ABSTRACT

The creation and assessment of a high-performance biodiesel and bioethanol blend for use as an alternative fuel in diesel engines are the main goals of this research. The mixture will be made using transesterification and fermentation processes, and its potential as a sustainable and renewable fuel source will be evaluated. In addition, the blend's physicochemical characteristics, including viscosity, density, and flash point, will be examined, and its emissions will be contrasted with those of petroleum diesel.

This initiative's study adds to the increasing body of knowledge on alternative fuels, their potential to lessen reliance on fossil fuels, and how to limit their environmental effects. The findings of this study will provide important light on the potential of biodiesel and bioethanol blends as a source of transportation fuel and may influence future regulations pertaining to sustainable mobility. In the end, the project's discoveries will contribute to the creation of environmentally friendly transportation fuels that can lower greenhouse gas emissions and boost energy security.

This system's significance stems from the urgent need to solve the environmental, economic, and geopolitical problems caused by dependency on fossil fuels. Due to their renewability, biodegradability, and potential to lower greenhouse gas emissions, biodiesel and bioethanol blends have become a promising alternative fuel source. The project's goal is to help create a more environmentally friendly transportation system where the negative consequences of using fossil fuels may be lessened by using alternative fuels. It's a good idea to have a backup plan in case something goes wrong.

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CHAPTER 1

INTRODUCTION

Over the years, the world's dependency on fossil fuels has caused significant challenges such as environmental degradation, economic instability, energy insecurity, and fluctuating fuel prices. As a result, there has been growing interest in alternative fuels such as biodiesel and bioethanol due to their renewability, environmental sustainability, and potential to reduce greenhouse gas emissions. Due to the damaging effects of fossil fuels on the environment and their scarcity, interest in renewable and sustainable energy sources has increased recently. Among the many renewable energy sources, biodiesel and bioethanol have emerged as viable biofuels that are the subject of extensive research into their manufacturing procedures, characteristics, and possible applications. (Raj et al., 2022; Sharma & Singh, 2009)

Using a procedure known as transesterification, biodiesel is a renewable diesel fuel that is primarily produced from vegetable oils, animal fats, or used cooking oils. Contrarily, bioethanol is an alcohol fuel created by fermenting the sugars and starches present in plants like wheat, corn, and sugarcane. In comparison to fossil fuels, these biofuels provide a number of benefits, such as lowered greenhouse gas emissions, less reliance on foreign oil, and increased energy security. It can be blended with petroleum diesel in varying ratios and used in diesel engines without significant modifications. (Ma & Hanna, 1999; Shukla et al., 2020)

The process of making biodiesel and bioethanol includes a number of processes, such as choosing the feedstock, pre-treating it, converting it, and purifying it. The choice of feedstock has a significant impact on the cost and sustainability of biofuel production. Purification is necessary to guarantee the biofuel is compatible with current infrastructure and engines, while conversion methods can vary based on the type of feedstock and desired end product. Notwithstanding the potential benefits, producing biodiesel and bioethanol has its share of problems, including restricted feedstock supply, land use rivalry, and technical constraints. As a result, ongoing research is required to enhance production sustainability, investigate novel feedstocks, and develop conversion technologies. (Collazo, n.d.; Demirbas et al., 2016)

Bioethanol, an alcohol fuel, is produced by fermenting plant sugars, primarily corn, sugarcane, and wheat, and can be blended with gasoline in varying proportions for use in gasoline engines without significant modifications. (Micic & Jotanovic, 2015)

1.1 INTERNAL COMBUSTION ENGINES

Despite the numerous advantages of biodiesel and bioethanol blends as alternative fuels, research gaps still exist in understanding their potential for engine applications. This research project aims to develop a high-performance blend of biodiesel and bioethanol for engine studies. The blend will undergo testing in a diesel engine to evaluate its performance characteristics and engine efficiency. The study results will provide valuable insights into the potential of biodiesel and bioethanol blends as viable alternative fuels for the transportation sector. (Heywood, 2018)

The most prevalent kind of engine used throughout mobility and industry is the internal combustion engine (ICE). They transform the chemical energy included in fuel into mechanical energy, which powers equipment including as generators, cars, and other machinery. ICEs exist in a wide range of sizes and shapes, but they always function by sparking a concoction of fuel and air inside a combustion chamber. A piston is pushed by the ensuing explosion, which drives a crankshaft and creates rotational energy that may be utilized to operate a machine. (Bae & Kim, 2017; Stone, 1999)

Due to their continuous use for more than a century, ICEs have significantly improved in terms of efficiency, power production, and emissions management. They still have some negative environmental effects, though. Pollutants from ICEs, such as carbon monoxide, nitrogen oxides, and particulate matter, can be hazardous to the environment and human health. Moreover, ICEs have a major impact on international greenhouse gas emissions that cause climate change. By increasing the effectiveness of ICEs and creating alternate fuels and propulsion systems, such as electric automobiles and hydrogen fuel cells, efforts are being made to lessen these detrimental effects.

Notwithstanding the environmental issues with ICEs, their adaptability, affordability, and high-power output ensure that they are still frequently employed. ICEs may be scaled up or down to suit various applications and can run on a range of fuels, including gasoline, diesel, and natural gas. They are a common option for machines and vehicles in poor nations since they are also rather easy to maintain and repair. It

is unclear how long ICEs will continue to rule the transportation and industrial sectors as new technologies are developed and the need for clean energy increases.(Fiore et al., 2020; Reitz et al., 2019)

1.2 BIODIESEL

Biodiesel is ecological and inexhaustible fuel source which can be produced from used vegetable oils, animal fats and etc. As an alternative petroleum diesel, it is slowly market attention due to its lower emission of harmful pollutants and greenhouse gases. It is a feasible option without any call for tempering or diminishing or any blending with any diesel in distinctive proportions. The production of biodiesel necessitates a chemical reaction known as Transesterification, in which triglycerides in the feed stock are reacted with an alcohol such as methanol and a catalyst such as sodium hydroxide or potassium hydroxide. The final resultant biodiesel is discrete from glycerol and decontaminated before using as fuel.(Taha et al., 2016)

The production of biodiesel has various number of profitable and environmental benefits. It is a cleaner-burning fuel that generates few levels of gases like carbon monoxide, hydrocarbons and particulate matter when distinguished with commercial diesel. More over biodiesel has a lesser carbon footprint than petroleum diesel, as we made this biodiesel from useless waste which is completely biodegradable and resulting even better in reduced emissions. Furthermore, into the bargain, biodiesel production assists the reliance on petroleum products and support local economies by giving a marketing advantage for agricultural waste. As good as the pros there are some cons concerning the biodiesel production, if food crops are not sourced legitimately, it can cause increased deforestation and food crop replacement.(Issariyakul et al., 2008; Sahoo & Das, 2009)

1.3 BIOETHANOL

A renewable, low-carbon fuel known as bioethanol is produced from plant-based feedstocks including sugar cane, corn, wheat, or materials with cellulose, such as wood or grass. It is widely utilized as a transportation fuel in many nations throughout the world and is a well-liked substitute for petroleum-based gasoline. In a procedure known as fermentation, microorganisms like yeast transform the carbohydrates in the feedstock into ethanol to generate bioethanol. In order to create fuel-grade ethanol

that can be utilized in typical gasoline engines, the resultant bioethanol is filtered and mixed with gasoline.

There are several financial and environmental advantages to producing bioethanol. Compared to petroleum gasoline, it burns more cleanly and emits less dangerous pollutants and greenhouse gases, such as carbon monoxide and nitrogen oxides. By establishing a market for agricultural waste products and by supporting local economies, the use of bioethanol can also aid in reducing reliance on imported oil. Yet, there may be some downsides to the production of bioethanol, such as heightened competition for food crops and worries about the long-term viability of the feedstock sources. To increase the environmental and economic advantages of bioethanol, researchers are attempting to create more sustainable and effective production techniques, such as employing non-food crops or waste materials as feedstocks.(Kim & Dale, 2004b; Saini et al., 2015)

1.4 BIODIESEL PRODUCTION

The extraction of biodiesel from waste cooking oil is a durable and ecologically beneficial solution. The fluid is transformed into a fuel that may be consumed in diesel engines during the process. This eliminates not just garbage but also the release of greenhouse gases. Ultimately, this strategy enhances a recycling industry while decreasing our dependence on petroleum and fossil fuels.(Demirbas et al., 2016)

1.4.1 TRANSESTERIFICATION

The chemical process of transesterification includes the transfer of ester bonds between an alcoholic and a triglyceride. The fats in vegetable oils or animal fats are synthesized into fatty acid methyl esters in this process, which is extensively utilized in the manufacturing of biodiesel (FAMES). A strong base, such as sodium hydroxide or potassium hydroxide, is frequently employed to accelerate transesterification. The resultant biodiesel can serve as an environmentally friendly and sustainable alternative to fossil fuels, emitting less greenhouse gas and being more recyclable. Transesterification, on the other hand, is a complicated process that demands proper control of process conditions in order to achieve high yields and purity.

1.4.2 APPLICATIONS OF BIODIESEL

Biodiesel is a sustainable fuel synthesized from naturally present and renewable resources such as vegetable oils, animal fats, and recycled grease. Here are four biodiesel applications:

Road transport fuel: Biodiesel, like petroleum - based diesel, can be used as a fuel source. It may be used in any diesel engine with few adjustments. Biodiesel is a cleaner-burning fuel that minimizes emission levels such as carbon monoxide, particulate matter, and hydrocarbons.

Heating fuel: Biodiesel may be utilized as a winter heating in both residential and commercial buildings. It may be used with petroleum products to minimize carbon emissions and improve energy efficiency.

Power generation: Biodiesel may be used as a feedstock in generating units to generate electricity. It may be used to produce electricity in remote areas when the grid is absent.

Industrial applications: Biodiesel can be used as a feedstock in the extraction of different industrial goods such as soaps, lubricants, and solvents. Biodiesel may also be used in heavy machinery and equipment used during construction, mining, and agriculture to substitute petroleum diesel.

1.5 BIOETHANOL PRODUCTION

Bioethanol is a reusable fuel which can be made from a wide range of agricultural sources, notably sugar, corn, and wheat. The organic material's hemicellulose and cellulose are broken down into simple sugars, which are ultimately transformed into ethanol via a succession of chemical processes. To mitigate greenhouse gas emissions, the produced bioethanol can be used as a substitute fuel or blended. (Kim & Dale, 2004b)

1.5.1 FERMENTATION AND DISTILLATION

Fermentation is the synthesis of carbohydrates into carbon dioxide and ethanol by microbes such as yeast or bacteria. Fermentation is exploited in the fabrication of bioethanol to metabolize simple sugars produced from plant matter into ethanol. The

procedure is typically carried out in large tanks or fermenters under temperature and pH control.

The process of distillation involves the separation of parts of an amalgam depending on their operating temperature. Distillation is used in the development of bioethanol to separate the ethanol from the water and other impurities present in the fermentation process. Heat is used to the fermented mixture to vapour the ethanol, which is then condensed and collected as a concentrate liquid. Bioethanol produced can be used as a fuel or as a vehicle fuel. Distillation is an essential phase in the manufacture of bioethanol since it enhances the integrity and saturation of the final result.

1.5.2 APPLICATIONS OF BIOETHANOL

Bioethanol is a recyclable fuel made from organic substances such as crops, trash, and forestry leftovers. These are five bio - ethanol applications:

Aviation fuel: Bioethanol is a common alternative fuel for mobility. It may be combined with gasoline to generate ethanol fuel blends such as E10, which includes 10% ethanol and 90% gasoline, and E85, which has 85% ethanol and 15% gasoline. With little or no modification, fuel ethanol blends are compatible with alternate fuel vehicles and even certain gasoline-powered vehicles.

Industrial Applications: Bioethanol is used in a variety of industrial applications, including eluent production, household cleaners, and pharmaceutical drugs. It is also exploited as a feedstock in the synthesis of other compounds including ethylene.

Cooking fuel: Bioethanol may be employed as a fuel for cooking in both private and business facilities. It burns faster and generates less pollutants than new culinary fuels such as charcoal and wood.

Power generation: Bioethanol may be used as a fuel in portable engines and turbines to generate electricity. It is also acceptable to be utilized in comparatively tiny electricity generating systems such as microturbines and battery storage.

Chemical feedstock: Bioethanol may be used to produce other molecules such as ethyl acetate, acetaldehyde, and acetic acid. These chemicals are used in a variety of sectors, including prescription medicines, polymers, and fabrics.

CHAPTER 2

LITERATURE SURVEY

- Influence of feedstock and process chemistry on biodiesel quality.(Saraf & Thomas, 2007)

Several elements, including the feedstock utilised and the process chemistry involved, have an impact on the quality of biodiesel. According to research, the kind of feedstock—such as vegetable oil or animal fat—can have a big influence on how well biodiesel turns out. The chemistry of the manufacturing process for biodiesel, which includes the kind and quantity of catalysts employed, reaction temperature, and reaction duration, is also very important in defining the calibre of the finished product. In order to maximise biodiesel production and enhance its qualities for use in engines, several research have looked at the impact of these elements on the quality of biodiesel.

- Biodiesel production: a review (Ma & Hanna, 1999)

Recent years have seen a substantial increase in interest in biodiesel production as a result of growing worries about global warming and the demand for sustainable energy sources. A survey of the literature on biodiesel production can give important insights on the status of the technology now, the difficulties the sector is encountering, and the future paths for research. Numerous studies have looked at various facets of biodiesel manufacturing, such as the choice of feedstock, process optimization, and quality assurance. The assessment also emphasizes the need for more study and development in this area as well as the promise of biodiesel as a sustainable energy source.

- Biodiesel production from mixtures of canola oil and used cooking oil (Issariyakul et al., 2008)

Due to its promise as a sustainable and affordable feedstock, the manufacture of biodiesel from a blend of canola oil and spent cooking oil has attracted a lot of interest recently. Cooking oil waste may be turned into a useful fuel source, while canola oil is a frequent feedstock for the creation of biodiesel. It has been demonstrated that the

biodiesel made from the combination of these two feedstocks has better characteristics than biodiesel made from either feedstock alone, including a greater cetane number and lower viscosity. A two-step transesterification reaction using an alkaline catalyst is generally used to produce biodiesel from canola oil and used cooking oil.

- Production and analysis of biodiesel from non-edible seed oil of *Pistacia Chinensis* (Qin et al., 2010)

Pistacia Chinensis non-edible seed oil has received a lot of interest in recent years for its potential as a sustainable and affordable feedstock for biodiesel production. The seeds of the plant species *Pistacia Chinensis*, which is abundantly found in arid and semi-arid areas, are a waste product that may be used to make valuable fuel. By replacing traditional diesel fuel with this non-edible seed oil, the problem of waste disposal may be solved while also offering a more affordable and ecological option. Using a variety of methods, including gas chromatography, Fourier-transform infrared spectroscopy, and nuclear magnetic resonance spectroscopy, the examination of biodiesel made from *Pistacia Chinensis* seed oil has revealed that the finished product satisfies the necessary standards.

