

**EFFECTS OF 1-HEPTANOL BASED FUEL ADDITIVES IN CI
DIESEL ENGINE PERFORMANCE AND EXHAUST EMISSION
CHARACTERISTICS USING CANOLA OIL**

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

by

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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MARCH 2021



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **M. VENKATA NARAYANAN (Reg no: 37150207)** and **K N SHAKTHIVEL (Reg no: 37150175)** who carried out the project entitled “**EFFECTS OF 1-HEPTANOL BASED FUEL ADDITIVES IN CI DIESEL ENGINE PERFORMANCE AND EXHAUST EMISSION CHARACTERISTICS USING CANOLA OIL**” under my supervision from November 2020 to March 2021.

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DECLARATION

We, **M. VENKATA NARAYANAN (Reg no: 37150207)** and **K N SHAKTHIVEL (Reg no: 37150175)** hereby declare that the Project Report entitled **“EFFECTS OF 1-HEPTANOL BASED FUEL ADDITIVES IN CI DIESEL ENGINE PERFORMANCE AND EXHAUST EMISSION CHARACTERISTICS USING CANOLA OIL”** done by us under the guidance of **Mr. DILLIP KUMAR SAHOO, M.E., (Ph.D.)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr.S. Prakash, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr.G. Arun Kumar, M.E., Ph.D.**, Head of the Department, Dept. of Mechanical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Mr. DILLIP KUMAR SAHOO, M.E., (Ph.D.)** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Alcohols are excellent replacement fuels for compression ignition (CI) engines due to their inherent fuel-enhancing properties such as higher calorific value, higher cetane number, and so on. Higher-chain alcohols (hexanol-C1, heptanol-C2 and octanol-C3), are a promising candidate for potential diesel engine applications as compared to lower chain alcohols (methanol-C1, ethanol-C2 and propanol-C3). 1-heptanol which has seven carbon atoms in the chemical structure, has the best fuel properties of higher alcohol. The key objective of our research work is to examine the engine output and exhaust emission activity of a single-cylinder, four-stroke diesel engine with EGR(Comp.) Compression ignition (CI) diesel engine operating on blends of biodiesel/diesel fuel and 1-heptanol in different proportions, such as C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5. For experimental use, biodiesel fuel was synthesized from canola oil via a transesterification process in the presence of sodium hydroxide and methanol. In order to achieve engine output characteristics, the engine tests were conducted at five separate engine loads (0% 25 %, 50%, 75% and 100%) with a set engine speed of 1500 rpm. The experimental results revealed that the overall thermal brake efficiency for C25D74Hp5 blends was found to be 0.28% at 100% of the engine load relative to diesel fuel. The blending of 1-heptanol with a combination of diesel/biodiesel fuel leads to an increase in Specific Fuel Consumption leading to a reduction in the energy content of the blend. C10D89Hp5 Specific Fuel Consumption decreased by 0.164kg/kwh at 0% engine load compared to diesel fuel. This is due to the improved use of oxygen in mixtures. The addition of 1-heptanol as an oxygenated additive to the biodiesel/diesel fuel mix resulted in lower CO and unburned HC emissions while rising CO₂, O₂ and NO_x emissions compared to diesel fuel. It may be inferred that this paper addresses the feasibility of proposing blends of biodiesel-diesel-alcohol to supply the potential energy needs of the planet.

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LIST OF ABBREVIATIONS

BTHE	---	Brake Thermal Efficiency
SFC	---	Specific Fuel Consumption
CO	---	Carbon monoxide
HC	---	Hydro Carbon
NO_x	---	Oxides of Nitrogen
BTU	---	British Thermal Unit
COBF	---	Canola Oil Biofuel
S-LTC	---	Senior and Long Term Care
RSM	---	Response Surface Graph
ANOVA	---	ANalysis Of VAriance
BTE	---	Brake Thermal Efficiency
BSFC	---	Brake Specific Fuel Consumption
DBVOPro	---	Diesel/Biodiesel of Vegetable Oil with Propanol
DBVOPen	---	Diesel/Biodiesel of Vegetable Oil with Pentanol
HHV	---	Higher Heating Value
JB	---	Jatropha Biodiesel
FFA	---	Free Fatty Acid

CHAPTER 1

INTRODUCTION

Biofuels are fuel fuels derived from biomass, in other words, they are classified as fuel generated from plant matter and animal fat. The word biofuel refers to liquid fuels, such as ethanol and biodiesel, which are used as a substitute for transport fuels such as gasoline, diesel and jet fuel. There are two primary types of biofuels, ethanol and biodiesel. The only way to differentiate between the two is by using ethanol as an alcohol and by using biodiesel as a gasoline. Ethanol is an alcohol formed by fermentation and can also be used as an ingredient for biodiesel. Biodiesel is an alternative fuel, much like natural fossil fuels. Biodiesel is also made from vegetable oil, animal fat and vegetable oil waste. The process used to transform these oils to biodiesel is referred to as transesterification. Biofuels may be categorised as first generation, second generation and third generation depending on the type of feed used to produce them.

- Biofuels of the first generation are derived from food crops. For ethanol, feedstock includes sugar cane, wheat, maize, etc. Biodiesel feedstock are naturally occurring vegetable oils such as soya beans, canola, etc.
- Second generation biofuels are made from cellulose materials such as wood, grass and inedible pieces of plants. This needs pre-treatment before it can be recycled so the substance is tougher and impossible to break.
- Biofuels of third generation are made using lipids produced from algae.

Biodiesel is a liquid fuel also referred to as B100 or pure, unblended biodiesel. Like petroleum diesel, biodiesel is used for compression-ignition gasoline. It is normally formed by the chemical reaction of alcohol lipids that create carboxylic acid esters. Biodiesel has major environmental advantages in terms of lowered emissions, increased energy freedom, reduced global warming and also a positive impact on agriculture. Biodiesel has a reduced sulphur content but has a significantly higher cetane rating than other low-sulphur diesel fuels. The addition of biodiesel decreases the wear of the fuel system and extends the life of the fuel injection system. Carbon-di-oxide is one of the major greenhouse gases. Since the combustion of biodiesel emits about as much CO₂ emissions as ordinary fossil fuels, the plant feedstock used for its processing extracts CO₂ from the environment when it develops. Biodiesel has a wide range of uses in the automotive and

electricity storage sectors. For e.g., the Volkswagen Group has issued a clarification that some of its vehicles are compliant with B5 and B100, made up of rapeseed oil.

1.1 WHY WE USE BIODIESEL?

The use of biodiesel is a way to reduce the global warming caused by humans. Vehicles are large sources of CO₂ emissions into the atmosphere, the greenhouse gas causing global warming, leading to the melting of icebergs. Recent studies have shown that the use of biodiesel decreases GHG emissions by more than 76% compared to diesel oil.

1.1.1 Lower greenhouse gas emissions:

Biodiesel processing is part of the carbon cycle. Unlike diesel fuel, biodiesel feedstock is not excavated from underground and does not emit CO₂ into the atmosphere for a long time. Biodiesel is instead produced from oil seed crops that absorb CO₂ in the air; as biodiesel is burned, CO₂ is released back into the atmosphere to complete the carbon cycle.

1.1.2 Better for our air:

New diesel engines are pretty clean. But diesel engines last for 30 years or more, so older engines currently on the road can enjoy clean fuel like biodiesel. The most noticeable benefit of biodiesel is that it does not have the insufferable scent and black smoke of diesel oil. Biodiesel is 11 per cent oxygen, which means that even when blended like B20, it helps to burn the hydrocarbons. Biodiesel eliminates emissions and, as a result, the exhaust from biodiesel combustion engines looks much healthier than diesel engines, although the amount of black soot is decreased.

1.1.3 Safer:

Biodiesel does much less harm than fuel oil when it is leaked or released to the atmosphere due to greater biodegradability of biodiesel. It's better than diesel and it's less fuel-efficient. The flash point for biodiesel is over 130°C (266°F) compared to around 52°C (126°F) for petroleum diesel. Biodiesel is safe for handling, storage and transport. The use of biodiesel as a transportation fuel improves air quality and the atmosphere, increases energy security and offers safety benefits.

1.1.4 Good for our engines:

Biodiesel can prolong the life of diesel engines because it is more lubricating than diesel oil. Biodiesel either has a higher cetane number or increases the cetane number of the fuel when combined with petroleum diesel. Higher cetane number means that it ignites quicker in the engine, but is less volatile and generally cleaner than diesel. Biodiesel has a somewhat higher oxygen content, which increases combustion and lowers emissions but has little energy benefit.

1.1.5 Economic opportunity:

Biodiesel has the ability to provide tremendous benefits for rural populations and producers by providing a demand for crops. Many people have worked to build an industry in their areas to keep some of their oil money going out of the city, the state, and the country. Biodiesel is thus a domestically made, clean-burning, green alternative for petroleum diesel. The use of biodiesel vehicle fuel improves air quality and the atmosphere, increases energy security and offers safety benefits. We choose canola oil as biodiesel in this project.

1.2 CANOLA OIL:

Canola oil was manufactured in Canada for the first time in 1974. Genetic alteration of rape seed contributes to a decrease in the concentration of erucic acid and glucosinolate. Unlike certain varieties, 'rapeseed' and 'canola' do not come from a single plant and do not generally apply to the same variety. The term "rapeseed" refers to oil seeds of the genus *Brassica napus* and *Brassica rapa*, while the term "canola" refers to unique varieties of rapeseed breeds for the supply of edible materials for human and animal consumption. These edible varieties must contain less than 2% erucic acid and 30 μmol glycosinolates per gram of air-dried oil-free meal. After palm oil and soya oil, canola oil is the third largest vegetable oil in the world, with the major producers in China, the EU 27, Canada, India and Japan. Canola oil is produced primarily from the seeds of genetically engineered *Brassica napus* L., but a small portion of canola oil is obtained from *Brassica rapa* L. *Brassica napus* is a member of the Brassicaceae family which consists of approximately 25 tribes, 338 genera and 3709 species. Canola oil is known only as a vegetable oil with a sulphur atom in some carboxylic acid structures that are responsible for the sulphur smell of the oil. Many dietitians agree that canola oil should be found to be the healthiest edible oil.

1.2.1 Origin and history of canola oil:

The centre of origin of *Brassica napus* is uncertain; some scholars assume that it originated in Mediterranean Europe, while others favour several centres of origin. Rapeseed (including *B. napus*) has been grown in Asia, Europe and North West Africa since ancient times as a source of oil for fruit, candles, soaps and later for industrial purposes. In Canada, rapeseed has been commercially produced in the western provinces since the middle of the 20th century, acting as a lubricant for steam engines. The cultivation of rape seed in Canada grew significantly during the First World War, with the goal of securing a gentle supply of industrial lubricants at the end of the war, Rapeseed production decreased due to reduced demand for industrial lubricants.

The war has produced an influence among Canadian suppliers as a result of which Canadian plant breeders have begun to cultivate edible oil alternatives. By mid-1950 rape oil was fully recognised in the West as edible oil and breeding schemes started to specialise in low-erucic acid and low-glucosinolate varieties for human and animal use. The primary viable agronomical low-erucic acid and low-glucosinolate variety was published in Canada in 1974 and the name "Canola" was extracted from "Canadian oil" in 1978. Originally the trade name, "Canola" is now a common word for the edible form of rape seed. In Canada, canola is officially identified as: "An oil that must contain <2% of erucic acid and <30µmol of glucosinolates per gram of air-dried oil-free meal."

Canola is now ranked among the world's top oil seed crops. In comparison, canola oil is the most commonly used edible oil in Canada's domestic market. Canola meal, a by-product of the oil seed extraction method of grinding, has also been widely accepted as meat, poultry, pigs and fish feed. Rapeseed remains grown to a lesser degree in North America for manufacturing uses (e.g. high quality lubricants, hydraulic fluids, plastics, etc.) and for use in food production (e.g. Candy bars or as an emulsifier in peanut butter, etc.).

1.2.2 Habitat:

In Canada, rapeseed is grown in summer temperatures ranging from 13°C to 16°C, in winter temperatures ranging from -14.5°C to -8°C and in average annual precipitation up to 700mm. When measured at a temperature of 0°C, these

organisms would take an average of 1560 growing days to mature. From this we can infer that rape seed plants thrive only in delicate conditions.

1.3 WHY DO WE USE CANOLA OIL AS A BIODIESEL?

The rapeseed plant, which is grown in revitalised prairie agriculture, has the ability to have a new golden opportunity-biodiesel-for farmers, manufacturers, retailers and consumers. The characteristics that make canola oil the healthiest alternative of all vegetable oils also make it the best candidate for biodiesel.