- A comprehensive review on properties of edible and non-edible vegetable oil-based biodiesel: Composition, specifications and prediction models (Sajjadi et al., 2016)

The characteristics of both edible and non-edible vegetable oil-based biodiesel have been thoroughly reviewed. The examination covers the make-up and characteristics of different vegetable oils as well as the standards of quality for biodiesel made from them. The paper also discusses methods for predicting the characteristics of biodiesel based on the make-up of vegetable oils, such as fatty acid profile, free fatty acid concentration, and iodine value. The models can aid in streamlining the manufacture of biodiesel and ensuring that the finished product satisfies quality requirements. The evaluation comes to the conclusion that non-edible vegetable oils can serve as a viable substitute for edible vegetable oils in the manufacturing of biodiesel, but further study is required to increase the output and quality of biodiesel made from non-edible vegetable oils.

- Lignocellulosic agriculture wastes as biomass feedstocks for second-generation bioethanol production: concepts and recent developments (Saini et al., 2015)

For the production of second-generation bioethanol, lignocellulosic agricultural wastes such as maize stover and sugarcane bagasse offer a viable source of biomass. This sort of bioethanol can lessen worries about food security and competition for arable land because it is made from biomass feedstocks other than food. It takes multiple stages to produce bioethanol from lignocellulosic biomass, including pretreatment, enzymatic hydrolysis, and fermentation. Numerous pretreatment techniques and enzyme technologies are being investigated to maximize the yield of fermentable sugars, with recent advancements in this sector concentrating on increasing the efficacy and cost-effectiveness of these stages.

- Bioethanol as fuel for internal combustion engines (Micic & Jotanovic, 2015)

Because it has a higher volatility and lower energy density than petrol, using bioethanol as a fuel has several drawbacks. When utilising bioethanol as a fuel, adjustments to the engine may be necessary to maximise performance and economy. To enhance the performance of bioethanol as a fuel, research has concentrated on creating fresh engine technology and refining already existing ones. Flex-fuel engines, direct injection, and hybrid electric systems are a few of these technologies. It is anticipated that the usage of bioethanol as a fuel for internal combustion engines will increase as nations explore for methods to lessen their reliance on fossil fuels and combat climate change.

- Global potential bioethanol production from wasted crops and crop residues (Kim & Dale, 2004a)

Several recent studies have looked at the potential global generation of bioethanol from discarded crops and crop leftovers. According to research, there is a sizable amount of unrealized potential for the generation of bioethanol from agricultural waste, including wheat straw, maize stover, and sugarcane bagasse. Due to their low sugar content and the presence of inhibitors that might obstruct fermentation, these feedstocks present a number of difficulties for the synthesis of bioethanol. The efficiency of converting these feedstocks into bioethanol has been improved through the development of different pretreatment techniques and enzyme technologies. New

yeast strains that can survive high ethanol and inhibitor concentrations have also been created as a result of technological advancements.

- Technoeconomic analysis and environmental sustainability estimation of bioalcohol production from barley straw (Kuittinen et al., 2022)

A viable replacement for fossil fuels is the generation of bioalcohol from barley straw. Recent research have examined the generation of bioalcohol from barley straw from a technoeconomic and environmental sustainability perspectives. The research takes into account every step of the production process, from gathering feedstock to distributing gasoline. According to the findings of these investigations, if the manufacturing method is improved and scaled up, producing bioalcohol from barley straw may be both commercially feasible and ecologically sustainable. The manufacture of bioalcohol from barley straw may be made more efficient and sustainable by utilising emerging technology like genetically engineered microbes and sophisticated pretreatment techniques. Overall, these research' findings imply that producing bioalcohol from barley straw has significant potential as a sustainable alternative to fossil fuels.

- Effects of Ethanol Blends on Performance of Spark Ignition Engine-A Review (Chansauria & Mandloi, 2018)

A potential strategy to lessen reliance on fossil fuels and cut greenhouse gas emissions is the use of ethanol blends in spark ignition engines. Recent research on the impact of ethanol blends on the efficiency of spark ignition engines has been reviewed. By raising the octane rating and lowering engine knock, the review discovered that ethanol blends can enhance engine performance. However, ethanol has a lower energy density than petrol, which may lead to a reduction in fuel efficiency. The analysis also emphasised how crucial it is to optimise engine tune and design in order to get the maximum performance from ethanol mixtures. Overall, the findings of these research point to the possibility of ethanol blends as a sustainable substitute for petrol in spark ignition engines.

- Performance and emissions of straight vegetable oils and its blends as a fuel in diesel engine: A review (Che Mat et al., 2018a)

The study discovered that while SVOs and their blends may be utilised as a fuel in diesel engines, their poor cold flow characteristics and high viscosity can cause engine deposits and poor atomization, which can reduce engine performance and raise emissions. Researchers have come up with a number of solutions to these problems, such as preheating and mixing with other fuels or additives. In order to achieve higher performance and emissions with SVOs and their mixes, the assessment also emphasises the significance of optimising engine architecture and fuel injection systems. Overall, these studies' findings point to the promise of SVOs and their blends as a greener substitute for diesel fuel, but further study is required to maximise its usage and assure that it won't interfere with current infrastructure.

- Performance analysis of IC engines with bio-diesel jatropha methyl ester (JME) blends (Shukla et al., 2020)

The performance of internal combustion engines (ICEs) running on mixes of jatropha methyl ester (JME) is examined in this article. According to the study, JME blends perform similarly to diesel fuel in terms of brake-specific fuel consumption and brake thermal efficiency. The study did discover, however, that JME mixes increased emissions of particulate matter (PM) and nitrogen oxides (NO_x). In order to lower these emissions and enhance engine performance using JME mixes, the scientists proposed optimising engine parameters such fuel injection time and combustion chamber design. The report sheds light on the potential use of JME blends as a greener substitute for diesel fuel, but it also emphasises the need for more research to maximise their usage and lessen their environmental effect.

- An experimental study on the performance parameters of an experimental CI engine fueled with diesel-methanol-dodecanol blends (Bayraktar, 2008a)

The performance characteristics of a compression ignition (CI) engine running on diesel, methanol, and dodecanol mixes are the subject of an experimental investigation presented in this article. The study discovered that by enhancing brake thermal efficiency and lowering fuel consumption, adding methanol and dodecanol to diesel fuel can enhance engine performance. The study did discover, however, that methanol and dodecanol added to diesel fuel enhanced emissions of nitrogen oxides (NO_x) and carbon monoxide (CO). According to the scientists, improving engine characteristics like the compression ratio and timing of the fuel injection might lessen

these emissions and enhance engine performance when using mixed fuels. The article discusses how blended fuels may be used as a sustainable substitute for diesel fuel, but it also emphasises the need for more study to maximise their potential.

- Assessment of performance, combustion and emissions characteristics of methanol-diesel dual-fuel compression ignition engine: A review (Saxena et al., 2021)

The performance, combustion, and emissions characteristics of methanol-diesel dual-fuel compression ignition (CI) engines are reviewed in this article. According to the review, using methanol-diesel dual fuel can enhance engine performance and lower emissions of pollutants including particulate matter (PM) and nitrogen oxides (NO_x). The analysis did highlight the possibility of increasing emissions of carbon monoxide (CO) and unburned hydrocarbons (UHC) from the usage of methanol-diesel dual fuel, though. The authors propose that optimising engine settings, such as the fuel ratio and injection time, can lower these emissions while enhancing engine performance when using dual fuel. The article discusses the potential advantages of using methanol and diesel in tandem, but it also emphasises the need for more study to maximise the usage of

CHAPTER 3

AIM AND SCOPE

3.1 AIM OF THE PROJECT

The aim of this study is to create and test a high-performance biodiesel and bioethanol blend as a potential replacement fuel for diesel engines. The project's objectives are to examine the biodiesel and bioethanol blend's physicochemical characteristics, such as viscosity, density, and flash point, as well as to evaluate how well it performs in a diesel engine. The study will examine the blend's potential to be utilized as a sustainable alternative fuel for transportation by comparing the performance of the biodiesel and bioethanol blend with petroleum diesel.

3.2 SCOPE OF THE PROJECT

The project's scope will include both the physicochemical characterization of the fuel mixture as well as the transesterification and fermentation processes used to produce the biodiesel and bioethanol blend. As part of the experiment, the torque, horsepower, and fuel economy of the mix in a diesel engine will also be assessed, and the findings will be contrasted with those of petroleum-based diesel. Also, the study will examine and contrast the emissions produced by the biodiesel and bioethanol blend with those produced by conventional petroleum diesel.

The project's purpose is to assess the performance and emissions characteristics of the biodiesel and bioethanol blend in order to decide if it can be used as a sustainable alternative fuel for diesel engines. The experiment will be carried out using laboratory-scale equipment. In order to lessen reliance on fossil fuels and the related environmental, economic, and geopolitical concerns, the research will also examine the possibility of biodiesel and bioethanol blends as an alternative fuel for the transportation industry.

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 BIODIESEL:

4.1.1 PREPARATION OF SAMPLES

Sample preparation plays a pivotal role in the efficient production of biodiesel from waste cooking oil. The purification of the feedstock by removing impurities and moisture content is critical for achieving high-quality biodiesel. The waste cooking oil is initially heated to 60-70°C to remove any moisture present, followed by filtration to eliminate solid impurities such as food particles and debris. The use of meticulous sample preparation techniques enables the purified waste cooking oil to be used as a feedstock for biodiesel production. The quality and purity of the feedstock are fundamental for obtaining high-grade biodiesel, and appropriate attention should be given to the sample preparation process to ensure maximum yield and optimal quality. It is imperative to adopt sound sample preparation practices to achieve the desired biodiesel quality standards. (Atabani et al., 2015; Erdiwansyah et al., 2019)

4.1.2 PRODUCTION

We require a biomass for each biofuel, and the biomass we utilize in our job is waste cooking oil. The following steps are used in the production as follows:

- Percentage of FFA (Free fatty acids)
- Determine the process to be implemented
 - Transesterification (single step)
 - Esterification followed by Transesterification (double step)
- Separation
- Extraction

4.1.3 FFA PERCENTAGE:

Take 5g of waste cooking oil and add 25ml of isopropyl alcohol, mix it well and add 4 drops of 0.1N Sodium hydroxide (NaOH) and heat until it reaches 60 degree Celsius.

Now cool it down to room temperature and add 2 drops of phenolphthalein indicator and simultaneously stir it well against 0.1N NaOH titration.

If the mixture slowly turns to light pinkish color, it is indicating the presence of Free fatty acids in the waste oil. We use a mathematical formula to calculate the FFA percentage level. If FFA percentage level is less than 4 it is necessary that we proceed with single step process, Transesterification. If the FFA percentage level is greater than 4, proceed with the double step process esterification followed by transesterification. (Ramesh et al., 2019; Tomić et al., 2021)

$$\text{FFA \%} = (28.2 \times \text{volume of NaOH} \times \text{Normality of NaOH}) / (\text{wt. of the sample})$$

Novelty:

The purpose of heating the mixture of waste oil with iso propyl alcohol and NaOH is to convert the mixture into fatty acid methyl ester (FAME) and glycerol. The FAMEs are the main source for our biodiesel production.

Process Implementation

It is acknowledged that for FFA% less than 4 – Transesterification and for greater than 4 – esterification and Transesterification.

4.1.4 TRANSESTERIFICATION:

Transesterification is a chemical reaction that involves the exchange of ester groups between an ester compound and an alcohol compound. In this reaction, the ester compound reacts with an alcohol in the presence of a catalyst to form a different ester compound and an alcohol. This reaction is commonly used in the production of biodiesel fuel, where a triglyceride (fat or oil) is reacted with an alcohol (such as methanol or ethanol) in the presence of a catalyst (such as sodium hydroxide or potassium hydroxide) to form fatty acid methyl esters (FAMEs) and glycerol. (Lin & Chiu, 2009)



Figure 1: Transesterification of Biodiesel

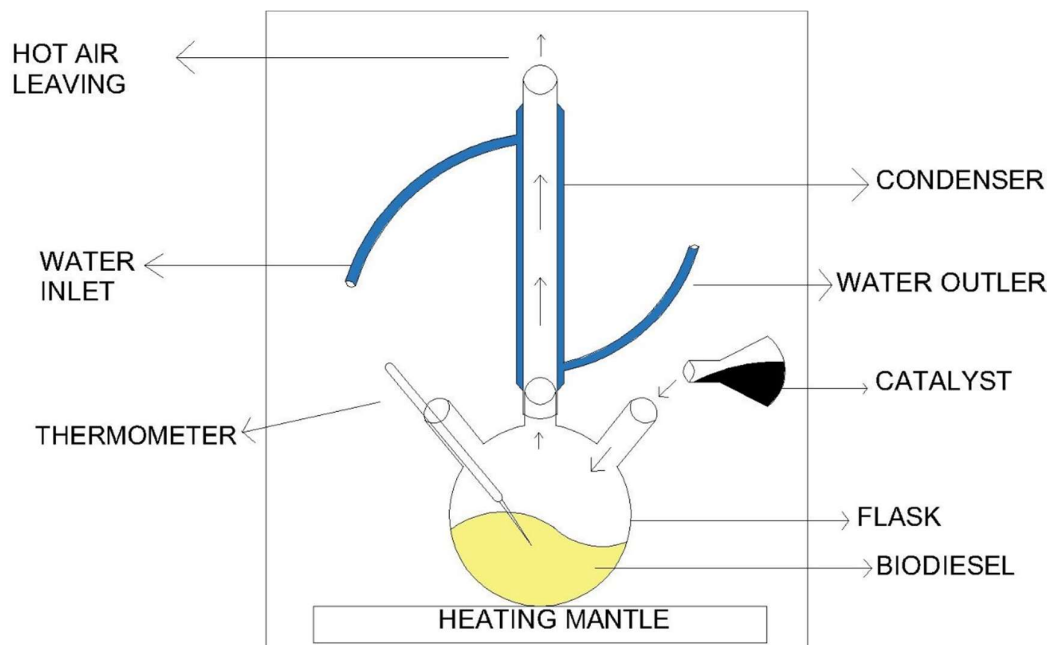


Figure 2: Schematic representation of Transesterification

For experimentation, Take the waste cooking oil as feed stock and prepare the necessary catalyst.

First, arrange a 3 neck round bottom flask and use a heating mantle with rpm rotation that allows us to simultaneously mix and heat the mixture at the same time.

4.1.5 CATALYST PREPARATION: For 1litre biodiesel, conclude that we need to add 90ml of methanol and dissolve 2-3g of NaOH in it.