1.3.1 High efficiency:

Canola seed contains more than 43 per cent of oil, which is more than other oil seeds, such as soya beans containing about 18 per cent of oil. As a result, canola is a highly powerful feedstock for biodiesel. Over the last three years, the oil content ranged between 43% and 44% of the crop and is projected to rise further. The importance of Canola is in the oil portion. It is only fitting for the industry to continue to concentrate on this area of strength, particularly given the increasing global demand for vegetable oils. It was not difficult to reassure the industry that increasing oil content would benefit those involved in the supply chain.

1.3.2 Better biodiesel:

Canola, in addition to its high oil quality, has many important benefits for biodiesel manufacturers and customers. Canola is the lowest saturated fat content of all large vegetable oils, at just 7%. Since canola oil has a low saturated fat content, its consistency is stronger in cold weather. Petroleum diesel crystallises or gel at cold temperatures, too. The temperature at which small stable crystals form in the fuel is 3°C(37°F) of pure canola biodiesel.

While low saturated fat levels increase productivity in cold weather, pure canola biodiesel also contains 10% oxygen by weight. This oxygen triggers a reduction in hydrocarbons, toxic components, carbon monoxide and particulate matter emissions. These benefits apply to biodiesel blends, which are often burning in diesel engines. As a result, canola biodiesel burns cleaner than straight fuel oil.

Fortunately, the high-stability canola profiles that have been so successful in producing trans-fat-free alternatives for the food industry have all the advantages of conventional canola oil profiles plus one: increased oxidative stability. Iodine levels have declined and oxidative stability has improved as polysaturated fatty acids have decreased in higher stability of canola oil. Many other potential qualities, such as

high oil content, lower saturated fat content, lower polysaturated fatty acid content, have benefits for both fuel and food applications.

1.3.3 Eco-friendly fuel:

Canola biodiesel emits about 12 per cent of the carbon dioxide generated by diesel oil. When any of the conventional methods of canola cultivation are taken into account, the disparity becomes much more pronounced. Biodiesel produces about 0.4 kg of carbon dioxide per litre and 0.6 kg of nitrogen oxides per litre of fuel, according to the Intergovernmental Panel on Climate Change, compared to 4 kg of carbon dioxide per litre of diesel oil. Biodiesel canola degrades five times faster than fuel oil, reducing greenhouse gas pollution. Canada records an average of 3,500 diesel spills per year, each weighing an average of 9 tonnes (9.9 tonnes). Pure biodiesel will take one to two weeks to degrade, but biodiesel mixes will degrade much faster than fossil fuel.

1.3.4 Food and fuel:

Canola oil, whether for food or gasoline, contains canola meal, which is an ideal feed for animals. More food production in the form of dairy and poultry will benefit from an increase in the supply of canola meal. Canola meal prices may decline as a result of increased use of canola oil, making it a more attractive feed commodity for the livestock and dairy industries.

1.4 PRODUCTION AND DISTRIBUTION OF CANOLA OIL:

Canola (*Brassica napus*) is one of the top five oilseed crops in the world and the most important oilseed crop in Canada. Due to its high nutritious value and flavour, canola oil is witnessing fast growth in the industry. The market is expanding due to increased demand for canola oil due to its high nutritional value and wide range of industrial applications. Canola oil has a peculiar fatty acid composition, low levels of saturated fatty acids, high levels of monounsaturated fatty acids and high levels of omega-3 and omega-6 fatty acids. Omega 3 and omega 6 fatty acids in canola oil support heart health. As a consequence of this vital feature, most consumers around the world add canola oil to their everyday use. Canola oil is a strong source of vitamin E, an antioxidant that prevents body fats and proteins from free radicals, so the global market for canola oil is booming. As a result of all these reasons, Canola has become one of the most valuable oilseed crops in the world. Some of the leading

Rapeseed producing countries are listed in the [Fig 1.1](#) Behind palm oil and soya oil, canola oil is the third largest vegetable oil by amount.

Sonora Foods (Canada), Archer Daniels Midland Corporation (US), Associated British Foods plc (UK), Jivo Wellness Pvt. Ltd. (India), Wilson Foods (USA), Arla Foods AmbA (Denmark), Richardson International Limited (Canada), Dalmia Continental Pvt. Ltd. (India), Borges International Group, S.L. (Spain), Louis Dreyfus Company B.V. (Netherlands), Borges International Group (UK). The above listed are the main organisations processing canola oil in the world.

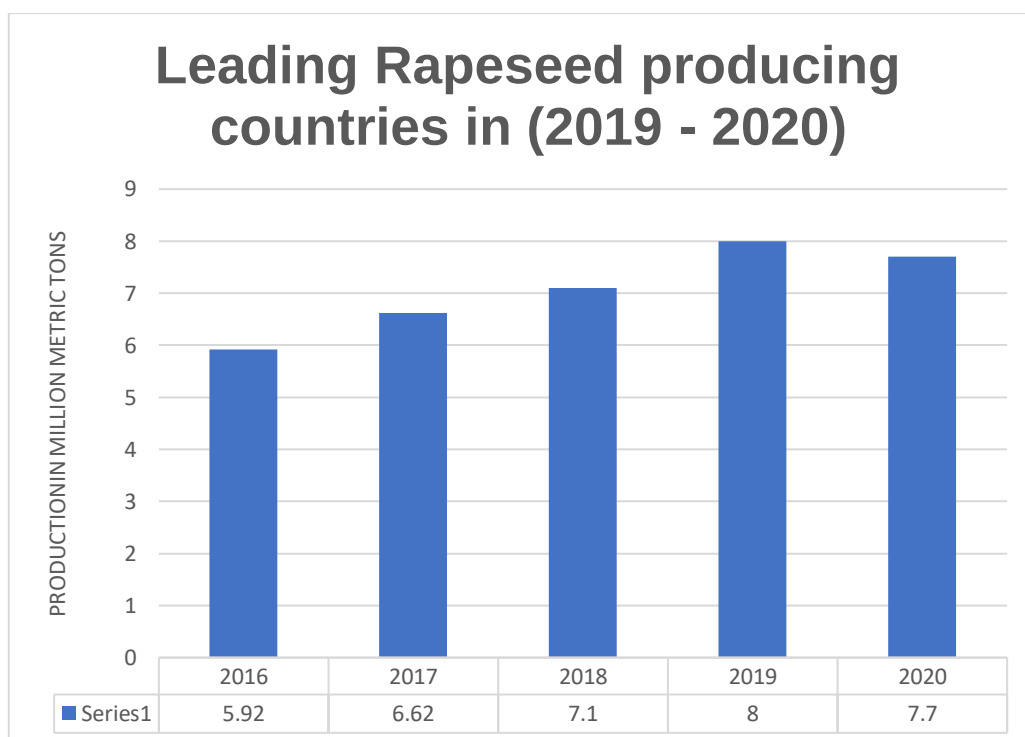


Fig 1.1 Leading Rapeseed producing countries in (2019-2020)

Courtesy: Statista.com

The transition in dietary tastes from animal to vegetable products as a result of increased public health issues is a significant driver of increased adoption of rapeseed oil. In addition, increasing demand for dietary fats and oils has helped to expand the rapeseed oil industry.

1.4.1 Production of Rapeseed in India:

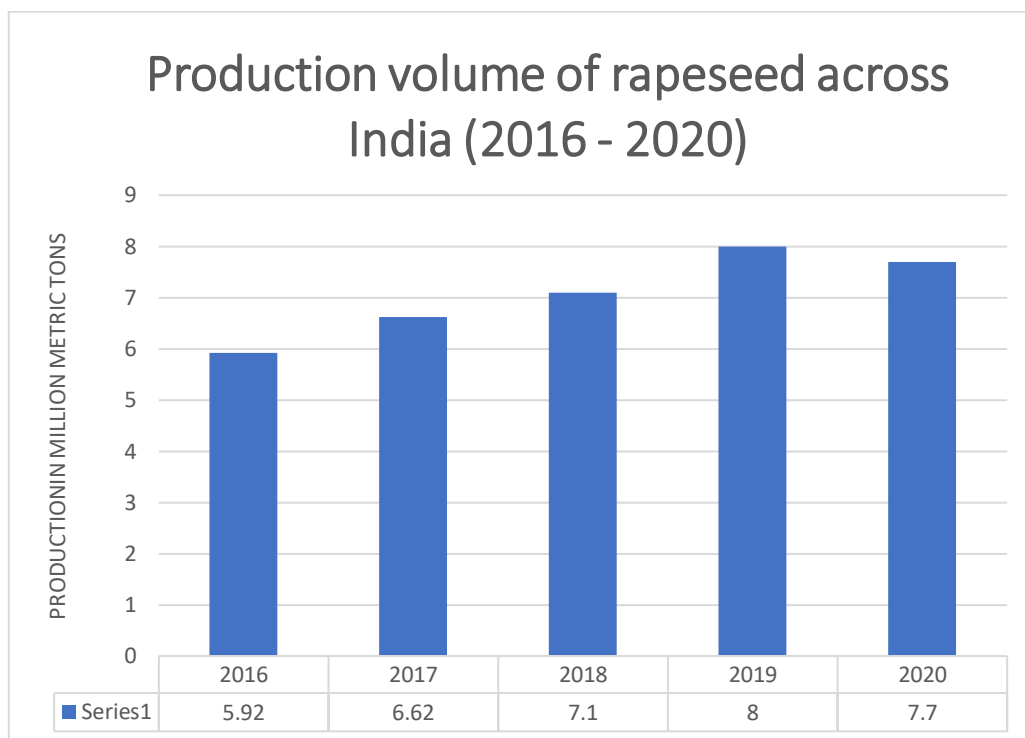


Fig 1.2 Production volume of rapeseed across India (2016-2020)

Courtesy: Statista.com

At a news conference in the north-western state of Rajasthan, which produces more than half of India's rape seed, the Solvent Extractors' Association of India (SEA) said that production amounted to 7.8 million tonnes in the June 2020 crop year. Good weather has led to higher yields in most parts of the region. The production volume of rapeseed across India is shown in the [Fig 1.2](#). According to the SEA, farmers planted rapeseed on 6.95 million hectares (17 million acres) this year, marginally smaller than last year's 6.98 million hectares (17.2 million acres). Crop yields are forecast to be 1,119 kg per hectare in 2019/20, up from 1,075 kg per hectare in the previous year, according to the report. Increased production of rapeseed will help India minimise the cost of imports of vegetable oil, the country's third-largest import of crude oil and gold.

New Delhi imports almost two-thirds of its vegetable oil needs, which are increased increasingly due to an increasing population, rising income levels and a preference for calorie-dense curry and deep-fried foods. India has historically purchased tropical palm oil from Indonesia and Malaysia, as well as soft oils such as soya oil from Argentina and Brazil, to compensate for the shortfall in soya, rapeseed and

peanut production. Sunflower oil from Ukraine and Russia, as well as canola oil from Canada, is also imported from New Delhi. Two-thirds of India's imports of vegetable oil are palm oil. However, efforts to increase domestic oilseed production have failed to force India to invest foreign exchange reserves on cooking oils and fats. Over the last two decades, India's consumption of vegetable oils, such as palm oil and soya oil, has tripled as population and incomes have risen, while demand has remained relatively steady.

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE STUDY ON BIODIESEL:

Suleyman Simsek et al. (2020): The effects of biodiesel ratio, engine load on engine efficiency and emission parameters were investigated by RSM in this study. The research is unique in that it uses RSM to optimise the working conditions of an engine that runs on biodiesel/diesel fuel blends. Experiments were carried out in a diesel engine with biodiesel blends of canola, safflower, and waste vegetable oil at varying engine loads and injection pressures. Biodiesel ratio and engine load were chosen as input parameters for the RSM, while BTE, EGT, NO_x, CO₂, and smoke were chosen as output parameters. BTE, EGT, NO_x, CO₂, and smoke were observed to have R² values of 99.81 percent, 99.36 percent, 98.31 percent, 99.00 percent, and 98.84 percent, respectively. Validation testing for BTE, EGT, CO₂, NO_x, and smoke yielded mean errors of 3.813 percent, 1.5 percent, 7.264 percent, 3.795 percent, and 5.714 percent, respectively. When the effects of optimization were compared to experimental results, it was discovered that the RSM methodology yielded good results and acceptable error rate. As a consequence, the RSM templates can be used. Defining the right engine operating parameters for optimization the response of the engine in terms of output and emissions.

Oguzhan Ilgen et al. (2009): In this research paper the biodiesel output, the effects of the methanol/canola oil molar ratio, reaction temperature, KOH loadings, reaction time, and catalyst volume were studied. One of the most important factors influencing the conversion to methyl esters is the molar ratio of methanol to canola oil. In principle, 3mol of methanol is required for each mole of triglyceride, but in reality, a higher molar ratio is used to speed up the reaction and create more methyl esters as a result. At four separate methanol/canola oil molar ratios higher than the norm, the dependency of canola oil conversions and ester yields on the methanol/canola oil molar ratio was investigated. In the presence of 10wt% KOH/MgO stoichiometrical ratio catalyzer. In this research paper we can also infer that the intrinsic rate constants are strong functions of temperature, the reaction rate

and biodiesel yield can be affected by the reaction temperature. 21 Methanolysis is a term used to describe the process of converting carbon dioxide into methane which is carried out at atmospheric pressure above the boiling point of methanol with a lot of strain. The results of reaction temperature were investigated in this research

J.C. Ge et al. (2018): When fossil fuels are burned in cars, a category of chemicals known as volatile organic compounds (VOCs) is released in significant amounts. The VOCs in exhaust emissions from a common rail diesel engine fuelled with canola oil biodiesel fuel (COBF), traditional diesel fuel (CDF), and B20 (20 percent COBF blended with 80 percent CDF by volume) at different engine loads (30 Nm, 80 Nm, and 130 Nm) and a constant engine speed of 1500 rpm was investigated in this report. The findings show that when COBF and B20 were used in a CRDI diesel engine, controlled emissions (CO, HC, and PM) were greatly reduced, and that CDF emits a greater number of VOCs (about 30 types) and a greater quantity of B20 and COBF. VOC emissions are used to produce an alternative fuel. The combustion and exhaust emission characteristics of the CRDI diesel engine fuelled with CDF, B20, and COBF (including controlled and uncontrolled emissions) were compared under different conditions of engine loads and a steady 1500 rpm engine speed.

Veera Raghavulu K et al. (2020): The effect of biodiesel extracted from canola oil and snake gourd oil biodiesel blended with diesel is seen in this research paper. According to the findings of this study, increasing biodiesel concentration in diesel–biodiesel blends reduces engine efficiency and has some positive effects on pollution characteristics. On both performance and emission characteristics, canola oil biodiesel outperformed snake gourd oil. Biodiesel fuels are seen to be a viable alternative to crude oil fuels in this analysis. Any of these blends also reduce the emissions released by the combustion of diesel fuel. CB5, CB10, CB20, SB5CB5 and SB10CB10 performance characteristics were compared. It was discovered that adding snake gourd oil did not yield better results than canola oil; in effect, it increased contaminants like CO and HC. The efficiency of the blends was increased when the proportion of blends was decreased. More analysis can be performed by varying the injection parameters and adding additives to these blends.

Amin Nedayali et al. (2016): The effect of biodiesel from waste cooking oil and diesel fuel blends (B0, B20, B50, B80, and B100) on the performance characteristics of a diesel power generator model CAT3412 (brake power, brake torque, BSFC, and brake thermal efficiency) was investigated in this research. The tests were carried out at a rated engine speed of 1530 r/min with different engine loads (25 percent, 50 percent, 75 percent and 100 percent). B20 has the highest braking thermal performance of the diesel power generator at max engine load of all the fuel mixtures. The study's findings also indicate an improvement in braking strength, torque, and thermal performance, as well as a decrease in BSFC at higher engine loads for all biodiesel-diesel blends. The test results suggested that fuel mixtures containing 20% and 50% biodiesel (particularly B20) could be recognised as potential candidates for certification for use in diesel power generators in terms of performance characteristics.

2.2 LITERATURE STUDY ON NEXT GENERATION HIGHER ALCOHOL:

Dogan B et al. (2020): In this research paper it is studied that the impact of different heptanol-diesel fuel blends on output and exhaust emissions in a single-cylinder compression-ignition engine were studied in this analysis at a constant engine speed of 1500 rpm for four different load values (25 percent -100 percent). Additionally, the data collected from the engine are used to perform environmental and economic assessments. It was found that as the volume of heptanol in heptanol diesel blends increased, fuel consumption increased in contrast to pure diesel fuel. In all loads, Hp0 fuel used 3–6%, 4–8%, and 7–11 percent less fuel than Hp5, Hp10, and Hp20 blends, respectively.

It was discovered that increasing the engine's load improved the exhaust exergy flow. With the addition of heptanol to the mix, exhaust exergy in heptanol fuel blends reduces in contrast to pure diesel fuel with the same engine load prices. In comparison to pure diesel fuel, heptanol fuel blends have a higher rate of energy destruction. The maximum exergy destruction in Hp20 fuel at a 25% load was estimated to be 3.08 kW, while the lowest exergy destruction in Hp0 fuel at a 100% load was calculated to be 1.94 kW. As a result, since heptanol fuel blends behave similarly to pure diesel fuel, they can be used as a substitute for diesel fuel.

However, heptanol's extremely high fuel cost renders it difficult to use as an alternative fuel in today's setting.

Nour M. et al (2019): Using a direct-injection single-cylinder air-cooled CI engine, the effects of butanol/diesel, heptanol/diesel, and octanol/diesel blends on diesel engine combustion, output, and emissions were investigated. In addition to the base diesel fuel, experiments were conducted with alcohol/diesel mixing ratios of 10% and 20% by volume. All of the blends were tested for stability and homogeneity over a four-month span, and no phase separation was detected. The blends were tested under a number of engine loads, varying from no load to 100% of the engine's maximum load, with a 25% step. And, to cover a broad variety of engine operating conditions, the tested engine speeds were 900 rpm (idling speed) and 1500 rpm (engine rated speed).

Erdiwansyah. et al (2019): Conventional fuels are known to be fast-depleting and detrimental to the earth when they emit dangerous chemicals into the atmosphere. Higher Alcohol and Biodiesel are the most promising alternative fuels extensively researched due to their affordability, ease of processing and environmental benefits. The use of alternative fuels such as alcohol and biodiesel in engines is intended to reduce air emissions and electricity costs. The most widely used higher alcohol fuel include bioethanol, isopropanol, propanol, ethanol-methanol, butanol, n-butanol, tert-butanol and isobutanol. Biodiesel widely used is extracted from waste cooking oil, Pyrolysis oil, Palmoil, Jatropha oil and Karanja oil. And the oil of Linn. The aim of this research is to assess engine efficiency and combustion characteristics using alternative fuels such as alcohol and biodiesel. The impact of alternative fuels on pollution properties such as NO_x, CO and HC are also summarised.

Atmanli et al. (2020): From this research paper it is understood that higher alcohols in biodiesel can minimise density, viscosity, boost atomization, auto-ignition characteristics, and provide additional oxygen content, potentially providing S-LTC and reducing NO_x emissions. Bio alcohols like C₃, C₄, and C₅ can be manufactured from waste or lignocellulosic materials using modern packaging methods and used as biodiesel additives in IC engines. Engine output and exhaust emissions of a diesel engine operating on different blends of WBC₃, WBC₄, and WBC₅ were

investigated for this reason in order to achieve S-LTC However, further research is needed to make them economically competitive and meet the rigorous pollution requirements that are necessary.

Subramani S et al. (2020): Higher alcohols (n-propanol, n-butanol, and n-pentanol) were investigated as a source for NO_x and smoke control in a compression ignition engine that was blended with diesel and biodiesel. Different combinations of injection timing, injection strength, and EGR fueling with these higher alcohol blends were checked. Due to improved atomization in the combustion chamber, the BSFC value is lower than expected, as seen by the response surface and contour plots. Because of the low peak pressure and temperature created by the high cetane number and high energy density, the NO_x Design points values are lower than anticipated. Because of the proper air fuel ratio and a lower percentage of carbon content in the mix, the Smoke Design points are lower than anticipated. When compared to the engine's normal operating conditions, this investigation resulted in a 31 and 37 percent reduction in NO_x and smoke emissions, respectively, as well as a 24 percent reduction in the BSFC.

Yilmaz N et al. (2018): From an environmental and economic standpoint, using alternative fuels in diesel engines with a high proportion of biofuel blend is useful. Alternative fuels such as vegetable oils and alcohols must be incentivized for production and use in multiple sectors in order to produce a 20 percent biofuel in diesel engines by 2020. The use of biofuel in diesel engines is improved by quaternary blends of vegetable oils, biodiesel, and alcohols with diesel. Thus, without changing the engine, the effects of applying higher alcohols (propanol and pentanol) to diesel biodiesel vegetable oil blends on engine output and exhaust emissions were explored in this research. The following are the key results of this research: Based on the results of this report, it is fair to conclude that DBVOPen and DBVOPro can be used as diesel fuel substitutes despite their low fuel efficiency. Furthermore, prospective studies should concentrate on a thorough examination of engine reliability.

Atabani A E et al. (2019): The aim of this experiment was to recycle and valorise waste cooking oil and oil derived from spent coffee grounds for biodiesel production.

The acid content of spent coffee grounds was greatly lowered as a result of this technique. Furthermore, due to the presence of changed structure in the fatty acids composition, the biodiesel's oxidation stability, HHV, cetane number, and iodine value increased. To boost density, kinematic viscosity, and cold flow properties, the biodiesel was blended with Euro gasoline, butanol, pentanol, and hexanol. This study shows that mixing waste cooking and used coffee grounds oils improves biodiesel properties and helps the industry's economics. The paper frequently encourages conservation as a way of protecting the environment. In comparison to lower alcohols, blending with higher alcohols increases the density and cold flow properties of biodiesel while maintaining appropriate levels of cetane number, flash point, and HHV. As a result, this analysis will be continued in the future research to determine the efficiency of compression ignition engines.

Murat Kadir Yesilyurt et al (2020): In this research paper it is observed that the effects of 1-heptanol (C7 alcohol) with diesel fuel and a peanut oil methyl ester/diesel fuel blend on CI engine efficiency, exhaust gas emissions, and combustion behaviour at various engine loads (from 25% to 100%) at a constant engine speed of 1500 rpm have been thoroughly investigated, and the results have been compared with traditional diesel fuel and a peanut oil methyl ester/diesel fuel blend. The addition of 1-heptanol as an oxygenated additive to diesel fuel and biodiesel/diesel fuel mix has resulted in lower CO and unburned HC emissions while increasing CO₂, O₂ and NO_x emissions relative to diesel fuel. It may be concluded that this paper addresses the feasibility of proposing mixes of biodiesel-diesel-alcohol to meet the potential energy needs of the planet.

Mahalingam A et al. (2017): In this study it is observed that, octanol, with its high cetane amount and energy quality, can be a perfect replacement fuel for current diesel engines. It is important to perform a detailed inquiry into the use of octanol as a diesel engine additive. The emission characteristics of neat mahua oil biodiesel blended with various proportions of octanol in stationary diesel engines are investigated in this analysis. Traditional transesterification is used to make Mahua oil biodiesel. The key goal of this research is to use octanol to mitigate various emissions from mahua oil biodiesel. By applying octanol in varying amounts to mahua oil biodiesel, this study discovered a substantial reduction in all pollution

associated with the biodiesel. The following findings were obtained by applying octanol to neat mahua oil biodiesel in amounts of 10% and 20% on a volume basis.

Devaraj A et al (2020): This research contrasts the emission patterns of compression ignition engines using Jatropha (J100), Deconal blends of Jatropha (JB90D10, JB80D20), and traditional diesel engines (D100). At different load conditions, emission parameters such as hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxides (NOx) were analysed using a gas analyser. Deconal can be blended directly with biodiesel without any additives. The engine runs quietly and smoothly, and no harm to the engine components has been discovered. With an increase in NOx emission, jatropha biodiesel contains lower amounts of carbon monoxide and hydrocarbon. As Deconal blends are added to JB100, the fuel consumption is reduced as compared to diesel at all loads. JB100, JB90D10, and JB80D20 emission parameters are equivalent to D100.

Purnachandran Ramakrishnan et al (2018): The higher alcohol, n-pentanol, was added to Calophyllum inophyllum (CI) biodiesel/diesel blends at 10, 15, and 20% by volume in this analysis. The CI ratio was kept stable at 20% by volume in all blends. The engine characteristics of the pentanol fuel blends were compared to those of diesel and the CI20 biodiesel blend (Calophyllum inophyllum 20% and diesel 80%). The nitrogen oxide (NO) emissions of pentanol fuel blends were higher than those of CI20 and pure diesel. The amount of carbon dioxide (CO₂) emitted increased with the addition of pentanol to fuel blends other than CI20 and diesel. Increased pentanol proportion in the mixture reduced carbon monoxide (CO) and hydrocarbon (HC) emissions compared to CI20 gasoline and diesel. The use of pentanol blended fuels minimised smoke emissions while also enhancing the engine's combustion characteristics. According to the results, adding 20% pentanol to biodiesel/diesel fuel increases the efficiency and combustion characteristics of a diesel engine without needing any engine changes, while CO₂ and NO emissions increased due to efficient combustion with the addition of pentanol.