A 3 neck round bottom flask consist of 3 openings, one for thermometer, one for catalyst and one for condenser.

Use the heating mantle to heat the sample then set the respective rpm based on the sample. A Condenser is necessary to keep the temperature intact; it prevents the flask from overheating. A thermometer is necessary to constantly check the temperature and the addition of catalyst and close all openings with aluminum foil.

Note that all ends must be closed during heating.

After adding the catalyst note the time and leave the equipment for 1 and half hour.(Lalhriatpuia & Pal, 2023)

4.1.6 ESTERIFICATION:

Esterification is same chemical process as transesterification, the catalyst preparation mixture for this process is different compared to transesterification.

Catalyst preparation: for 1 percent of FFA, add 0.25ml of H₂SO₄.

For 1litre sample, we add 182ml methanol and dissolve 1.5ml of H₂SO₄ in it.

We use the above catalyst and proceed with same process.

After completion if we check the sample, the FFA percentage will be less than 4. Later, we are gonna proceed with Transesterification(Dharma et al., 2017)

4.1.7 SEPARATION:

After transesterification, let the sample cool down and pour the entire sample into a separating funnel. After 1-2hrs we can see a layer separation in the funnel, this is glycerol separating from biodiesel. Using the funnel, we will separate the glycerol from biodiesel and extract it into a separate flask.

Note that this biodiesel is impure and not ready for usage.

4.1.8 EXTRACTION:

Now we have impure biodiesel, we need to wash the sample until we achieve a pH 7 Neutral biodiesel. Add 1L of warm water and stir it well, repeat this process from time to time and note the pH value every time we clean the sample. When the sample achieves a pH of 7. The biodiesel and water no longer separate, instead they fleet and mix well. Now take the sample and heat until the sample reaches a temperature of 110degrees Celsius (for water removal). The final sample we get is pure biodiesel ready for engine usage.

4.1.9 EXPERIMENTATION:

Wt. of sample = 5.013g

Take a conical flask and add the sample, 25ml of isopropyl alcohol and 4 drops of 0.1N NaOH. Now heat the mixture till it reaches 60degrees and cool it down to room temp.

Take a stand and attach a burette filled with 0.1N NaOH with the conical flask at the end.

Now add 2 or 3 drops of phenolphthalein and titrate it with the sodium hydroxide in the burette until we achieve the pink color.

Burette reading after titration = 0.5ml

Normality of sodium hydroxide (NaOH) = 0.1N

Calculation:

$$\text{FFA}\% = (28.2 \times 0.5 \times 0.1) / (5.013) = 0.2812$$

The FFA percentage is less than 4 and we can proceed with Transesterification.

We now take a 3 neck round bottom flask filled with oil; Catalyst used (91ml of methanol + 2.6g of NaOH). We will now proceed with transesterification.

After transesterification we will remove glycerol from the sample and clean the mixture until we achieve a pH neutral biodiesel.

4.2 BIOETHANOL:

4.2.1 PREPARATION OF SAMPLE:

The efficiency of the procedures that come after sample preparation directly affects the effectiveness of the entire bioethanol manufacturing process. The first step in sample preparation for sugarcane biomass is to remove the leaves and break the stalks into tiny pieces. After being cut, the stalks are dried to remove moisture and ground to a consistent particle size. The grapes are first crushed to extract the juice, then the leftover skins and seeds are dried and processed into a fine powder for use as grape biomass. The complex sugars in the powdered grape biomass are then broken down by enzymes into simpler sugars that can be readily fermented to make bioethanol. The sample preparation procedure is critical to the success of bioethanol production, and care must be taken to pick the suitable biomass source and optimize the sample preparation stages. (Chansauria & Mandloi, 2018; Yuan et al., 2007)

One typical approach for drying sugarcane and grape biomass is to expose them to sunshine. The biomass is spread out in a thin layer and dried in direct sunlight for many days using this process. To produce grape biomass, for example, the skins and seeds are normally sun-dried for around 3 weeks until they become brittle. With a mill or a blender, the dry biomass may be readily pulverized into a fine powder. Nevertheless, it is critical to protect the biomass from rain and excessive moisture throughout the drying process, since this might result in rotting and a loss of biomass quality. (Erdiwansyah et al., 2019; Mujtaba et al., 2021)

4.2.2 PROXIMATE ANALYSIS:

In the present study, proximate analysis was conducted on dry biomass samples of tomato and potato. The moisture content of the samples was found to be 0.62%, which indicates that a significant amount of water had been removed from the biomass. The ash content of the samples was found to be 6.98%, indicating the presence of minerals in the biomass. Volatile matter content, which represents the organic matter that gets vaporized during heating, was found to be 7.06%. Fixed carbon content, which represents the organic matter that remains after heating, was found to be 85.34%. These values are crucial in determining the quality and composition of the biomass,

which has implications in various fields such as energy production and agriculture. The findings of this study contribute to the existing knowledge base and provide valuable insights for future research in this area.

S.no	Property	Sample	Result
1	Moisture content	5.012 grams	0.62%
2	Ash Content	5.03 grams	6.98%
3	Volatile Matter	5.06 grams	7.06%
4	Fixed Carbon	-	85.34%

Table 1: Proximate Analysis

4.2.3 PRODUCTION:

Different types of biomasses have been used and used for this work. We totally collected five biomass – tomato and potato wet waste, grape dry waste, sugarcane dry waste, sugarcane juice and banana dry waste. When a biomass sample is made, we will conduct the respective analysis on that particular waste. We conducted proximate analysis on the dry waste, we will measure the moisture content, ash content, volatile matter and fixed carbon. The lesser the moisture content the better the bioethanol production. (Jesu Godwin et al., 2019; Safieddin Ardebili et al., 2020)

4.2.4 FERMENTATION AND DISTILLATION:

A key step in the manufacturing of bioethanol is fermentation, which is essential for yeast or other microbes to convert carbohydrates to ethanol. I have researched the crucial phases in the fermentation process for the generation of bioethanol as a researcher in the field of bioenergy. Usually, the feedstock is crushed or milled to make it easier to extract the sugars. In some circumstances, the feedstock may need to be treated with enzymes to reduce complicated sugars to simpler ones so that yeast may more easily ferment them. For feedstocks like cellulose that include complex carbohydrates, this phase is very crucial.

The prepared feedstock is combined with water and yeast during fermentation, and the combination is then left to ferment for a few days to a few weeks. The kind of feedstock and the fermentation conditions are two variables that affect how long fermentation takes. The yeast eats the sugars in the feedstock throughout the

fermentation process, resulting in the production of ethanol and carbon dioxide as byproducts. (Zhong et al., 2022)

The combination of ethanol and water is separated from the leftover particles once fermentation is finished, and the ethanol and water are then separated by distillation. The mixture is heated in this phase to make the ethanol evaporate, which is then condensed and collected as a liquid. The ethanol is then dried out to eliminate any last traces of water and boost its concentration. line. In order to create pure ethanol that may be used as fuel or combined with gasoline, this phase can be completed using a variety of techniques, such as molecular sieves or distillation.

In conclusion, my study has demonstrated that fermentation, which makes it easier for carbohydrates to be converted to ethanol, is an essential stage in the creation of bioethanol. Depending on the feedstock and the fermentation circumstances, the specifics of the fermentation process may vary, but the basic phases of feedstock preparation, enzyme treatment (if necessary), fermentation, distillation, and dehydration are universal to the majority of bioethanol production methods.

(Armas et al., 2007)



Figure 3: Fermentation

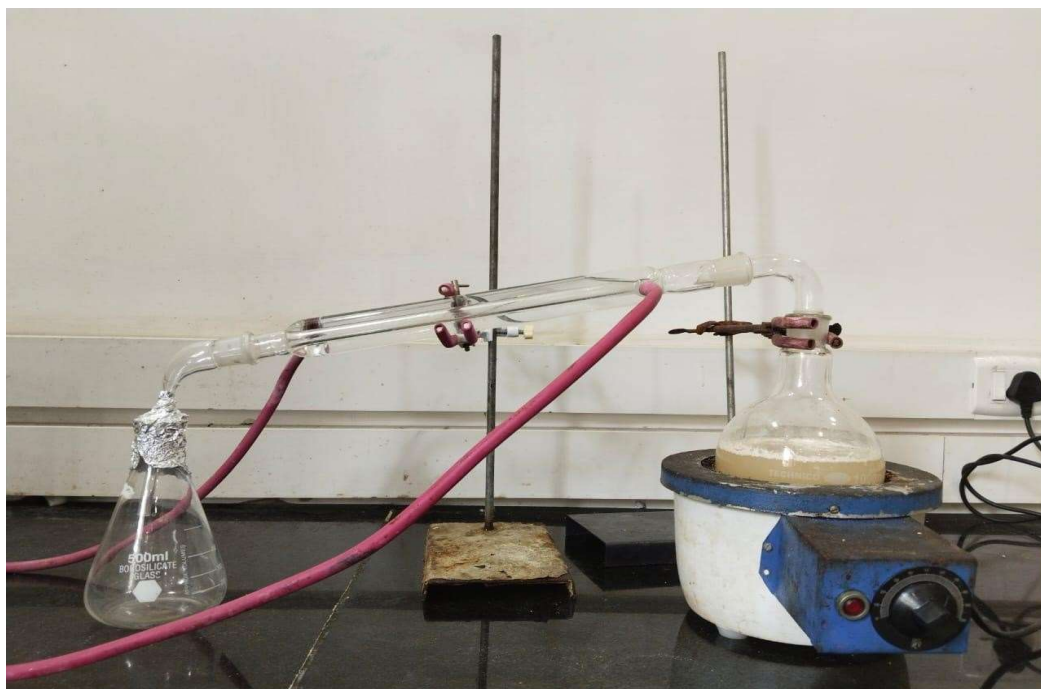


Figure 4: Distillation

4.2.5 EXPERIMENTATION:

Initially, we collected different samples like sugarcane, grapes and vegetable waste.

Fruits and vegetables are collected from local fruit vendors, locals throw away a lot of fruits and vegetables due to lack of sales and rotting of fruits. These samples were collected and squeezed until we remove the water content present in the sample and allowed to dry in sunlight for 2-3 weeks. Samples were dried until we see a crisp nature, later these are grinded into fine powder and allowed for fermentation.

For Fermentation, we need to prepare a nutrient mixture,

Take a fermentation jar and pour our dried powder sample and add water until we receive a 1 Liter mixture. Now take a conical flask, dissolve sugar in luke warm water and add yeast in the flask. We can see the expansion of yeast in the flask, this is the accurate time to add the nutrient solution in the fermented jar.

We need to add yeast nutrient solution according to the amount of sample, the yeast must expand the entire fermented mixture.

Purpose of Yeast:

The yeast nutrient solution will allow the carbon dioxide gas to escape and extract the sugar content from the powder sample in the fermented jar and induce them in the liquid, giving us ethanol water product.

Distillation:

Distillation allows us to heat the sample and the heated vapor is travelled through condenser cooling down the temperature, which in turn condensation takes place converting the vapor into liquid, giving us a high concentration of ethanol.

The ethanol water mixture is carefully removed and filtered and kept for distillation.

For Distillation, we take round bottom flask with a heating mantle beneath it, the prepared sample is now transferred into the round flask. The flask is attached to a condenser to prevent it from overheating. At the end of the condenser, we attach a 500ml conical flask to contain the ethanol extracted.

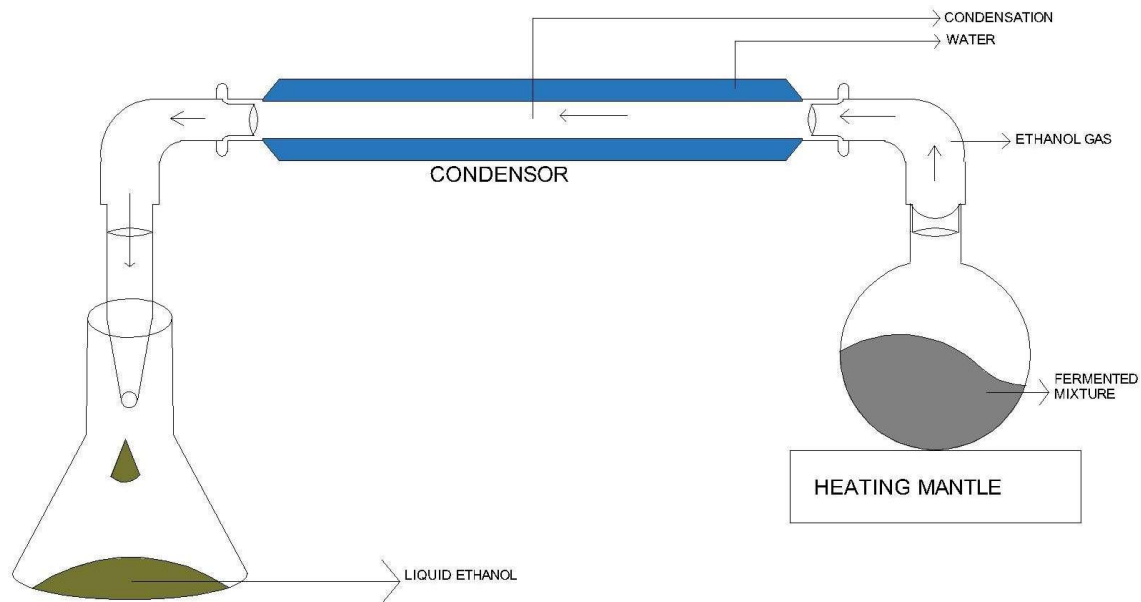


Figure 5: Schematic representation of Distillation

4.3 PROPERTIES:

Moisture Content:

The quantity of water in biodiesel is alluded to as its moisture content. Moisture from the air or water inherent in the allocation system's tanks and pipelines might contaminate the gasoline during storage and transit. Biodiesel may dissolve up to 1,500 parts per million of water.

Because of the weight of the water, high moisture content biomass has a substantially lower net energy density by mass, but also by volume, due to the energy required to

evaporate the water. This means that transportation is less efficient because water makes up a considerable amount of the burden.



Figure 6: Moisture Content Measurement

Copper strip corrosion:

The copper strip corrosion test determines how corrosive hydrocarbon liquids are. It is a subjective test that compares the discoloration and corrosion of a copper coupon under specified test settings to a series of ASTM criteria. The Copper Strip Tarnish Test



Figure 7: Copper strip corrosion test

determines the corrosivity of petroleum products such as aviation fuels, automobile gasoline, natural gasoline, solvents, kerosene, diesel fuel, distillate fuel oil, lubricating oil, and others.

Density:

It is the distribution of a quantity (such as mass, electricity, or energy) per unit of space.

One of the most significant biodiesel qualities is density, because engine injection systems (pumps and injectors) must supply a correct amount of fuel to ensure optimum combustion while limiting greenhouse gas emissions.

Biodiesel with a greater density contains more oxygen and mass per unit volume. There are also several publications in the literature that claim CO₂ increases and CO reductions when biodiesel is used.

Kinematic Viscosity:

Kinematic viscosity is the intrinsic reluctance of a fluid to flow under gravitational forces. It is calculated by measuring the duration in seconds it takes for a defined volume of fluid to flow a known distance by gravity through a capillary within a calibrated viscometer at a tightly regulated temperature.

It governs the atomization of fuel and the full combustion of the diesel engine. Biofuel kinematic viscosity is related to the quantity of carbon atoms, the number of double bonds, and the temperature.



Figure 8: Viscosity Measurement

Cloud and pour point:

The cloud point is the lowest temperature at which the first crystals form. The pour point is the lowest temperature at which a liquid loses its flow properties. The cloud



Figure 9: cloud and pour point Measurement

point test determines the temperature at which the liquid fuel begins to transition from a single-phase to a two-phase system. The pour point test determines the lowest temperature at which the gasoline continues to travel when the container is tipped.

Flash and Fire point:

A liquid hydrocarbon's flash point is the temperature at which it must be heated in order to release enough flammable vapour for it to ignite when in contact with a flame. The higher temperature at which oil vapours will continue to burn when ignited is known as a hydrocarbon liquid's fire point.



Figure 10: Flash and Fire point Measurement

Bomb Calorimeter:

Combustion Calorimeters figure out how much heat a combustible solid-liquid substance produces. To do this, a precise quantity of the sample material is measured into a crucible, the crucible is placed within a "bomb" (an enclosed metal container also known as a pipe), oxygen is added to the pipe, and the substance is ignited. It is mainly used to determine the calorific value for any fuel.



Figure 11: Bomb Calorimeter

4.3.1 PROPERTIES OF BIODIESEL

<i>Property</i>	<i>Sample (biodiesel)</i>	<i>Result</i>
<i>Moisture content</i>	5g	1.739
<i>Copper strip</i>	12ml	No corrosion
<i>Cloud point</i>	10-14ml	8
<i>Pour point</i>	10-14ml	-11
<i>Density</i>	22.50g	0.8996
<i>Viscosity</i>	-	6.706

Table 2: Properties of Biodiesel

4.3.2 PROPERTIES OF BIOETHANOL

<i>Property</i>	<i>Sample (bioethanol)</i>	<i>Result</i>
<i>Flash point</i>	25%	68 degrees
<i>Fire point</i>	25%	74 degrees
<i>Density</i>	19.4g	0.7768
<i>Viscosity</i>	-	1.316
<i>Calorific value</i>	0.62g	
<i>Copper strip</i>	11ml	No corrosion

Table 3: Properties of Bioethanol

Experimentation and calculation:

Moisture content:

Fill a silicon crucible with 5g of biodiesel and weigh the sample and crucible together. Put the crucible in a hot air oven and close the door. The sample will be heated to 110 degrees Celsius in the hot air oven. Take note of the moment when we begin heating the sample. Remove the crucible gently after 3 hours and weigh the sample. Take note of the sample's original and final weights, and then compute the moisture content.

Weight of the crucible = 21.40g

Weight of the biodiesel = 5.04g

Initial weight of the sample = 26.44g

Final weight of the sample = 25.98g

Moisture content percentage = $((\text{initial weight} - \text{final weight}) * 100) / \text{initial weight}$

Moisture content percentage = $((26.44 - 25.98) * 100) / 26.44$

Moisture content percentage = 1.739%

Cloud and pour point:

Assemble the apparatus, pour isopropyl alcohol into the machine, and fill a flask halfway with biodiesel and place it inside the machine. It is worth noting that the temperature before keeping it inside was 29 degrees Celsius. The machine will begin

cooling it down, and it should be checked every 5 minutes until the sample begins to solidify and resembles a cloud; the temperature at this stage is the sample's cloud point. The pour point of the sample is when it has entirely solidified. Such temperature is referred to as the pour point.

Cloud point of biodiesel = 8 degrees Celsius

Pour point of biodiesel = (-11) degrees Celsius

Flash and fire point:

The flash and fire point equipment will heat the bioethanol until it begins to burn. The flash point is the temperature at which the bioethanol starts to ignite and gradually burns fire. The bioethanol will be heated at a rate of 5-6 degrees per minute. The sample will continually burn at one point, and the temperature here represents the sample's fire point.

Flash point of bioethanol = 68 degrees Celsius

Fire point of bioethanol = 74 degrees Celsius

Calorific value:

We use a gadget called bomb calorimeter to measure the calorific value of bioethanol.

Bomb apparatus: Nichrome wire, 14cm cotton thread, bioethanol and positive negative charges.

This bomb will have a nichrome wire fixed on both positive and negative charges, a 14cm cotton thread linked to this wire, and a little cup with 0.62g of ethanol at the bottom, with the lid closed. The pressure inside this explosive is 400 psi. This bomb is then placed in a bucket of 5lites water, closed, and let to heat for 7 minutes before we push fire and allow it to heat for 22 minutes at an increasing temperature of 1.02 degrees Celsius.

Density: Density is defined as the mass per unit volume. We weigh a miniature round bottom flask, then fill it with the appropriate fuel and weigh it again. Using these two weights, we compute the density of fuel using a mathematical formula.

Density of biodiesel:

Weight of the flask, $W_1 = 19.82\text{g}$

Weight of the flask filled with biodiesel, W2= 42.31g

Density of biodiesel = $(W2-W1) / 25$

Density of biodiesel = $(42.31-19.82) / 25$

Density of biodiesel = 0.8896

Density of bioethanol:

Weight of the flask, W1 = 19.80g

Weight of the flask filled with bioethanol, W2= 39.22g

Density of bioethanol = $(W2-W1) / 25$

Density of bioethanol = $(39.22-19.80) / 25$

Density of bioethanol = 0.7768

4.4 BLEND OF BIODIESEL AND BIOETHANOL

Biodiesel and bioethanol are two different forms of biofuels made from renewable sources that are combined. Unlike bioethanol, which is produced using plants like corn, sugar cane, or wheat, biodiesel is produced using vegetable oil or animal fat. These two biofuels can decrease harmful emissions while increasing fuel economy when combined.

Different blends of fuel were made and formulated in a tabular format.

	Bioethanol (%)	Biodiesel (%)	Diesel (%)
Blend 1	05	20	75
Blend 2	10	20	70
Blend 3	15	20	65
Blend 4	20	20	60

Table 4: Blend Concentrations

We keep B20 biodiesel as constant and adjust the concentrations of bioethanol and diesel.

4.5 ENGINE TESTING

4.5.1 ENGINE PARAMETERS

Engine tested – Single cylinder four stroke diesel engine

Description:

The setup consists of single cylinder, four stroke, Diesel engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for P θ -PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Labview based Engine Performance Analysis software package “Enginesoft” is provided for on line performance evaluation.

4.5.2 SPECIFICATIONS:

Product Specification	Details
Product code	224
Engine Type	1 cylinder, 4 stroke Diesel, water cooled
Engine Make	Kirloskar
Engine Model	TV1
Engine Power	5.2 kW at 1500 rpm
Engine Stroke	110 mm
Engine Bore	87.5 mm
Engine Displacement	661 cc
Engine Compression Ratio	17.5
Dynamometer Type	Eddy current, water cooled
Propeller Shaft	With universal joints

Air Box	MS fabricated with orifice meter and manometer
Fuel Tank Capacity	15 lit with glass fuel metering column
Calorimeter Type	Pipe in pipe
Piezo Sensor Range	5000 PSI
Crank Angle Sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse
Data Acquisition Device	NI USB-6210, 16-bit, 250kS/s
Piezo Powering Unit	Model AX-409
Temperature Sensor Type	RTD, PT100 and Thermocouple, Type K
Temperature Transmitter Type	Two wire
Temperature Transmitter Input	RTD PT100, Range 0–100 DegC
Temperature Transmitter Input	Thermocouple, Range 0–1200 DegC
Temperature Transmitter Output	4–20mA
Load Indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load Sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel Flow Transmitter	DP transmitter, Range 0-500 mm WC
Air Flow Transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	“Enginesoft” Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump Type	Monoblock
Overall Dimensions	W 2000 x D 2500 x H 1500 mm
Optional	Computerized Diesel injection pressure measurement

Table 5: Engine Specifications

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 Analysis of fuel properties

Biodiesel:

Biodiesel's characteristics are critical in determining its usefulness as a fuel source. The moisture concentration 1.739 shows an abundance of water, which could negatively impact biodiesel quality. The absence of corrosion on the copper strip, on the other hand, is a beneficial indicator, showing that the biodiesel is corrosion resistant. The cloud point, or temperature at which the fuel starts to form visible solids, is quite low at 8 degrees Celsius, which is advantageous for biodiesel use in cold locations. The pour point, or the lowest temperature at which the gasoline flows, is likewise low at -11 degrees Celsius, indicating excellent cold weather performance.

Biodiesel has a density of 0.8996, indicating that it is less dense than standard diesel fuel. Finally, the viscosity of 6.706 shows that biodiesel is viscous, which might impair its operation in particular fuel systems. Overall, these features indicate that biodiesel has potential as a renewable fuel source, but further research and study are required to confirm its feasibility as a fuel alternative. *(Full Article: Review of Fuels for Internal Combustion Engines in the Aspect of Economy, Performance, Environment and Sustainability, n.d.; Series & 2020, n.d.)*

Bioethanol:

The characteristics of bioethanol must be examined in order to assess its potential as a fuel source. Bioethanol has a low flammability, as seen by its flash point of 68 degrees Celsius and fire point of 74 degrees Celsius, which improves its safety while handling and transit. Bioethanol has a density of 0.7768, which means that it is less dense than conventional petrol, and a viscosity of 1.316, which suggests that it is less viscous, indicating that it may flow readily through fuel systems.

Furthermore, the calorific value of 4197.377 calories/gram indicates that bioethanol has a high energy content, allowing it to produce a high power output. The lack of corrosion on the copper strip demonstrates that bioethanol is corrosion resistant. Taken together, these qualities suggest bioethanol's promise as a renewable fuel

source, albeit further research and analysis are required to assess its performance and viability as an alternative fuel. (Bovo et al., 2023; Saxena et al., 2021; Singh & Agarwal, 2021)

5.2 Performance Graphs:

5.2.1 Brake Thermal Efficiency

Brake thermal efficiency is a metric used to evaluate the engine's ability to convert the chemical energy from fuel into useful mechanical work. It is determined by comparing the engine's brake power output to the heat input from fuel. Fuel quality, engine design, and operating conditions are all factors that can affect the brake thermal efficiency of an engine. Fuels with higher heating values and densities typically have higher brake thermal efficiencies. Other factors that can influence brake thermal efficiency include compression ratio, fuel injection timing, and air-fuel ratio. Brake thermal efficiency is a crucial metric that can be used to optimize engine design and operating conditions for improved engine performance.

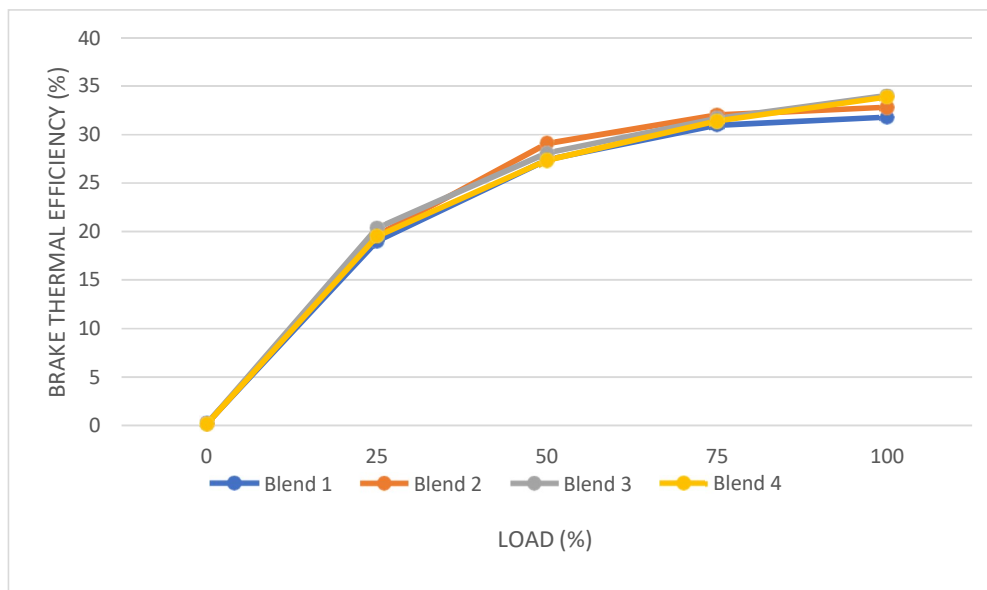


Figure 12: Brake Thermal efficiency vs Load

Under all situations involving a combination of fuels, the brake thermal efficiency (BTE) drops as the load is increased. However, as the load increases, the heat loss decreases. The BTE of the engine will improve as the mixture's ester concentration increases. Based on the graph, Blend 3 exhibits the highest BTE, followed by Blend 4 and Blend 2. On the other hand, Blend 1 demonstrates the lowest BTE due to its low bioethanol percentage and boiling point. Blend 3 has a greater BTE because it has

roughly equal amounts of biodiesel and bioethanol. (Korakianitis et al., 2011; Mrityunjaya et al., 2013; Mujtaba et al., 2021)

5.2.2 Volumetric Efficiency

Volumetric efficiency refers to the proportion of air that the engine draws in compared to the volume that the piston moves through. During the expansion stroke, the piston moves to the bottom dead center, but the amount of air that it takes in from the outside is not the same as the volume it covers while expanding.