Yesilyurt M K et al. (2020): The lack of petroleum-based fuels and the rise in emission levels have been the driving factors behind the development of new and exciting alternative fuel blends for compression-ignition (CI) engine applications. In

this sense, research on green and sustainable fuels for diesel engines, such as vegetable oils, biodiesel, and alcohol, has been underway for quite some time. Pure vegetable oils or biodiesel fuels, on the other hand, cannot be used in diesel engines without being accompanied due to their high viscosity and density.

As a result, there is a lot of scope for using quaternary blends of biodiesel vegetable oil, alcohol, and diesel fuel to increase density and viscosity. Diesel fuel was combined with biodiesel (safflower oil methyl ester), biodiesel-vegetable oil (safflower oil), and biodiesel-vegetable oil-alcohol (ethanol-C2, isopropanol-C3, n-butanol-C4, or isopentanol-C5) mixtures in the current research. The test fuels of diesel–biodiesel (80–20%), diesel–biodiesel–vegetable oil (70–20–10%), and diesel–biodiesel–vegetable oil–alcohol (60–20–10–10%) blends were prepared using the splash blending technique and tested in a single-cylinder, four-stroke, air-cooled, direct-injection diesel engine generator set to investigate output, combustion, and exhaust emissions. The engine test results showed that the fuel blends' brake specific fuel consumption improved by 4.54 percent to 27.82 percent as compared to diesel fuel, while brake thermal performance decreased due to the lower calorific value. As opposed to gasoline, the average pollution values of all the measured fuel blends decreased. The addition of different alcohols to the ternary blends resulted in a rise in in-cylinder pressure and a decrease in heat release volume, according to the combustion characteristics. The diesel–biodiesel–vegetable oil–pentanol blend was found to be a suitable fuel mixture for improving efficiency, combustion habits, and lowering exhaust emissions.

2.3 PROBLEM IDENTIFICATION:

Diesel engine emissions contribute to the creation of ground-level ozone, which is detrimental to crops, trees, and other vegetation. Acid rain is also created, and has an effect on land, waterways, and streams, as well as entering the human food chain by water, produce, meat, and fish. Property loss and decreased visibility are also caused by this pollution. Human activities such as driving vehicles and heavy-duty, diesel-powered trucks and buses, as well as coal combustion, are the main causes of air emissions. Diesel exhaust can cause severe health issues such as asthma and respiratory disorders, as well as intensify underlying heart and lung disease, especially in children and the elderly. Increased emergency department visits, hospital stays, absences from work and education, and premature deaths may all result from these circumstances.

Fine particulate matter (also known as PM_{2.5}) is a significant contributor to air pollution. These particles are so small that they can penetrate the lungs and digestive system, increasing the risk of stroke, pulmonary disease, lung cancer, and pneumonia. A main factor in the formation of PM_{2.5} air emissions is black carbon, a super-pollutant that also leads to climate change. PM 2.5 particles are tiny enough to move across the skin and into the bloodstream. Air and water quality, weather conditions, sea levels, fisheries, and agriculture are all affected by climate change. Improved fuel efficiency and idle elimination policies will better combat climate change, boost our nation's energy stability, and enhance our economy by lowering greenhouse gas (GHG) emissions from diesel engines. We get a decrease in black carbon emissions as we reduce air pollution from diesel sources. This is a major victory for the environment and air quality.

Biodiesel is a biofuel made from vegetable oil. Biodiesel is a straight chain of carbon atoms that can be saturated or unsaturated depending on the source of feedstock oil. Biodiesel is made up of mono alkyl esters of free fatty acids derived from vegetable and animal fats. It may be used alone or in mixtures of petroleum-based diesel fuel. Triacylglycerides, which are three fatty acid chains attached to a three-carbon skeleton known as glyceride, are present in all oils. So when we use biodiesel as a fuel, emission is reduced drastically. The emission of major pollutant CO, HC and NO_x are very minor when compared to diesel. On the other hand, biodiesel is also more efficient than petroleum diesel.

CHAPTER 3

AIM AND SCOPE

The main aim of our project is to obtain biodiesel from canola oil using transesterification process, blending it with different compositions of petroleum diesel and 1-heptanol as higher alcohol fuel additives then testing it in the VCR engine at different varying load conditions for performance and emission characteristics.

In the light of the above-mentioned parts of the literature review, it is clear that there is a large gap in the performance, combustion behaviour and environmental characteristics of diesel engines operating with 1-heptanol blends, in particular with low mixing proportions, i.e. up to 20% by volume of 1-heptanol.

In our day-to-day life we face many problems due to usage of diesel fuels.

This study was carried out to determine the characteristics of canola development and conversion to biodiesel.

- The optimization is used to increase brake thermal efficiency (BTE) while lowering exhaust gas temperature (EGT), smoke, nitrogen oxide (NO_x) emissions, and carbon dioxide (CO₂) emissions. In a four-stroke, single-cylinder, air-cooled, direct injection diesel engine, the effects of different rates of biodiesel/diesel fuel blends on engine performance and exhaust emissions were investigated experimentally.
- Since biodiesel has been recognised as a viable alternative to conventional diesel fuel, we've been experimenting with diesel engines powered by biodiesel derived from a variety of sources to see how it affects engine parameters.
- Biodiesel made from canola degrades five times faster than petroleum diesel, resulting in lower greenhouse gas emissions.
- The search for low carbon energy resources is a top priority due to rising energy demand, climate change, and CO₂ emissions from fossil fuels.

Canola oil can be recreated as biodiesel because it has only 7% of saturated fat content which is the lowest saturated fat content of any major vegetable oil. In addition of 1-heptanol along with biodiesel the emission of greenhouse gas is reduced.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHODS

The present experimental test included the use of biodiesel fuel produced from canola oil and 1-heptanol as an oxygenated fuel additive to diesel fuel and biodiesel/diesel fuel mixture. The materials have been supplied and the necessary investigations have been carried out, according to the convenience of the appropriate. A possible and appropriate methodology for the exploration of prepared fuel samples for further study was accepted.

4.1 MATERIALS

In the current study, canola (*Brassica napus* L) oil was selected as the primary source for the synthesis of alternative fuel through the transesterification process and was purchased from a local oil mill. Traditional oil-based diesel fuel was used as a reference fuel for the comparison of experimental findings. Diesel fuel is commercially available in hand and is purchased from a local petrol station.

It can be indicated that the material and reagents have been selected on the basis of availability and ease of use of power of attorney. Methanol (99.8 per cent purity) as a short-chain alcohol and sodium hydroxide (NaOH) pellet (>90 per cent purity) as a homogeneous base catalyst was used and supplied by the International Research Centre, the Sathyabama Institute of Science and Technology. Finally, 1-heptanol (98 percent purity), 7-carbon straight-chain alcohol was used as an oxygenated fuel additive and was purchased from local market place the physical appearance of 1-heptanol is shown in [Fig \(4.4\)](#).

4.2 EXPERIMENTAL METHODS:

In particular, canola oil has been exposed to the process of transesterification for the production of biodiesel. Second, binary fuel mixtures (canola oil biodiesel/diesel fuel and 1-heptanol) of different compositions have been prepared. Here, 1-heptanol was chosen as the next generation oxygenated fuel additive. The production and testing methods for the preparation of biodiesel (methyl ester) have been introduced step by step in the following subsections. Biodiesel production from canola oil was carried out using a transesterification technique in a laboratory-scale biodiesel

processor located in the Biofuel Laboratory, the International Research Centre, the Sathyabama Institute of Science and Technology. The canola oil was subjected to the filtration tanks of the cloth filter to remove the large, non-soluble, suspended particles remaining from the extraction process. The temperature of the canola oil was then increased to 120 °C for about 2 h to evaporate the excess water in the oil. Before starting the production of biodiesel, it is also necessary to determine the FFA content of canola oil. This is due to the fact that the FFA of the feedstock is one of the most important characteristics for the selection of the step number of the transesterification process.

4.2.1 Transesterification:

Transesterification is a straightforward process that chemically transforms vegetable oil into a fatty acid methyl ester by treating it with sodium hydroxide and alcohol (FAME). It was not possible to obtain pure esters after transesterification because there are impurities in the esters, such as di and monoglycerides. Examples of alcohol that can be used for the transesterification of triglycerides are methanol, ethanol, propanol, butanol and amyl alcohol. The high conversion rates observed for long chain alcohols relative to methyl ester are due to the higher reaction temperatures required for their boiling points. Methanol and ethanol are the most commonly used transesterification alcohols. Catalyst used in the transesterification of triglycerides and graded as homogeneous, heterogeneous and enzyme catalysts. In this transesterification process, two forms of homogeneous catalyst are the acid catalyst (H_2SO_4 or HCl) and the alkali catalyst (KOH or NaOH). In heterogeneous catalytic processes, the catalyst is typically solid and the reactant and the sample are in liquid or gaseous form. Alkaline earth metal oxides, anion exchange resins, different alkaline metal compounds backed by alumina and various forms of zeolites can be used as heterogeneous catalysts for the manufacture of biodiesel. The transesterification chemical reaction is shown in [Fig \(4.1\)](#). Homogeneous simple catalysts have much higher response times than heterogeneous catalysts, but it is difficult to differentiate the homogeneous catalyst from the reaction mixture. Enzymes can also be used as biocatalysts for reactions.

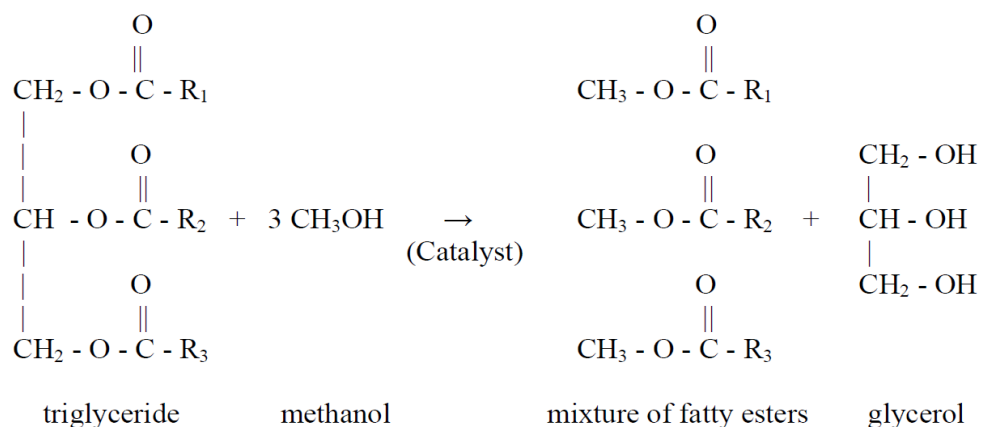


Fig 4.1 Mechanism of transesterification reaction

In the case of alkali-based transesterification, oil and alcohol should be anhydrous as the presence of water can produce soap. The soap reduces the yield of esters and allows the isolation of ester and glycerol impossible. In addition, the free fatty acid content of the feedstock must be less than 2% for successful transesterification. If more water and free fatty acids are present in the oil, acid catalysed transesterification can be used. The acid value and hence the free fatty acid content of the crude oil samples are calculated by the standard titrimetric process. The free fatty acid content of the oil can result in the formation of soap and water. Soap prevents the mechanism of biodiesel-glycerine isolation. The free fatty acid content of the oil can result in the formation of soap and water. Soap prevents the mechanism of biodiesel-glycerine isolation. Free fatty acids are a concern since they make the fuel acid, which can kill the engine. There are a variety of ways to deal with them. If the percentage of free fatty acids is less than around 2%, the oil can still be treated using an alkali catalyst. In this case, an additional volume of catalyst should be added to maximise the yield of biodiesel. Above 2%, the volume of soap prevents the isolation of glycerine. The most appropriate approach is to test the FFA using an acid catalyst. It catalyses the esterification reaction of fatty acids to methyl esters. When the amount of free fatty acids has been lowered to below 0.5 per cent, the mixture can be moved into the mechanism of transesterification as if it were distilled oil. Transesterification is the reaction of fat or oil triglyceride with alcohol to the production of esters and glycerol. Usually, a catalyst is added to increase the response time.

Since the reaction is reversible, excess alcohol is used to move the balance to the product side. Glycerine is the primary by-product of the reaction. Transesterification is commonly used to reduce the viscosity of vegetable oils. Transesterification reactions continue well in the presence of certain homogeneous catalysts such as potassium hydroxide and sodium hydroxide or heterogeneous catalysts such as metal oxides or carbonates. Enzymes such as lipase can also catalyse transesterification. Sodium hydroxide is favoured over potassium hydroxide due to its low cost and high yield.

4.2.1.1 One step transesterification:

In the presence of a base, the esters form an anionic intermediate that can dissolve back into a new ester or form a new ester. Base catalysed transesterification progresses quicker than the acid catalysed reaction. In the first step, the base reacts with the alcohol generated by the intermediate from which the alkyl ester is formed. The chemical formula and reaction of one step transesterification is shown in [Fig \(4.2\)](#). Diglycerides and monoglycerides are converted into a combination of alkyl esters and glycerol by the same mechanism. Alkoxides are stronger catalysts than hydroxides. Alkoxides are prepared by dissolving clean metals in an alcohol. Alkoxide ion targets the carbonyl carbon of the triglyceride that produces tetrahedral intermediate. When using NaOH and KOH, water is formulated as a substance that will further result in the formation of soap. Unwanted saponification lowers the yield of ester and makes the isolation of glycerol impossible. Carbonates can be used as a replacement for NaOH.

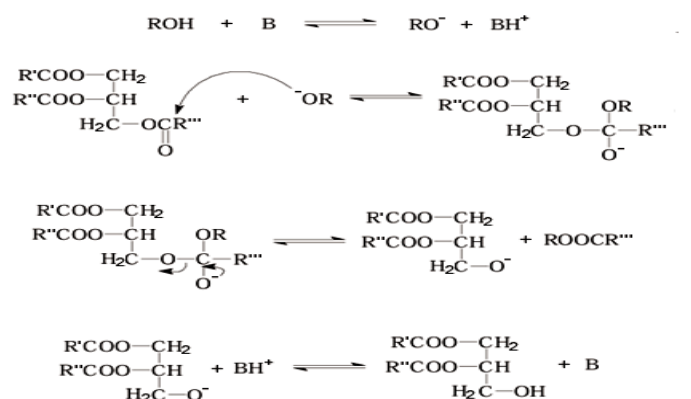


Fig 4.2 Mechanism of one step transesterification reaction

4.2.2 Flowchart of production of canola oil to biodiesel:

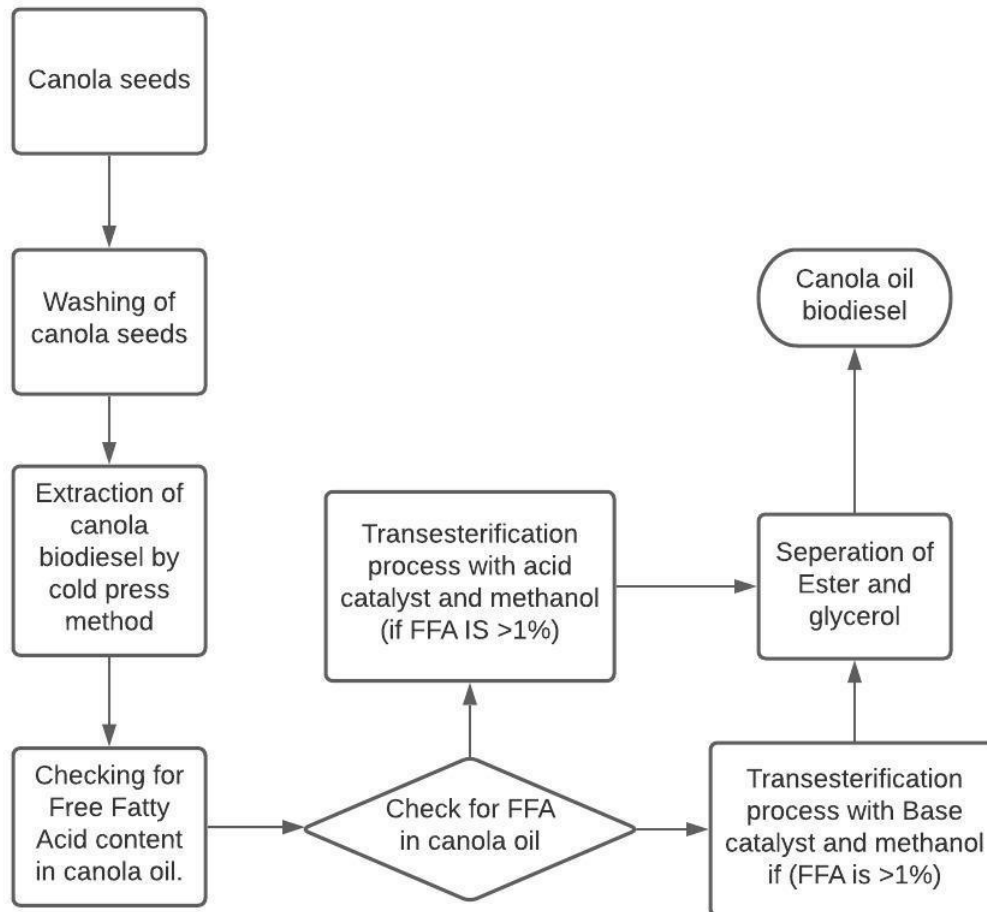


Fig 4.3 Flowchart of production of Canola oil to biodiesel

The [Fig \(4.3\)](#) shows the complete production of seed to biodiesel. Initially the canola seed is take from rapeseed plant and sent for cleaning purposes as it may contain small impurities. After washing, it is sent to the extraction of canola oil by Cold press method. In this next step, the canola oil is checked for FFA (free fatty acid) and if the FFA is more than 1% it is again sent for the extraction of oil by cold press method. If FFA is less than 1% transesterification process is done. After the transesterification of process is indulged separation of ester and glycerol take place. Finally, the reduced free fatty acid by transesterification process is cleaned and given as pure biodiesel(B100).

4.2.3 Transesterification parameters of canola oil:

The canola oil was subjected to the filtration tanks of the cloth filter to remove the large, non-soluble, suspended particles remaining from the extraction process. The temperature of the canola oil was then increased to 120 °C for about 2 h to evaporate the excess water in the oil. Before starting the production of biodiesel, it is also necessary to determine the FFA content of canola oil. This is due to the fact that the FFA of the feedstock is one of the most important characteristics for the selection of the step number of the transesterification process. In transesterification process the canola oil is tested for FFA (Free Fatty Acid) content, the value of FFA should be less than 1% to be satisfied as a fuel, if not the oil is treated with acid catalyst. The various parameters which are considered for the transesterification process is shown in [Table \(4.1\)](#). For us the FFA of canola oil was 0.1% so it is good to proceed further process. The oil is then added with NaOH and methanol to produce esters and glycerol as a by-product. Then it is filtered and biodiesel is extracted.

Table-4.1 Transesterification parameters of canola oil

S.No	Parameters	Units	Results
1	Free Fatty Acid	%	0.11
2	Catalyst(NaOH) Quantity	grams	5
3	Oil to methanol molar ratio	-	1:6
4	Temperature	°C	60
5	Reaction time	Minutes	90
6	Yield	%	93.2

4.3 PHYSICOCHEMICAL CHARACTERISTICS OF CANOLA OIL BIODIESEL, PETROLEUM DIESEL AND 1-HEPTANOL:

As an oxygenated additive, 1-heptanol, which has 7 carbon atoms in its molecular structure, was selected [Fig \(4.4\)](#). Both studied fuel samples were obtained using readily available diesel fuel, canola oil biodiesel, and 1-heptanol in the current experimental work. In this article, some of the most important physical and chemical properties of diesel fuel, peanut oil biodiesel, and 1-heptanol were discussed and listed out in [Table \(4.2\)](#). From observation it is noted that the flash point of canola

biodiesel is very high when compared to petroleum diesel, so in order to reduce the flash point of the blends, diesel is mixed in a higher proportion. And as there is increase in cetane number there will be a clean burning of fuel inside the engine.



Fig 4.4 1-Heptanol

Table-4.2 Physicochemical characteristics of canola oil biodiesel, petroleum diesel and 1-heptanol

S.No	Parameters	Units	Petroleum diesel	Canola oil biodiesel	1-Heptanol
1	Chemical formula	-	$C_{14}H_{28}$	$C_{57}H_{110}O_6$	$C_7H_{16}O$
2	Cetane number	-	54	60	23
3	Density@15°C	g/cc	0.817	0.819	0.818
4	Kinematic viscosity@ 40°C	cSt	2.631	1.98	3.320
5	Flash point	°C	54	182	76
6	Fire point	°C	57	191	79
7	Calorific value	Cal/g	10755.25	7012.68	8276.01
8	Molecular weight	g/mol	193	876.6	116.2
9	Carbon	wt.%	87.05	-	72.16
10	Hydrogen	wt.%	12.95	-	13.71
11	Oxygen	wt.%	0	-	14.13

For the testing of fuel samples five different blends has been prepared. The volume of canola biodiesel and petroleum diesel were taken in terms of percentage form the total volume of fuel sample. Initially, sample 1 has 10% of canola biodiesel, 89% of

Diesel and whereas the amount of 1-Heptanol is added in a constant amount of 5ml in all samples. The concentration of canola biodiesel is incremented by 5% in the other blends and the concentration of petroleum diesel were reduced from the second blend according to the volume of canola biodiesel and 1-heptanol, i.e., when the concentration of canola biodiesel is 10% in first blend and volume of 1-heptanol is constant 5ml, so by subtracting the volume of canola biodiesel and 1-Heptanol from the volume of the blend (500ml) we get 89% of diesel. So this method was followed throughout the blend preparation. By the above mentioned method we prepared five different blends of Canola biodiesel/ Diesel/ 1-Heptanol which is shown in the [Table \(4.3\)](#) along with the abbreviation of each blend.

Table-4.3 Blending % of Fuel mixtures

Sample	Canola oil	Diesel	1-Heptanol
S1 (C10D89Hp5)	10%(50ml)	89%(445ml)	5ml
S2 (C15D84Hp5)	15%(75ml)	84%(420)ml	5ml
S3 (C20D79Hp5)	20%(100ml)	79%(395ml)	5ml
S4 (C25D74Hp5)	25%(125ml)	74%(370ml)	5ml
S5 C30D69Hp5)	30%(150ml)	69%(345ml)	5ml

The blends were prepared in a beaker and stored in five different bottles. The physical appearance of all the fuel blends and were displayed in the [Fig \(4.5\)](#), where “C” indicates concentration of canola biodiesel, “D” indicates concentration petroleum diesel and “Hp” indicates the concentration of 1-heptanol (in ml). In the [Fig \(4.5\)](#) the test samples were placed in sequential order.