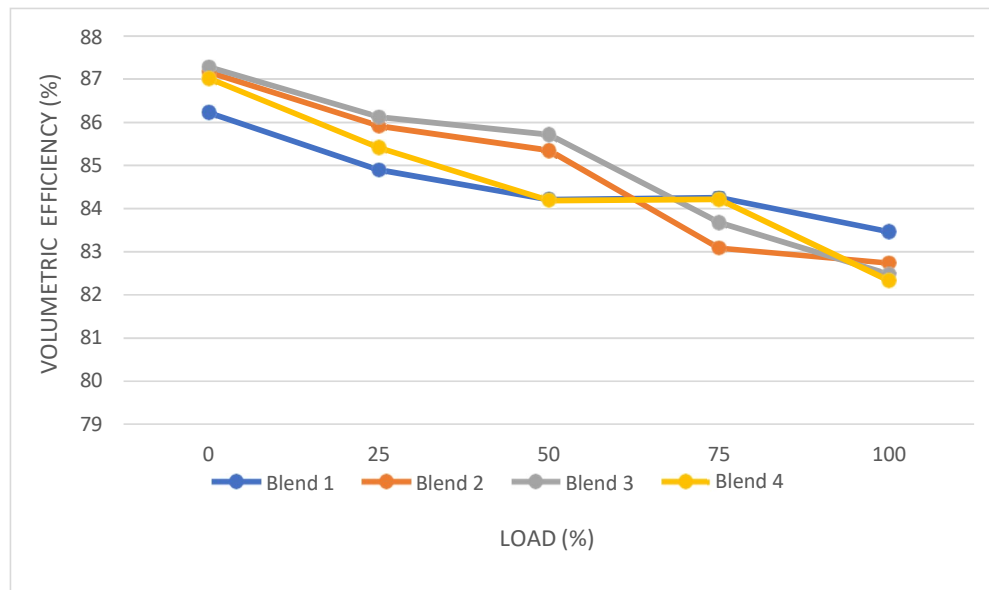


Figure 13: Volumetric efficiency vs Load

Upon examination of the graph, it is evident that Blends 2 and 3 exhibit the highest volumetric efficiency. However, when the load is increased, the volumetric efficiency of these blends drops sharply. Blend 4 has consistent volumetric efficiency at 50% and 75% loads. In contrast, Blend 1 has the lowest volumetric efficiency and shows almost similar volumetric efficiency at 25%, 50%, and 75% loads. (Bayraktar, 2008b; Che Mat et al., 2018b; Verma et al., 2021)

5.2.3 Exhaust Gas Temperature

Exhaust gas temperature (EGT) is the term used to describe the measurement of the temperature of the gases emitted from the engine. This measurement is taken at the engine's manifold. EGT is a crucial factor for the efficient functioning of the catalytic converter in an internal combustion engine.

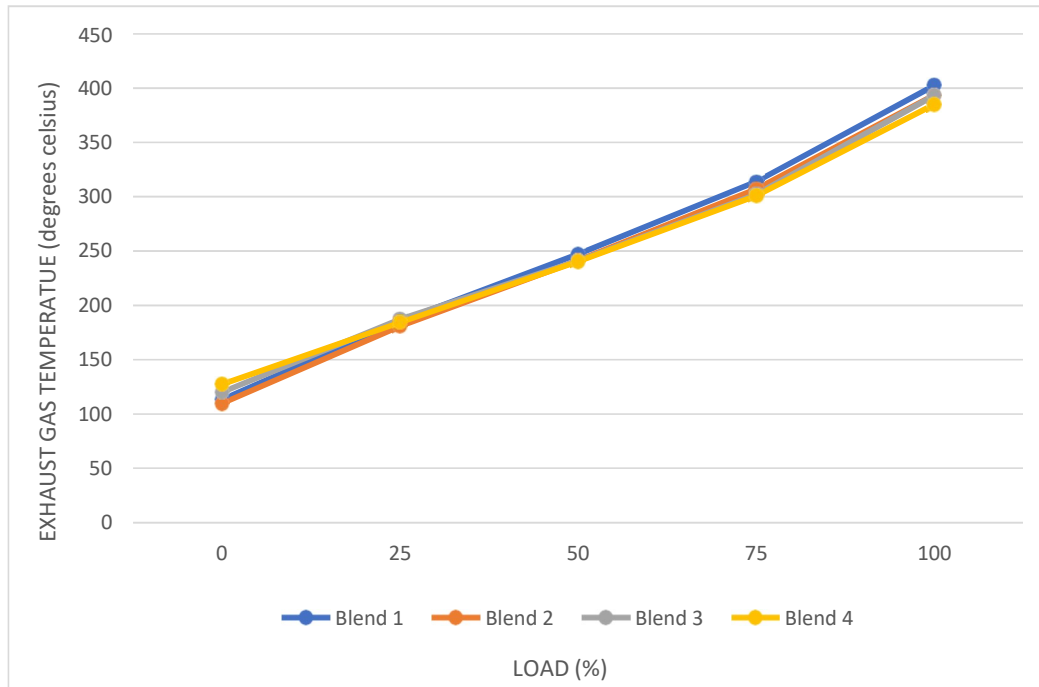


Figure 14: Exhaust Gas Temperature vs Load

As represented in the graph, as load increases EGT increases, we can see at maximum load blend 1 has the highest EGT compared to others and blend 4 has the lowest EGT. (Bayraktar, 2008a; Kale & Patle, 2022a, 2022b)

5.2.4 Specific Fuel Consumption

Specific fuel consumption is the amount of fuel consumed by a vehicle to generate a single unit of output power. It is the measure of the fuel burnt by an engine to produce one unit of thrust. In the case of shaft output, specific fuel consumption is utilized to compare the efficiency of internal combustion (IC) engines. (Bari et al., 2020a, 2020b; Derikvand et al., 2022)

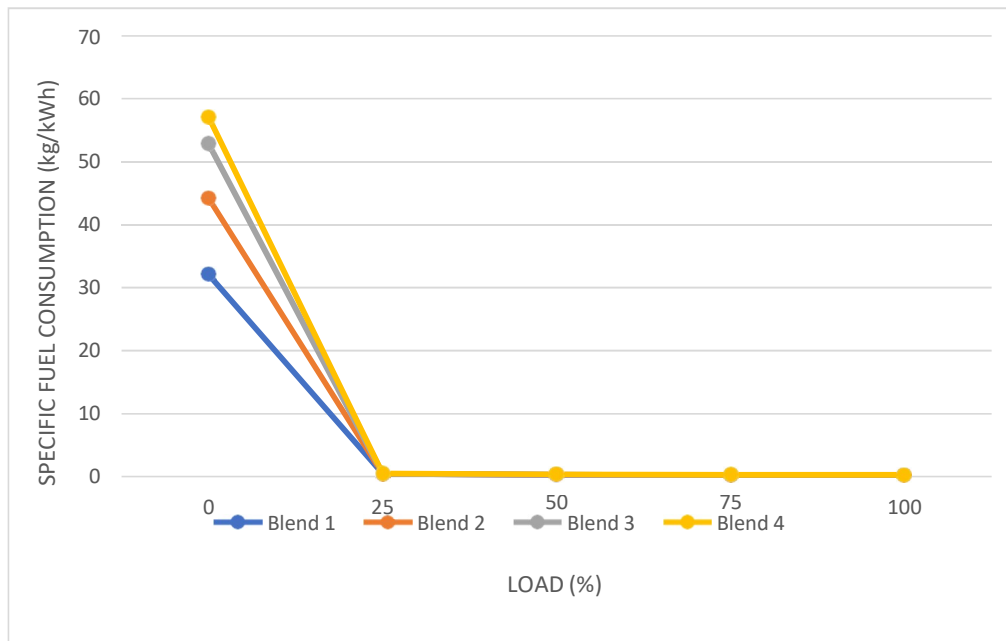


Figure 15: Specific fuel consumption vs Load

5.3 Emission Characteristics

5.3.1 Carbon Monoxide

Carbon monoxide (CO) is a colorless and odorless gas that can be highly hazardous when inhaled in substantial quantities. It can cause severe harm to all living organisms. CO is emitted when any material burns in an outdoor setting. The primary sources of CO emissions are from the combustion of fossil fuels and car exhaust.

In this graph the lowest CO emission is for blend 3 and blend 4 is approximately same for all loads except 100% load. The highest CO emission is blend 1 at 100% load, but after the maximum load it is as low as diesel. (Ali & Seraj, 2022; Singh & Agarwal, 2021)

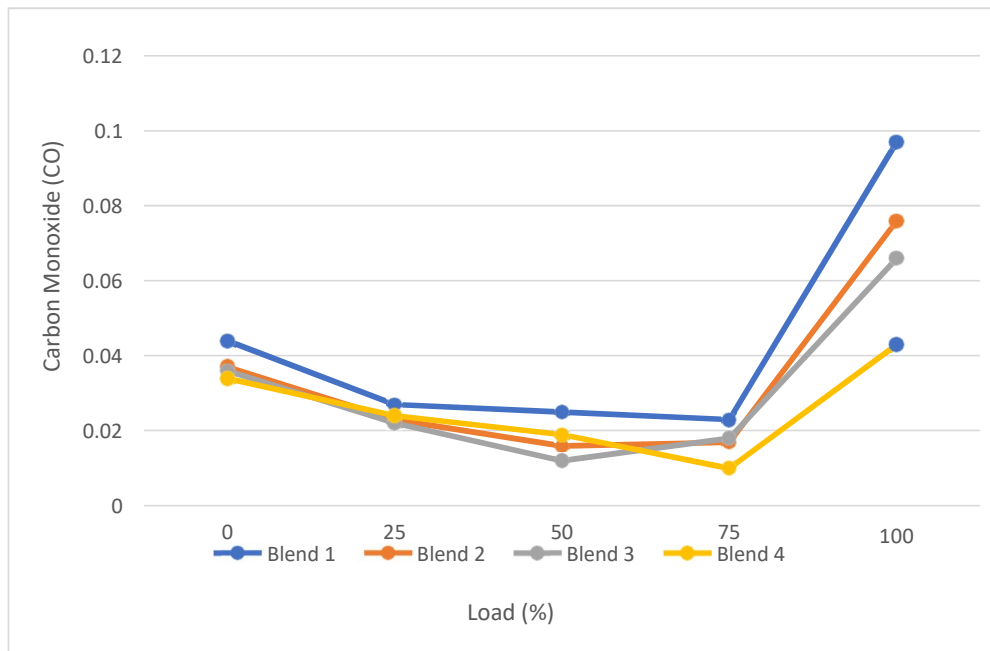


Figure 16: Carbon Monoxide vs Load

5.3.2 Carbon Dioxide

CO₂ emissions serve as evidence that the air and fuel mixture has been completely burned, indicating that there was an adequate supply of oxygen to combust the fuel injected into the chamber. CO₂, a fundamental greenhouse gas, is discharged into the atmosphere alongside other exhaust gases. Since plants require CO₂ for growth, its impact on the atmosphere is relatively minor. However, CO₂ emissions are primarily responsible for climate change. It is widely acknowledged that reducing emissions as soon as possible is critical in order to avert the most severe consequences of climate change. In this graph, blend4 has the lowest emission at the maximum load, all blends have the lowest emission at the lowest load, and blend 1 has the greatest emission at the lowest load. (Research & 1998, 1998; Schäfer & Van Basshuysen, 1995)

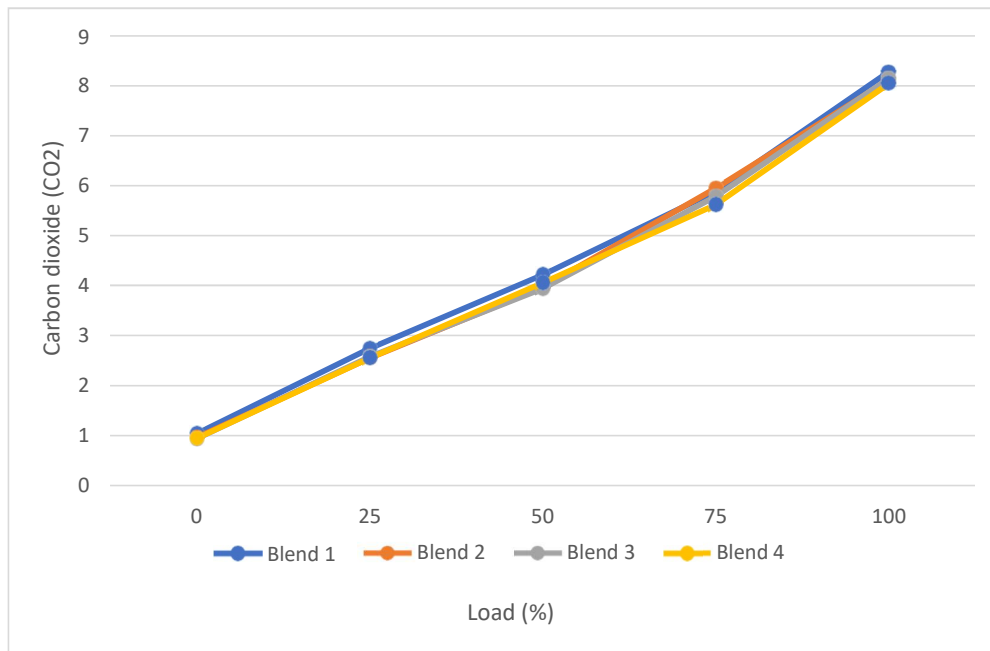


Figure 17: Carbon dioxide vs Load

5.3.3 Nitrogen Oxide

Nitrogen oxides (NOx) are highly reactive and toxic gases that are produced when fuels are burned at high temperatures. Various gases are produced when fuel is burned, and NOx is one of them. NOx pollution is generated by a range of vehicles, including cars, trucks, and off-road equipment such as boats and construction machinery. The appearance of NOx is often brown in color. In this graph blend 4 has the lowest emission of NOX at the lowest load and blend 1 at highest load, Highest emission is for 100% load compared to other loads. (Kumar et al., 2022a, 2022b)

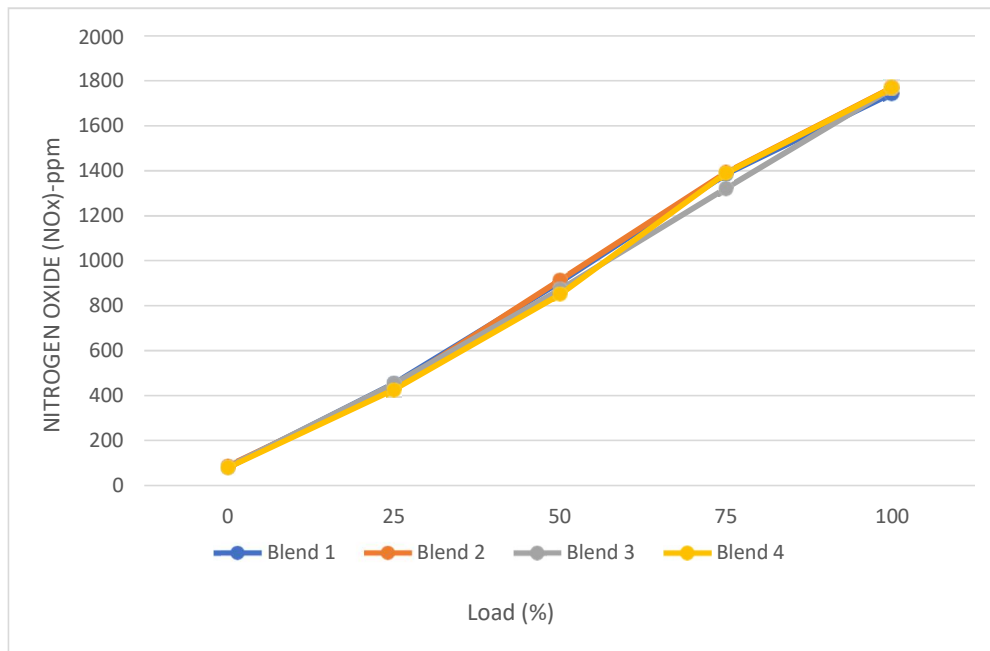


Figure 18: Nitrogen oxide vs Load

5.3.4 Hydrocarbon Emission

Insufficient fuel combustion in the combustion chamber is the primary cause of the problem. This results in unburned fuel being directly released into the exhaust system. Ignition problems or internal engine failures can result in a reduction in compression, which exacerbates the issue. Inadequate fuel ignition leads to the release of large quantities of hydrocarbons (HC) into the environment. *(Full Article: Performance and Emission Studies in a Diesel Engine Using Bio Oil-Diesel Blends, n.d.; Mustayen et al., 2022)*

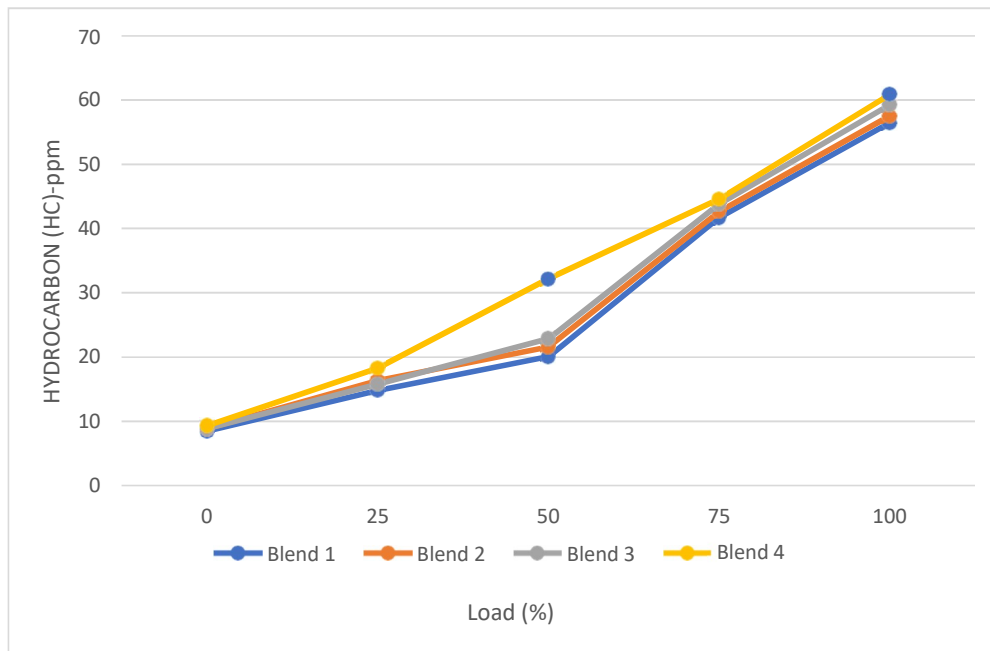


Figure 19: Hydrocarbon vs Load

As shown in the graph blend 4 has the highest HC emission value at the maximum load and blend 2 has the lowest emission at maximum loads. Blend 1 has the highest emission and blend 2 has the lowest emission at 0% load.

5.3.5 Smoke Opacity

It is a type of emission particulate that results from the buildup of gasoline on the walls of the engine's cylinders. The opacity of smoke emitted by internal combustion engines is influenced by the gasoline residue that accumulates on these cylinder walls. This makes it easier to measure the level of emissions. (Mrityunjaya et al., 2013; Mujtaba et al., 2021)

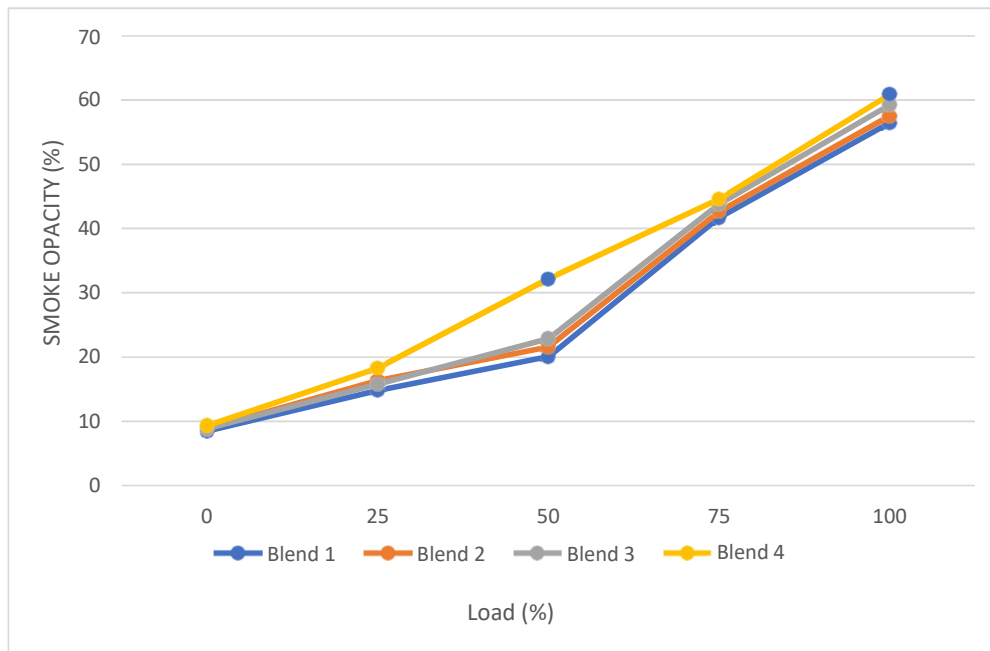


Figure 20: Smoke Opacity vs Load

It is harmful to health as shown in the graph, blend 4 has the highest opacity at maximum load. Blend 4 has shown a significant increase at 50% load compared to other blends. Blend 1 has the lowest smoke opacity at both 0% and 100% loads.

5.4 Combustion Graphs

5.4.1 Crank Angle vs Cylindrical Pressure

The below graph represents crank angle and cylindrical pressure.