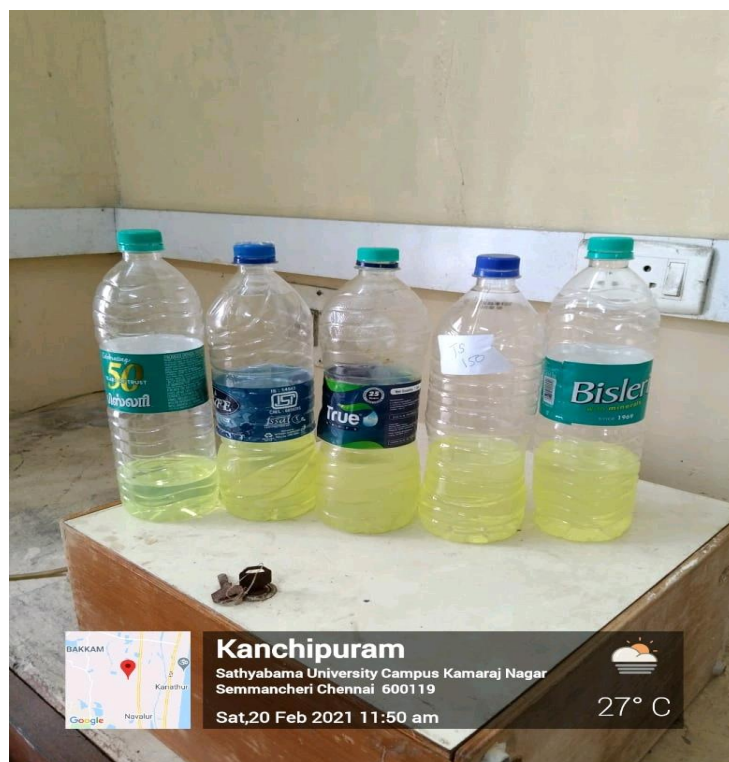


Fig 4.5 Canola biodiesel/Diesel/1-Heptanol blends of different composition

4.3.1 Properties of tested fuel samples:

From the above observation, it is clear that there are some changes in density, kinematic viscosity and calorific value due to addition of increasing composition of canola oil biodiesel in the blend. According to the *B. dogan et al* [6] journal it was noted that addition of more and more composition of alcohol in the blend, the overall performance was reduced and more fuel consumption was noted, but in the same time the emission of dangerous gasses was reduced i.e., it did not affect the emission characteristics. So, in our work we took a standard amount of 1-heptanol. Furthermore, it can be deduced that the addition of 1-heptanol to diesel fuel and biodiesel/diesel fuel mix increased the ID value. One of the most important fuel characteristics that affects the ID time is the fuel's cetane number. By definition, the cetane numbers of alcohols are very low as compared to standard diesel fuel, while the cetane numbers of biodiesels can be marginally higher or lower than diesel fuel depending on the feedstock. Actually, the fatty acid structure has an effect on the cetane amount of biodiesel. The cetane number of the 1-heptanol used was discovered to be 23. Since the cetane numbers of the alcohol and canola oil biodiesel were lower than those of diesel fuel, the cetane numbers of the fuel blends

were cut, as stated in the [Table \(4.4\)](#). A low cetane number can allow more fuel to evaporate within the combustion chamber, resulting in a greater amount of heat. It is possible to assume that prolonged ID times were obtained. The higher fuel viscosity resulted in a weak atomization operation, a slower mixing path, greater penetration, and a smaller cone angle in the CI engine, and thus the ID time was marginally extended. However, the alcohols' density and viscosity levels are observed to be smaller, which increases the air/fuel combination. As a result, a larger volume of fuel has been combusted easily prior to the premixed combustion stage.

Table-4.4 Properties of tested fuel samples

S.No	Fuel properties	Units	S1 (C10D89 Hp5)	S2 (C15D84 Hp5)	S3 (C20D79 Hp5)	S4 (C25D74 Hp5)	S5 (C30D69 Hp5)
1	Density@15°C	g/cc	0.8198	0.8196	0.8194	0.8191	0.8183
2	Kinematic viscosity@ 40°C	cSt	1.89	1.87	1.83	1.81	1.79
3	Flash point	°C	-	-	-	-	-
4	Fire point	°C	-	-	-	-	-
5	Calorific value	cal/g	10339.64	10301.11	10249.54	10219.21	10178.75

4.4 EXPERIMENTAL SETUP:

The engine efficiency and exhaust emissions characteristics of the prepared fuel mixtures were carried out on the engine test rig in the Thermal engineering lab, Science and Technology Department, Sathyabama Institute of Science and Technology. the engine test was conducted in single cylinder four stroke VCR (variable compression ratio) diesel engine.

4.4.1 Description:

A single-cylinder, four-stroke VCR (Variable Compression Ratio) electric start diesel engine is connected to the eddy current dynamometer for loading. By using a specially designed tilting cylinder block configuration, the compression ratio can be changed without halting the engine or adjusting the combustion chamber geometry. The installation must be outfitted with the required instruments for measuring combustion pressure and crank-angle. The PO-PV diagram engine predictor is used to interface these signals to the CPU. The flow of cooling water and calorimeter water is calculated using rotameters. The configuration allows for the study of VCR

engine output with EGR for brake strength, indicated power, frictional power, BMEP, IMEP, brake thermal performance, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, simple fuel consumption, A/F ratio, and thermal balance. For online performance measurement, a LabVIEW-based Engine Performance Analysis software package called "Engine soft" is available. Optionally, a measured Diesel injection pressure measurement is given.

4.4.2 Features:

- ✓ CR changing without stopping the engine
- ✓ No alteration in Combustion chamber geometry
- ✓ Water cooled EGR
- ✓ Electric start with battery and charger
- ✓ Arrangement for blend test
- ✓ PO-PV plots, performance plots and tabulated results
- ✓ Data logging, editing, printing and export, Configurable graphs
- ✓ IP, IMEP, FP indication, combustion analysis.

4.4.3 Range of Experiments:

- ✓ Study of VCR engine performance (Computerized mode)
- ✓ Study of emissions with EGR variation
- ✓ Study of combustion with different fuel blends
- ✓ Study of pressure volume plot and indicated power

4.4.4 Utilities required:

Electric supply

230 +/- 10 VAC, 50 Hz, 1 phase.

Computer

IBM compatible with standard configuration.

Water supply

Continuous, clean and soft water supply @ 1000 LPH, at 10 m. head. Provide tap with 1" BSP size Connection.

The various specifications of the engine are described in the [Table \(4.5\)](#). The physical appearance of a VCR engine is shown in the [Fig \(4.6\)](#).

Table-4.5 VCR Engine test setup specification

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1 cycle., 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18. With electric start arrangement, battery and charger.
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
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
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	RTD PT100, Range 0–100°C, 3 Nos; Thermocouple, Range 0-1200 °C, 2 Nos
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 with injection variation 0-25 deg 25BTDC



Fig 4.6 VCR Engine

4.4.5 Software:

Apex Innovations Pvt. Ltd. created Engine Soft, a LabVIEW-based software package for the engine performance control system. Engine Soft can handle all of the engine testing application's requirements, such as monitoring, documentation, data entry, and data recording. The software assesses power, efficiency, fuel consumption, and heat production. It can be customised based on the engine configuration. Under various working conditions, various graphs are produced. While the engine is in RUN mode, the requisite signals are scanned, interpreted, and displayed in a graph. The stored data file is accessed to view the data in graphical and tabular formats. Printing of results and graphics is possible. The stored data file is accessed to view the data in graphical and tabular formats. Printing of results and graphics is possible. The excel data will be used for further analysis.

4.5 EMISSION TEST SETUP:

4.5.1 GAS ANALYZER: DIGAS 444

To take the readings from Gas analyzer to ADCS Software kindly follow these steps.

1. Kindly fill the details (Engine No. Model, Engine Type, Engine Speed) in respective text boxes given on the form.
 2. Click on “Connect button “to connect the PC with equipment and wait for 2-3 minutes. if the readings are not coming it show the message in red color “CO HC power not communicating.” kindly check the following:
 - Be sure that gas analyzer settings in “MAHA Euro” mode
 - Check the COM port settings with PC and the software.
 - RS232 Cable is working properly and connected with equipment.
 - Readings are coming with equipment and display on panel.
 3. After 6 seconds readings are automatically save in database and status bar strip moving according to readings save in database.
 4. After taking the readings click on “Disconnect button” it disconnects the communication with equipment and show the message “Data Saved in Database”.
 5. Report: Click on report button to take the report of the test.
 6. Print: Click on print button to take the printout of screen as bitmap image.
 7. Export to MS Excel Sheet: To export data in excel sheet click on “EXPORT TO EXCEL” button. When pressing export button a excel file is generated in a path “C:\digasFolder\”. The file name of excel file is same as Test Date and VIN no (Tuesday, January 06, 2021).
 8. Close button: click on close button to exit from current active window or screen.
- The framework and appearance of gas analyser DIGAS 444 is shown in [Fig \(4.7\)](#).

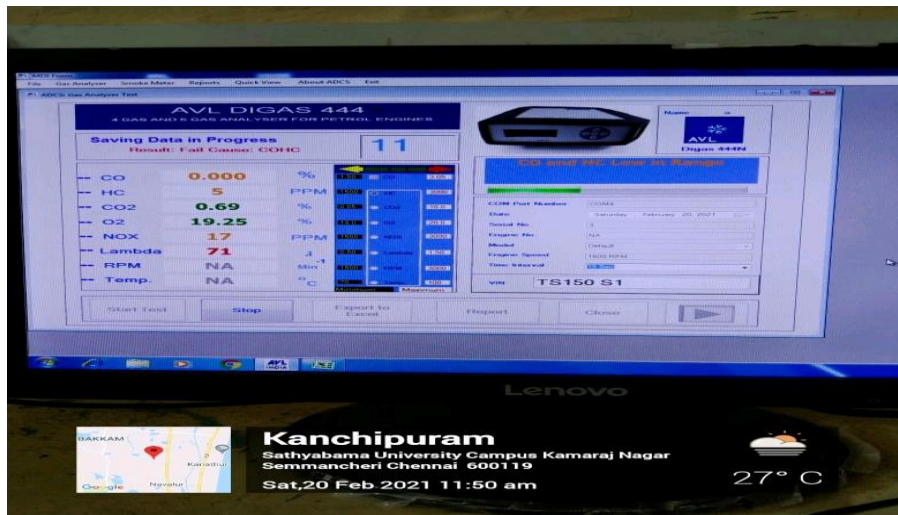


Fig 4.7 AVL DIGAS 444 software

4.6 TEST METHODOLOGY:

First of all, calibrations of the apparatus used were made prior to the start of the engine tests. Pre-tests were then carried out to observe the working conditions of the engine tested. Afterwards, the length of the engine stabilisation was perceived and thus the engine was stabilised with all fuel samples tested. The key experiments were started after all the weaknesses found during the pre-tests had been eliminated. The air temperature and relative humidity were estimated at 20–22 °C and 59–65 percent over the course of the studies. The synthetic diesel fuel has been tested as a reference fuel. The engine output, exhaust emissions and combustion behaviour of the CI engine operating on the fuel samples tested were achieved at various engine loads and at a constant engine speed of 1500 rpm. After testing of petroleum diesel for reference, the other fuel blends were tested one by one and analysed for different characteristics. Initially sample 1(C10D89Hp5) is added in the burette of the engine. Then the engine is made to run for a period of 10 to 20 minutes until the fuel in the burette is fully consumed for all the loads and with the help of the computer software the readings were noted. When the first sample is done, the second sample (C15D84Hp5) is tested in the above mentioned method. At the same time the emission test is also performed. This is carried out when the combustion in the engine is completed and the exhaust gas is analysed using a probe. Probe is an equipment used to determine the percentage of each component in the exhaust gas. The image of a probe is shown in [Fig \(4.9\)](#). Finally, the probe, which is connected

to a computer with the AVL DIGAS 444 software displays the composition of different particles like, CO, CO₂, O₂, NO_x and HC. The values are also displayed in the digital output, which is also connected to the computer [Fig \(4.8\)](#). But using the software for output is considered as a best. Because, at last we can export the output result in the form of an excel file. Which is easier way to plot graphs.



Fig 4.8 Emission test output display

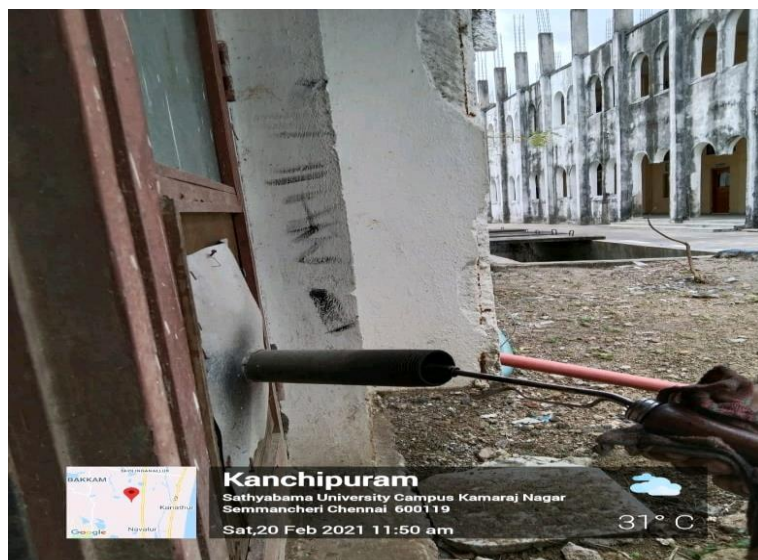


Fig 4.9 Probe inserted inside exhaust pipe

CHAPTER 5

RESULTS, DISCUSSION AND ANALYSIS

The engine efficiency and exhaust emission characteristics of all the fuel samples tested (C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5, C30D69Hp5) were collected at different (0%, 25%, 50%, 70%, 100%) engine loads, these are mentioned in the [Table \(5.1\)](#). The experimental results were contrasted with conventional diesel fuel and pure peanut oil biodiesel in terms of a deeper understanding of the effects of the addition of 1-heptanol to diesel fuel or biodiesel/diesel fuel mixture.