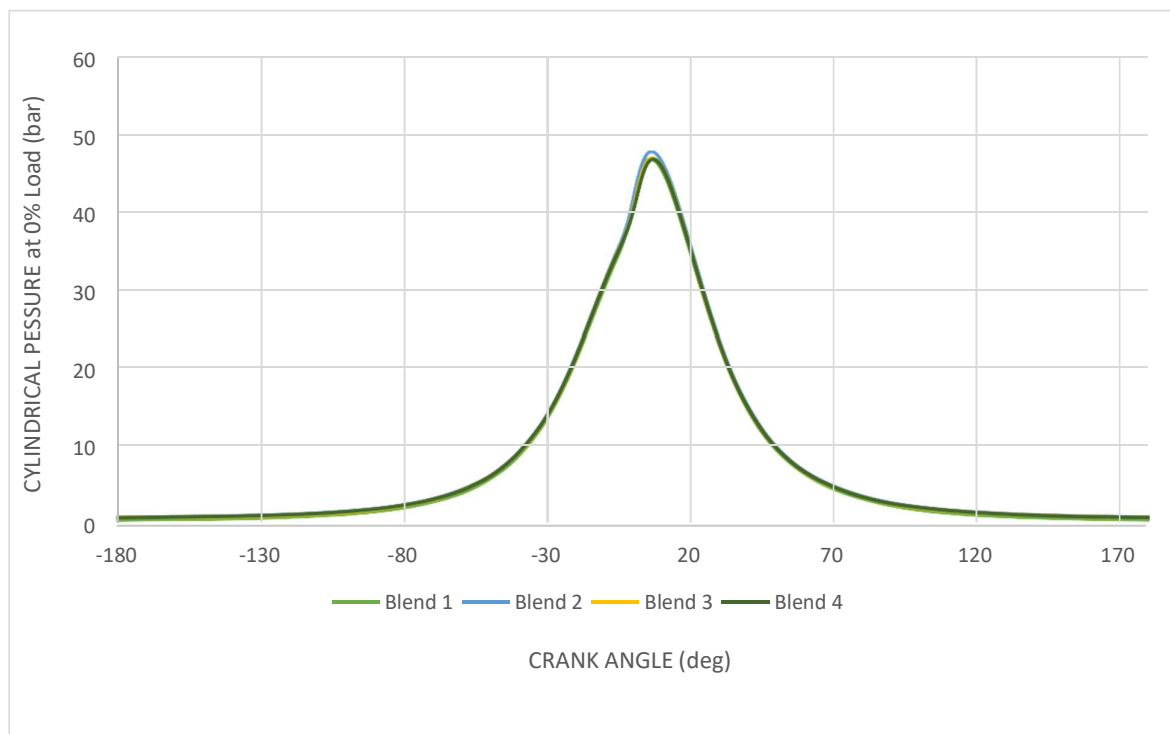


Figure 21: Cylindrical pressure vs Crank angle at 0%

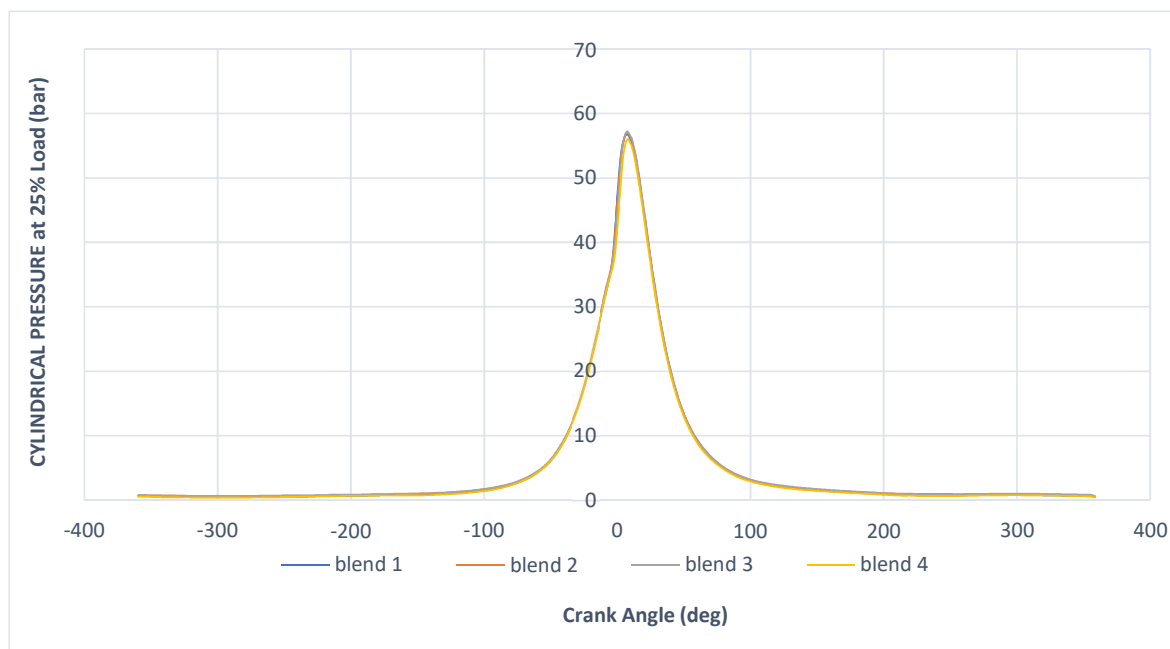


Figure 22: Cylindrical pressure vs Crank angle at 25%

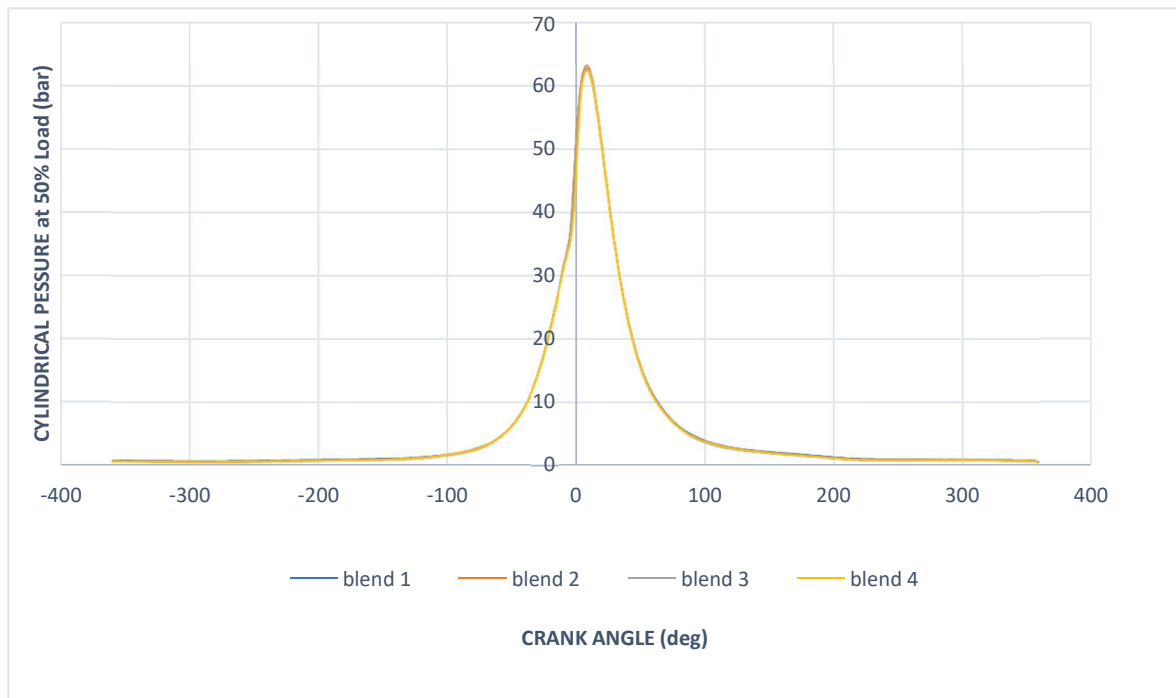


Figure 23: Cylindrical pressure vs Crank angle at 50%

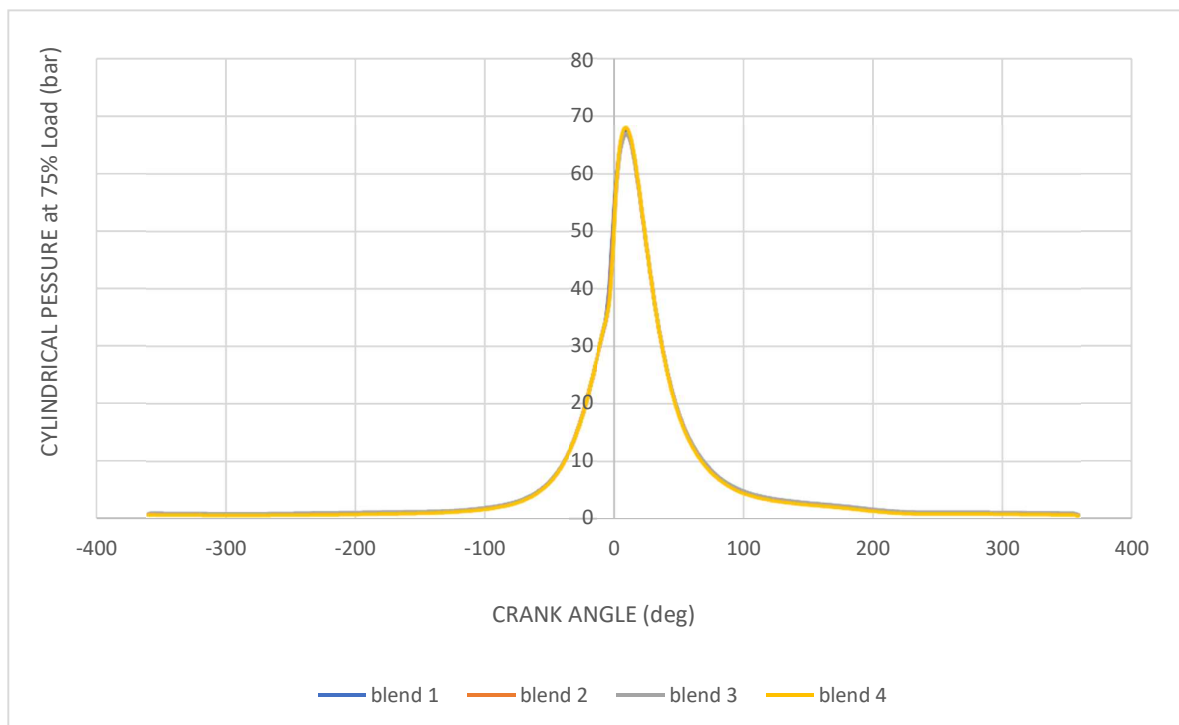


Figure 24: Cylindrical pressure vs Crank angle at 75%

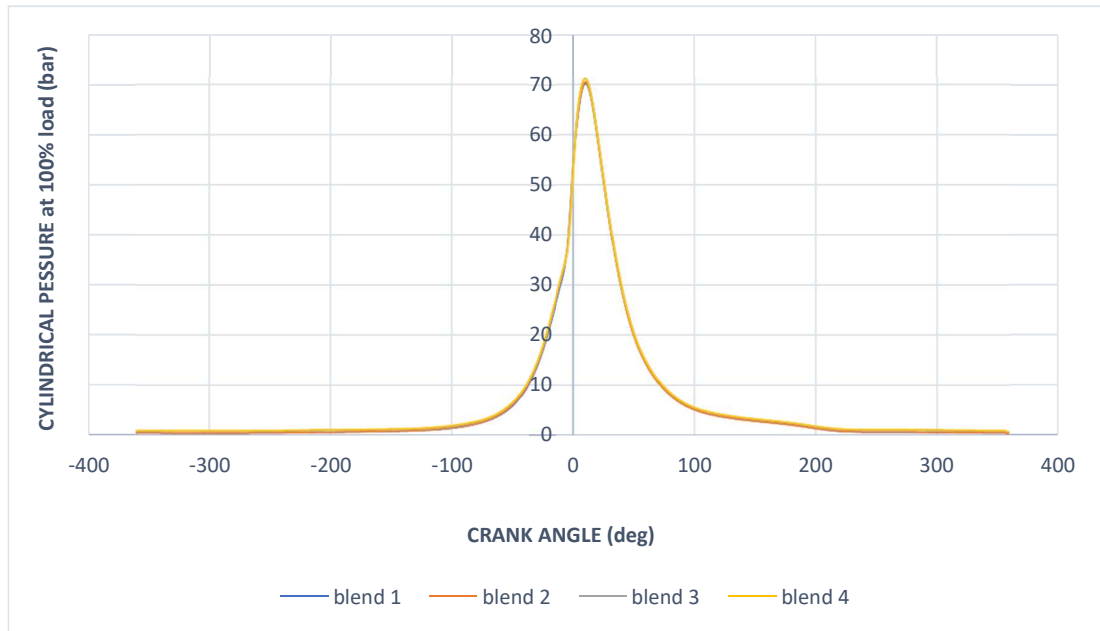


Figure 25: Cylindrical pressure vs Crank angle at 100%

So, we can see that increase in crank angle is inversely proportional to cylindrical pressure.

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

Table 6: Cylindrical pressure graph readings

From the above table we can see the maximum and minimum Cp of all blends at different loads. We can observe that as load increases blend 2 and blend 3 tend to have the maximum Cp until 50% load. At maximum loads blend 4 with high concentrations on bioethanol compared to other blends has shown the highest CP.

5.4.2 Crank Angle vs Net HR dQ_n/dq

Net heat rate depends on crank angle. We can see deviations of blends at -100 and -10 in the following graphs.

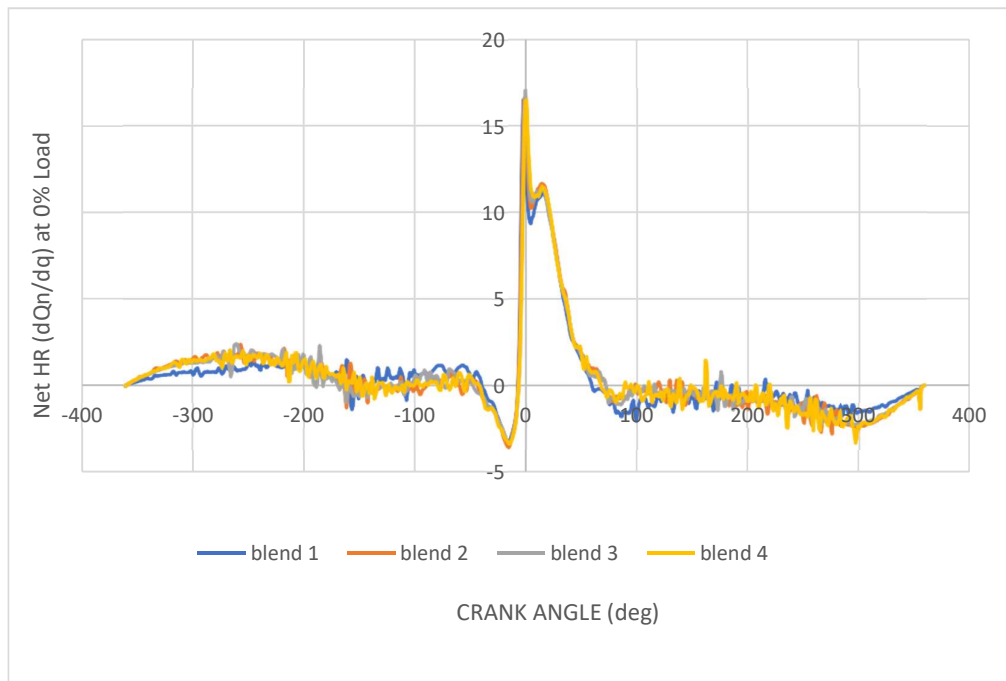


Figure 26: Net HR (dQ_n/dq) vs Crank angle at 0%

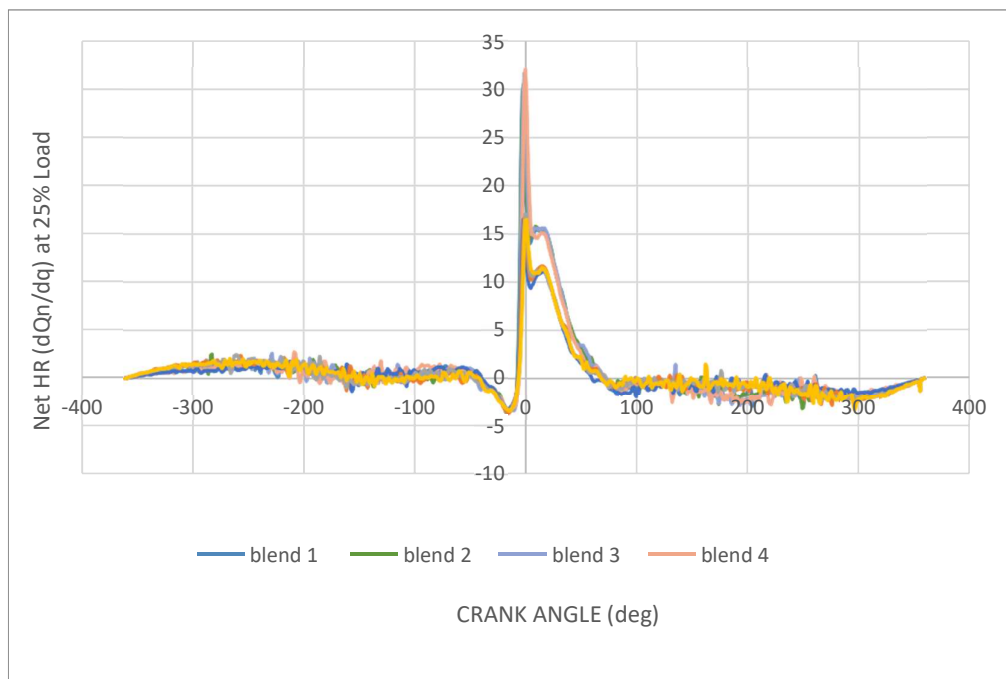


Figure 27: Net HR (dQ_n/dq) vs Crank angle at 25%

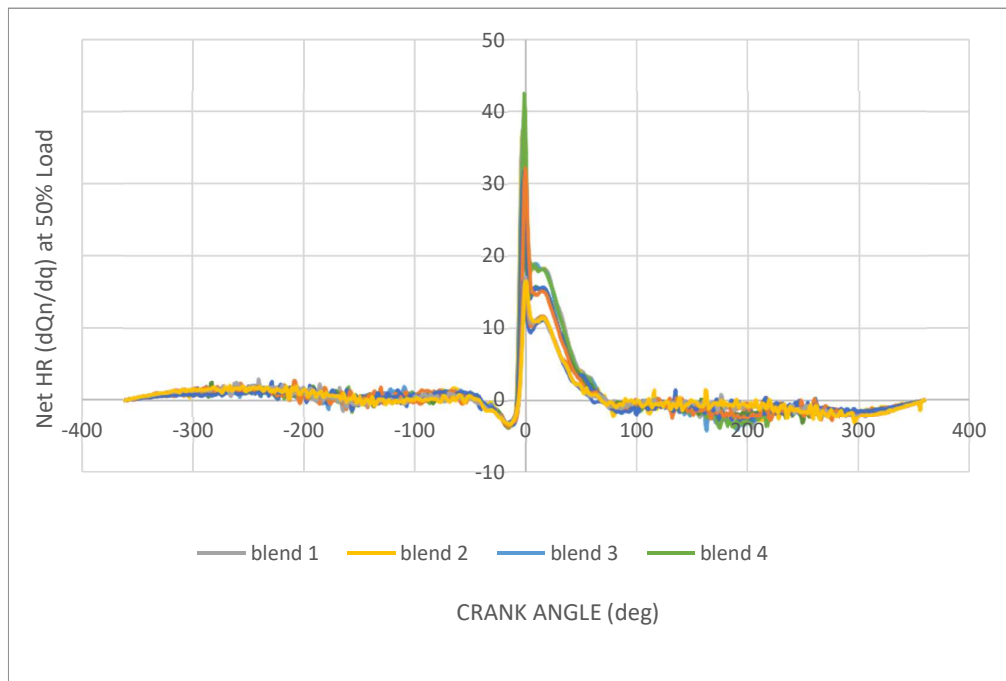


Figure 28: Net HR (dQ_n/dq) vs Crank angle at 50%

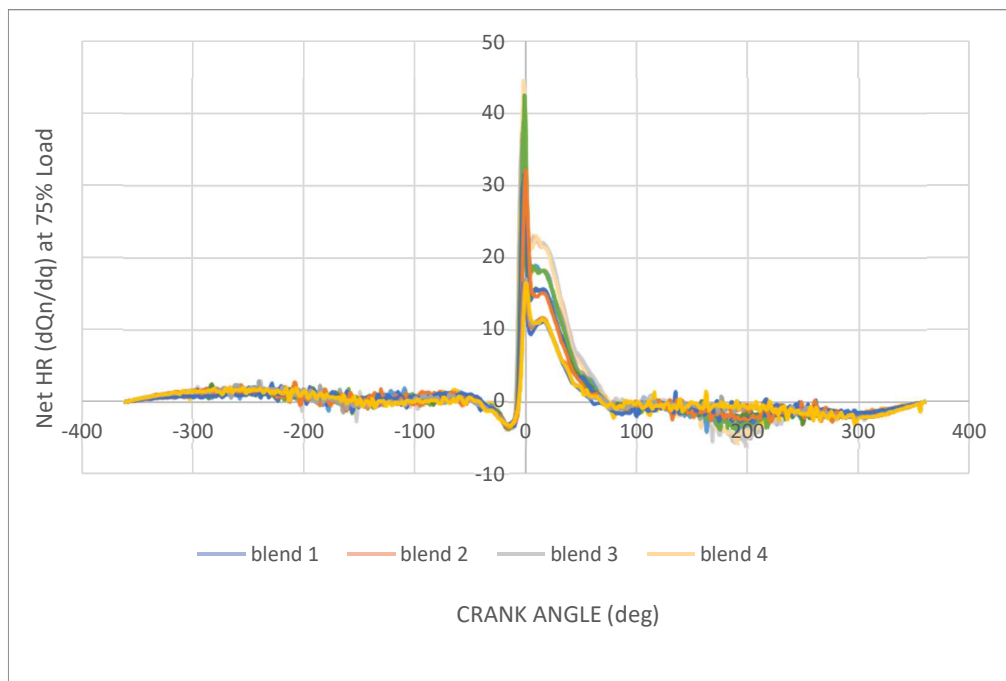


Figure 29: Net HR (dQ_n/dq) vs Crank angle at 75%

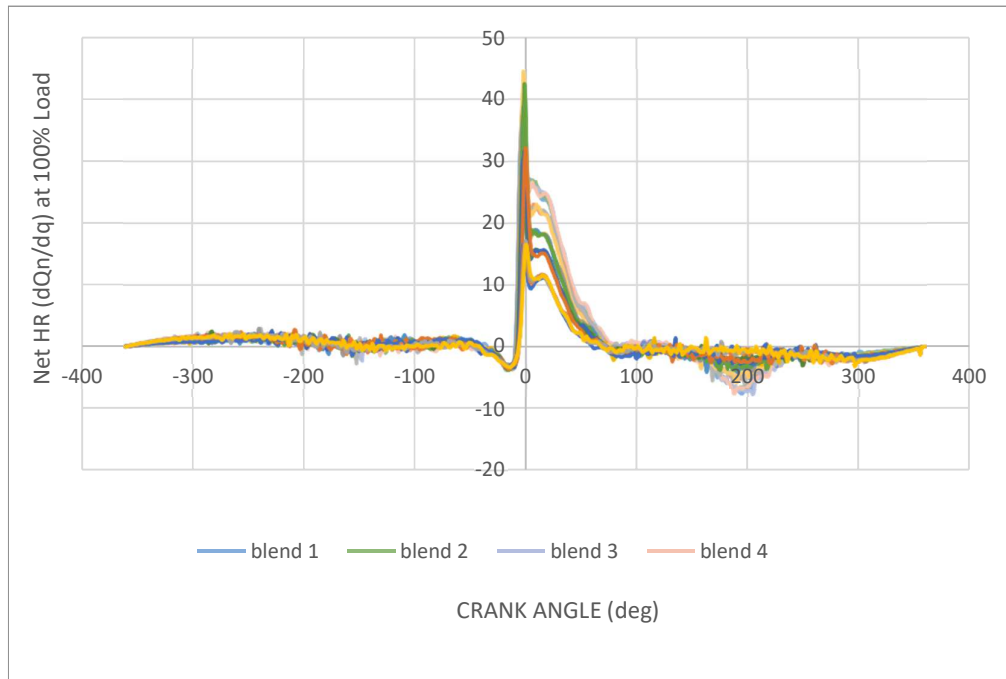


Figure 30: Net HR (dQn/dq) vs Crank angle at 100%

S.no	Load	Maximum NHR	Minimum NHHR
1	0%	Blend 3	Blend 4
2	25%	Blend 4	Blend 1
3	50%	Blend 4	Blend 2
4	75%	Blend 4	Blend 2
5	100%	Blend 4	Blend 1

Table 7: Net Heat Rate graph readings

We can observe that blend 4 has maximum load at all loads except for 0%. Blend 1 and Blend 2 has shown low NHR comparably with other blends. Blend 3 with 15% Bioethanol has shown significant NHR at all loads variably.

5.4.3 Pressure vs volume

The volume for blends is at constant, the difference in pressure is observed when the load is applied.

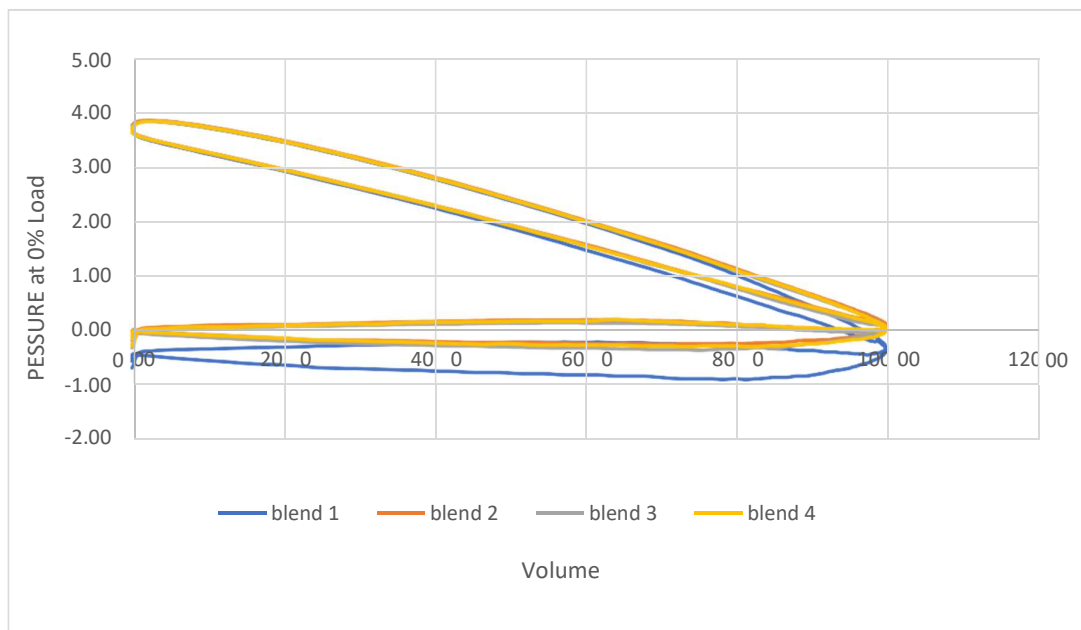


Figure 31: Pressure vs Volume at 0% Load

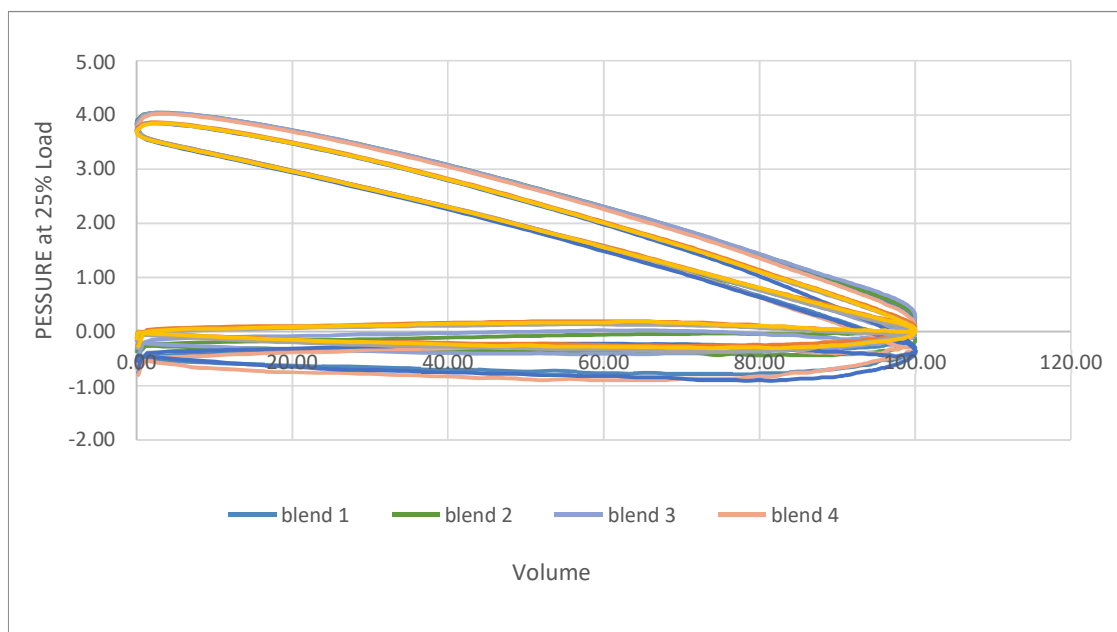


Figure 32: Pressure vs Volume at 25% Load

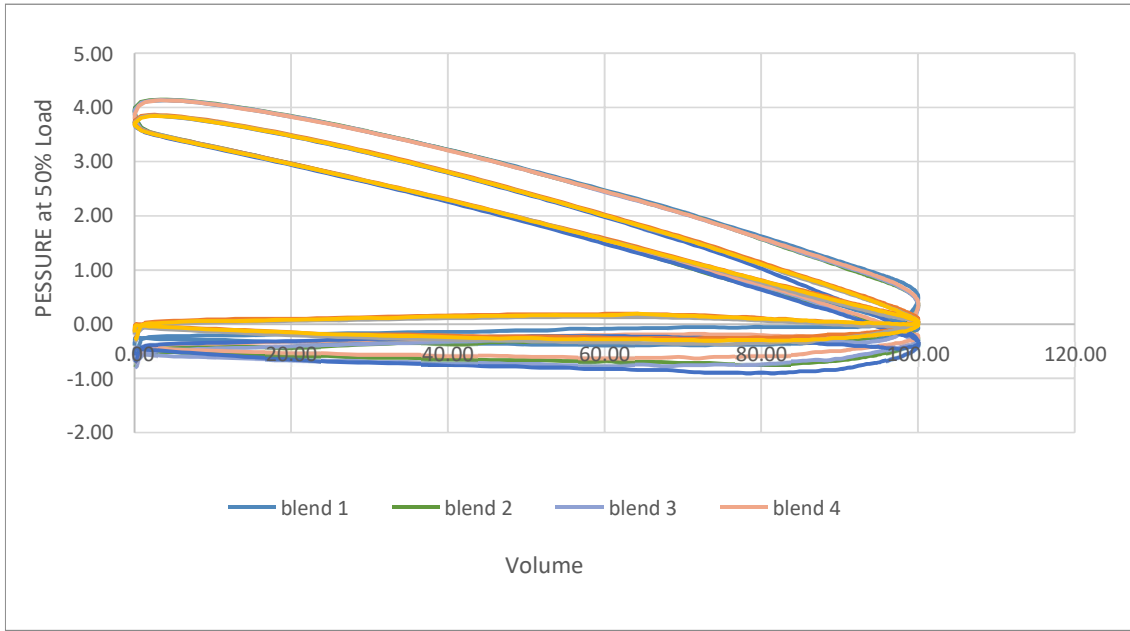


Figure 33: Pressure vs Volume at 50% Load

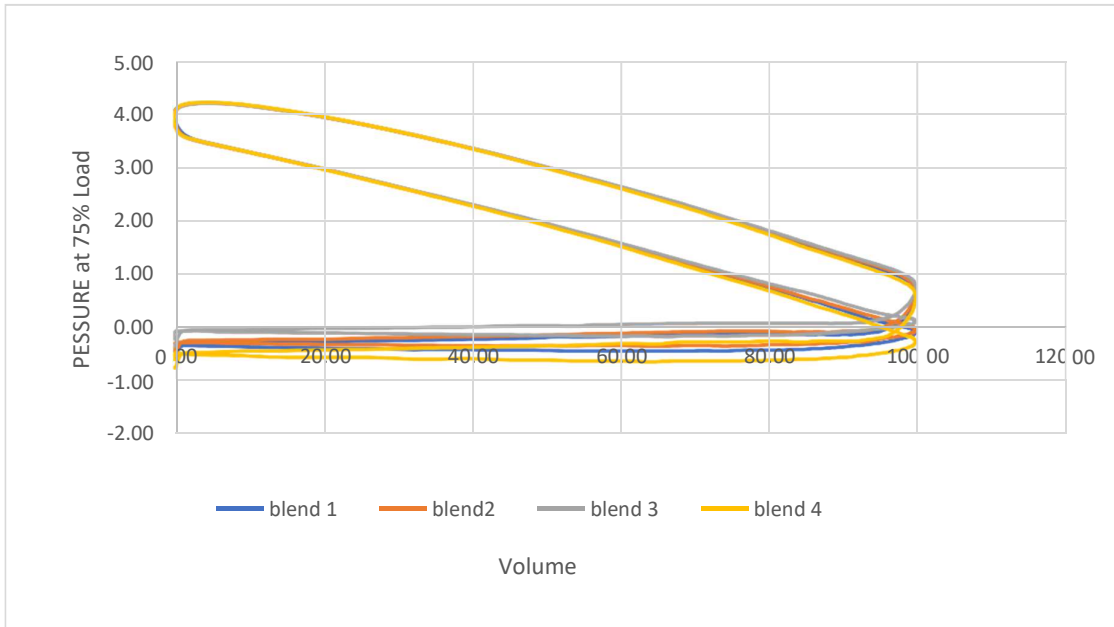


Figure 34: Pressure vs Volume at 75% Load

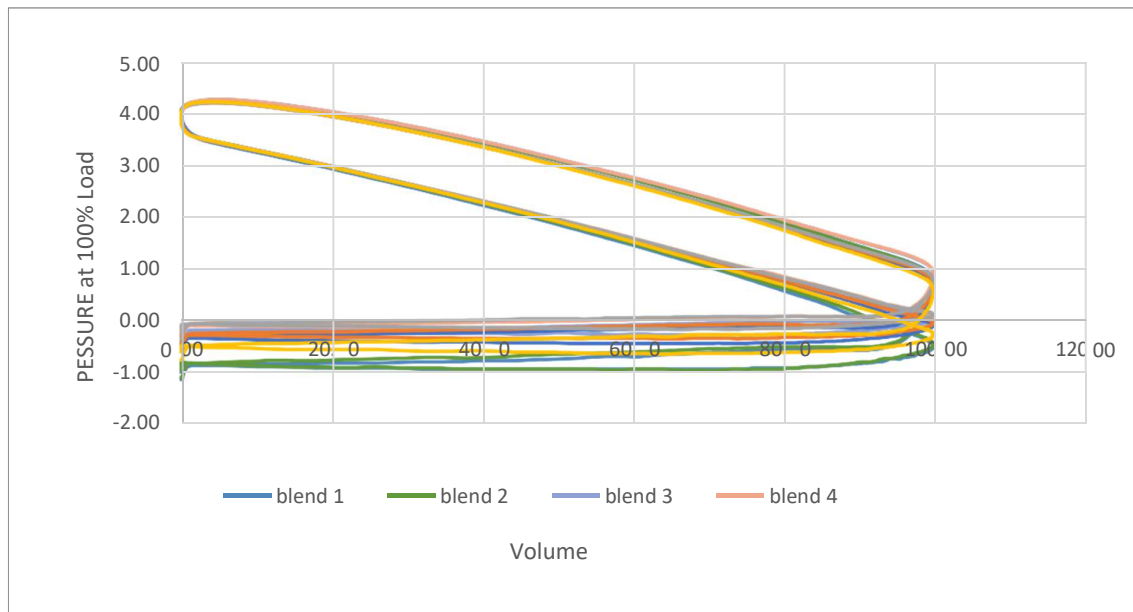


Figure 35: Pressure vs Volume at 100% Load

S.no	Load	Maximum Pressure	Minimum Pressure
1	0%	Blend 1	Blend 3
2	25%	Blend 3	Blend 1
3	50%	Blend 4	Blend 3
4	75%	Blend 4	Blend 3
5	100%	Blend 1	Blend 4

Table 8: Pressure graph readings

At 0% and 25% loads we can observe that all blends have shown a difference with blend 1 and 3 generating maximum pressure. At 50% load, blend 4 and blend show similar characteristics and at 75% load blend 4 and blend 2 show almost similar readings as well.

CHAPTER 6

CONCLUSION

An inference that can be drawn from extensive study and analysis is that producing a high-performance blend of biodiesel and bioethanol for engine experiments offers a potential alternative to traditional fossil fuels. The project's findings suggest that this blend can significantly reduce greenhouse gas emissions while maintaining engine efficiency. As a result, it provides a workable and long-term answer to the global energy crisis. To fully explore the benefits and real-world applications of this innovative technique, it is strongly urged that more research in this area be done.

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