The Brake power versus the Engine load:

Table-5.1 Brake power versus the Engine load

Engine load	0%	25%	50%	75%	100%
BP (KW)	0.00	0.87	1.74	2.61	3.5

Fuel consumption is used to calculate the performance of the fuel used to extract usable power from the engine and, in general, to determine the fuel economy of the engine. The variation in the specific fuel consumption for the different engine load values of the heptanol-biodiesel/diesel mixtures obtained in the study is shown in the figure: During engine operation, fuel consumption rises due to the lack of good air/fuel blends at low engine power and the lack of efficient combustion.

It is important to use more gasoline to achieve the same amount of energy as the viscosity of heptanol is much greater than that of diesel fuel, thus, fuel consumption increases as the ratio of heptanol in fuel mixtures increases [6]. According to the experimental works in *B. dogan et al*, it is shown that the addition of more and more 1-heptanol in biodiesel/diesel blends raises the fuel consumption of the vehicle. So we took a steady volume of 5 ml of 1-heptanol for our experimental work.

Emissions of CO, CO₂, HC and NO_x, which have toxic effects on humans, are emitted into the atmosphere by diesel engines. In the laboratory trials, HC, CO, CO₂ and NO_x emission shifts were calculated for different engine load values.

5.1 ENGINE PERFORMANCE CHARACTERISTICS:

5.1.1 Brake Thermal efficiency characteristics:

Brake Thermal Efficiency is defined as the breaking power of the heat engine as a function of the thermal input of the fuel. It is used to assess how efficiently the engine transfers heat from fuel to mechanical energy. Thermal efficiency is a measure of the output work divided by the input energy of the thermal engine. This case also demonstrated that the addition of small amounts of 1-heptanol and biodiesel to standard diesel fuel resulted in a decline in BTE performance. This can be explained by the deterioration of the energy content of the fuel blends and the decrease in performance, which is mostly due to poor combustion characteristics. However, it should be recognised that many parameters affect the BTE of an internal combustion engine, including injection pressure, injection timing, air/fuel ratio, compression ratio, and, most notably, the energy content of the fuel sample. The variations of BTHEs as a function of engine load for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 blends are shown in [Figure \(5.1\)](#). Since BTE is inversely proportional to the lower heating value and BSFC, it decreases with respect to load as BSFC increases [3]. BTE raises the engine load for all fuel mixtures. This can be due to an increase in power output and a decrease in heat borne by coolant at higher loads. The mean BTE values of C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were found to be 19.72%, 20.07%, 21.26%, 21.475% and 19.6% respectively. Compared to petroleum diesel, the BTHE of C10D89Hp5, C15D84Hp5, C30D69Hp5 decreased by 1.47 %, 1.12% and 1.59% respectively. BTHE of C20D79Hp5 and C25D74Hp5 Increased by 0.07% and 0.28% respectively relative to diesel fuel. From this we can note that there is an improvement in the composition of canola biodiesel in the blend in BTHE with differing load conditions. Owing to the above observation, we may infer that C20D79Hp5 and C25D74Hp5 are more powerful than diesel fuel. In specific, C25D74Hp5 is more powerful than other fuel blends. Therefore, changes in viscosity, surface tension, and density immediately increase the atomization properties of the fuel and the air/fuel mixing ratio.

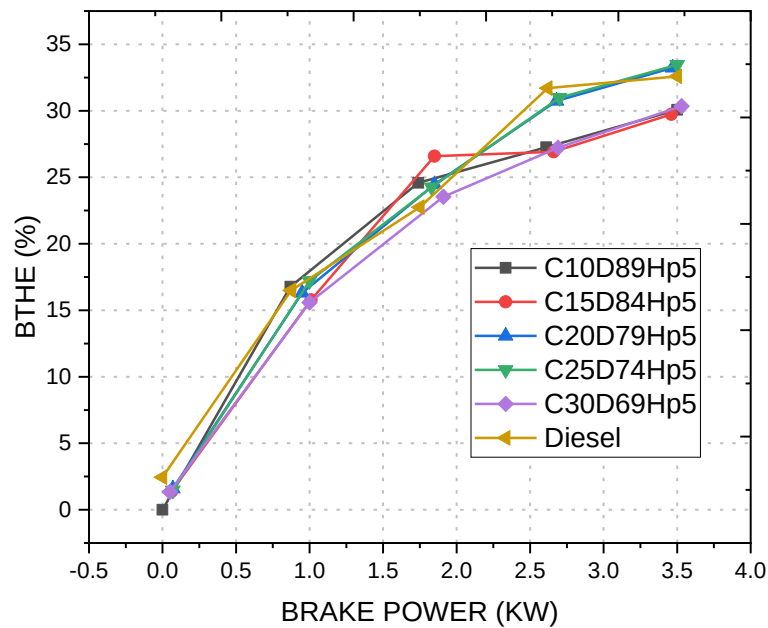


Fig 5.1 Variation of break thermal efficiency with engine loads for the test fuels.

5.1.2 Specific fuel consumptions characteristics:

The BSFC is a calculation of how well the engine uses the fuel supplied, and thus a lower BSFC value is often preferable. In order to achieve the same power output as if it were running on clean diesel, the higher alcohol mixing engine must use more fuel. In this situation, BSFC fails because of the reduced energy content of higher alcohols. Compared to that of diesel fuel, the BSFC of C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 increased by 0.778kg/Kwh, 0.584kg/Kwh, 0.678 kg/Kwh and 0.794 kg/Kwh respectively as shown in [Fig \(5.2\)](#). The BSFC of C10D89Hp5 decreased relative to the diesel fuel. This is attributed to the greater availability of oxygen in the mixtures. From this we can observe that the BSFC of C10D89Hp5 is less when compared to other biodiesel/diesel blends. Owing to the above observation, we can infer that C10D89Hp5 consumes less fuel when compared to other biodiesel blends. Due to the addition of 1-Heptanol there is an increase in fuel consumption and it is obvious for many reasons like, due to the presence of more oxygen content more amount of fuel is burnt inside the cylinder. And this leads to increase in fuel consumption.

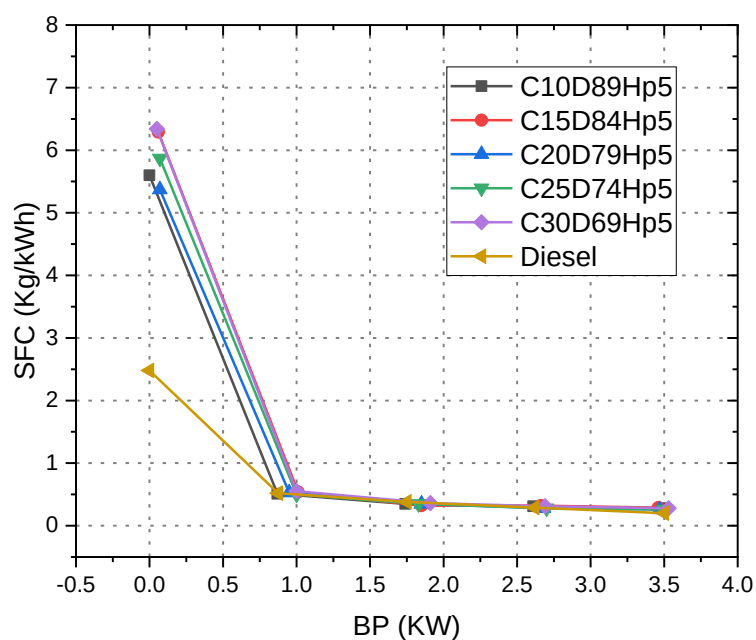


Fig 5.2 Variation of Specific Fuel Consumption with engine loads for the test fuels.

5.2 EXHAUST EMISSION CHARACTERISTICS:

In this section, the various emission parameters for exhaust gases such as carbon monoxide (CO), carbon dioxide (CO₂), oxygen (O₂), nitrogen oxides (NO_x) and unburned hydrocarbon (HC) emissions have been analysed and further discussed for comparative assessments of 1-heptanol infused blends with conventional diesel fuel and canola-oil biodiesel/diesel fuel mixtures in the following subsection.

5.2.1 Carbon monoxide emission characteristics:

Carbon monoxide (CO) is a gas that has no colour or scent. Its density is significantly greater than that of ambient pollution, and it is extremely toxic to humans. Variation of the CO emission ratio with the engine load for different fuel samples was shown in Figure. CO pollution patterns for all fuel samples tested have been alleviated with an improvement in engine load. The variation in oxygen emission versus different load conditions were plotted in a graph [Fig \(5.3\)](#). This is partly explained by certain metrics, such as higher BTE at higher engine loads and early flame-out time, since

the increased overall in-cylinder gas pressures contributed to a decrease in CO emissions.

The lack of excess oxygen also hinders the transformation of carbon monoxide into carbon dioxide and greatly adds to CO emissions. In addition, canola oil biodiesel released a lower CO emission ratio than diesel fuel due to the additional oxygen content in the chemical composition. Even, 1-heptanol has less C atoms in the chemical system resulting in less CO emission. Maximum CO emissions for all fuel samples tested were found to be at the peak engine load of 100%. At this load, the CO emission of pure diesel fuel was estimated at 0.029 %, while the carbon footprint of canola biodiesel was reported at 0.05 %. In other words, the minimum CO emission of canola biodiesel blends compared to diesel fuel to the atmosphere was observed at 0.004 % of 0 % engine load. Owing to the above observation, we can conclude that C15D84Hp5 emits less amount of carbon monoxide when compared to other biodiesel/diesel and 1-heptanol blends.

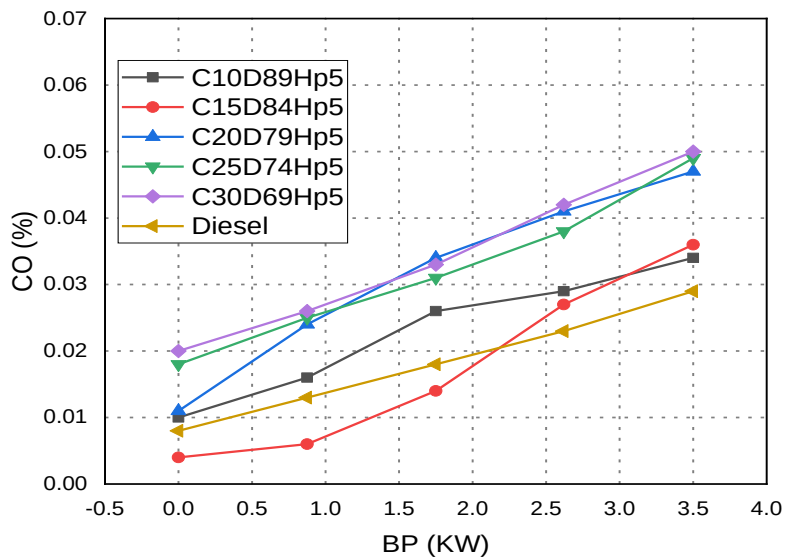


Fig 5.3 Variation of Carbon monoxide emission with engine loads for the test fuels.

5.2.2 Carbon-di-oxide emission characteristics:

Carbon dioxide (CO_2) is related to the full combustion of fuel for internal combustion engines and is also an end-of-combustion product of fuels consisting of carbon molecules in their chemical composition. The presence of an appropriate quantity of oxygen molecules in the combustion chamber for full combustion also increases the percentage of CO_2 emissions. The hydroxyl radical OH, one of the major oxidising agents turns carbon monoxide into carbon dioxide due to the adequate concentration of oxygen presents the carbon dioxide emission rate as a function of the engine load for all the fuel samples examined. It can be seen from the [Fig \(5.4\)](#) that the CO_2 emissions have increased as the engine load has increased. These increases in CO_2 emissions referred to above can be blended into the increase in BTE with an increase in engine load.

Among fuel samples, C30D69Hp5 emitted the highest CO_2 emissions for all engine loads, while diesel fuel generated the lowest CO_2 emissions due to its higher energy content, improved BTHE and even atomization properties due to the droplet size of the fuel allows the CO_2 emission levels to be reduced. Heptanol reacts seamlessly with CO molecules due to the indigenous oxygen molecules in its chemical bonds and thus has a significant impact on the formation of CO_2 emissions.

The CO_2 emissions for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were estimated to be 3.89%, 6.59%, 5.47%, 6.24%, 6.27% and 5.12% respectively at maximum load operating conditions. It seen in the [Fig \(5.4\)](#) that C10D89Hp5 emits less carbon-di-oxide at 0%, 75% and 100% engine loads when compared to all other diesel/biodiesel and 1-heptanol blends.

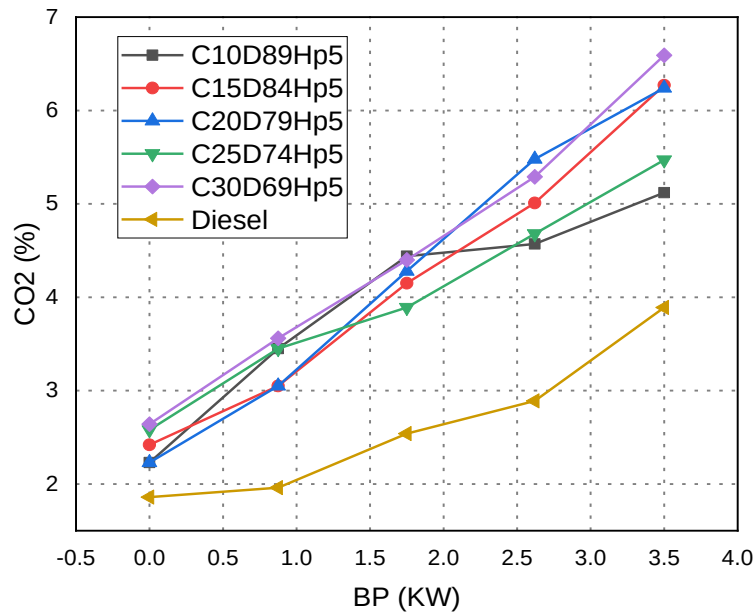


Fig 5.4 Variation of Carbon-di-oxide emission with engine loads for the test fuels.

5.2.3 Oxygen emission characteristics:

Fig. shows oxygen (O₂) emission ratios with diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 tests. Total O₂ emissions for all fuel samples tested were registered at the lowest engine load while the O₂ emissions were decreased with increased engine load. O₂ emissions for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were found to be 11%, 13.24%, 11.13%, 11.58%, 15.89%, 13.95%, respectively, at 100% of engine load. One of the most important conditions for the full combustion phase inside the engine cylinder is the concentration of oxygen molecules in the combustion chamber. The amount of O₂ emissions increased with the addition of biodiesel and 1-heptanol, as alcohol and biodiesel have an excess oxygen content at different fractions in their atomic structure. The addition of higher alcohols such as 1-heptanol to the biodiesel/diesel fuel blend by 5 per cent and the creation of ternary blend has boosted O₂ emissions. The addition of alcohol to the biodiesel/diesel fuel mix contributed to a rise in oxygen emissions relative to traditional diesel fuel. In addition, there is no published literature analysis on the oxygen emission of 1-heptanol infused fuel blends. From the [Fig \(5.5\)](#) we can infer

that, C25D74Hp5 emits higher amount of oxygen content at all different engine loads when compared to other diesel/biodiesel and 1-heptanol blends.

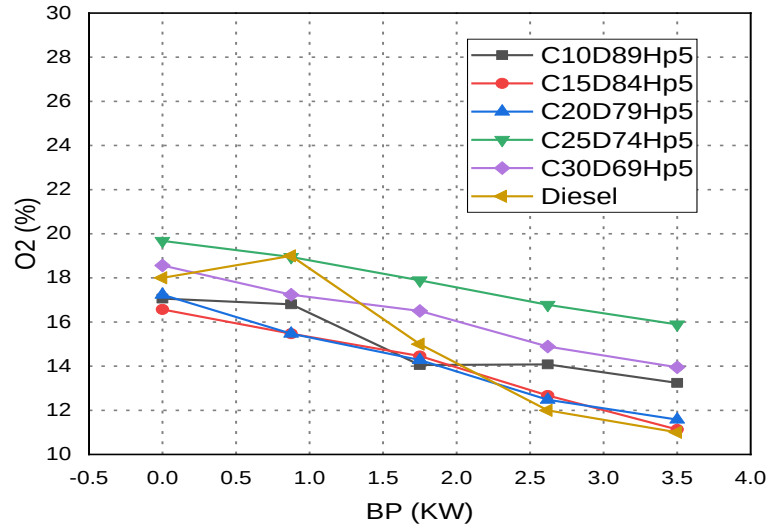


Fig 5.5 Variation of oxygen emission with engine loads for the test fuels.

5.2.4 Hydro-Carbon emission characteristics:

Unburned hydrocarbon (HC) emissions for all fuel samples tested as a function of engine load have been reported in Fig (5.6) for advanced combustion characteristic analysis. It can be seen from the graph that the HC emissions for all the fuel samples measured rose from 25% to 100% with an improvement in engine load. From the figure, it can be shown that the HC emission level for C30D69Hp5 was the highest for all engine loads between diesel fuel and fuel samples measured. This can be explained by the high efficiency, the lack of oxygen and the high carbon weight of the molecule. Canola biodiesel recorded dramatically lower HC emissions relative to diesel fuel at 25 per cent, 50 per cent, 75 per cent and 100 per cent. The oxygen molecules inherent in the biodiesel are in the form of esters. Unburned hydrocarbons reacted with these oxygen molecules during the combustion process. As a consequence, both RCHO and ROH have arisen. The injection of higher alcohol to these fuel samples drives forward the above-mentioned reactions due to higher temperatures within the combustion chamber. From the [Fig \(5.6\)](#) it is concluded that HC emission of diesel fuel is higher only at 100% engine load. Besides that, C30D69Hp5 blend is higher than diesel fuel at 0%, 25%, 50% and

75% engine loads. The maximum unburned HC emission for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were found to be 11%, 13.24%, 11.13%, 11.58%, 15.89% and 13.95% at 100% engine loads respectively. The minimum unburned HC emission were found to be for C15D84Hp5 blends in 15.47% and 14.46% at 25% and 50% engine loads. Owing from the above observation we can conclude that C15D84Hp5 emits less unburned HC when compared to all other biodiesel/diesel blends.

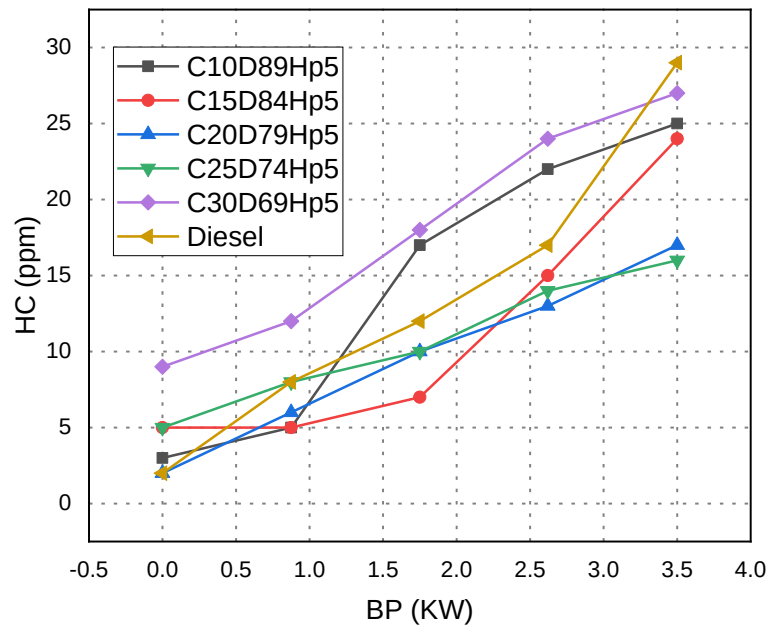


Fig 5.6 Variation of Hydro-Carbon emission with engine loads for the test fuels.

5.2.5 The Oxides of nitrogen emission:

[Fig \(5.7\)](#) shows the modification of brake specific nitrogen oxide (NOX) emissions for diesel fuel, canola oil biodiesel, biodiesel/diesel fuel mix, 1-heptanol/diesel fuel blend, and 1-heptanol/biodiesel/diesel fuel blend at various engine loads. The addition of 1-heptanol to diesel fuel and biodiesel/diesel fuel mix raised the amount of oxygen content in the fuel, resulting in slow combustion at lower combustion chamber temperatures. The foregoing considerations resulted in lower NOX emissions while testing sample 4 (C25D74Hp5) on loads: 0%, 75% and 100% when compared to other blends. NOX is formed when nitrogen molecules react with oxygen molecules at high temperatures. The excess volume of oxygen molecules

keeps the combustion chamber temperature under balance, lowering NO_x emissions. The C20D79Hp5 blends portrays least NO_x emission at 25% engine loads when compared to all other diesel/biodiesel and 1-heptanol blends. However, the C20D79Hp5 blends emits maximum NO_x emission at 100% engine loads when compared to diesel/biodiesel and 1-heptanol blends. [17] During the combustion process takes place in the cylinder, peanut oil biodiesel occurs by-products such as ketones and aldehydes that, in turn, reduce nitrogen and carbon oxides. Owing from the above observation we can conclude that C25D74Hp5 blends emits less NO_x when compared to all other diesel/biodiesel and 1-heptanol blends.

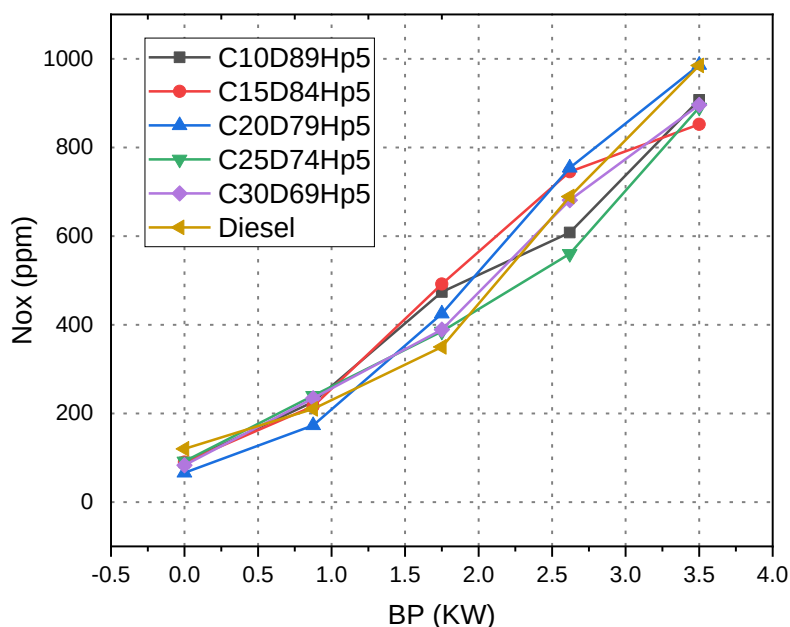


Fig 5.7 Variation of emission Oxides of nitrogen with engine loads for the test fuels.

CHAPTER 6

SUMMARY AND CONCLUSION

The effects of 1-heptanol in the present experimental study (C7 alcohol) mix with diesel fuel and canola biodiesel fuel performance of the CI engine and exhaust emissions behaviour at different engine loads (from 25% to 100%) under constant loads. The engine speed of 1500 rpm has been extensively investigated and the findings were compared to traditional diesel fuel. As a result, the following important results are achieved from that work:

- In general, the addition of higher alcohol to diesel fuel and biodiesel fuel blends leads to a longer ID time due to the lower cetane number of 1-heptanol. Since the lower cetane number affects the self-ignition features that trigger prolonged ID length.
- The blends of 1-heptanol/diesel fuel and canola biodiesel developed less BTE compared to diesel fuel because their calorific value was lower than that of diesel fuel. However, the excess oxygen content induces an increased combustion reaction within the cylinder. BTHE of C20D79Hp5 and C25D74Hp5 Increased by 0.07% and 0.28% respectively relative to diesel fuel. Owing to this C20D79Hp5 and C25D74Hp5 are more powerful than diesel fuel. In specific, C25D74Hp5 is more powerful than other fuel blends.
- The mixing of 1-heptanol with a mixture of diesel/biodiesel fuel leads to an improvement in BSFC due to a decrease in the energy content of the blend.
- The BSFC of C10D89Hp5 decreased by 0.164kg/Kwh relative to the diesel fuel. This is attributed to the greater availability of oxygen in the mixtures. C10D89Hp5 blends is the best choices for consumption of less fuel when compared to diesel and other biodiesel blends.
- HC that is not burned out is emitted after fuel is burned. Some of the mixtures of air and fuel inside the engine Piston is hidden from burning in the cracks open On the grooves of the piston ring. Moreover, it is likely that from Some of the combustion chambers, the flames are very small and the temperatures of combustion are mild. As a consequence, when the fuel is not burnt, the HC is produced by the exhaust is released. Compared to diesel, the emissions of HC from biodiesel/diesel/alcohol are higher. This is because alcohol has a lower calorific content and molecular weight than diesel fuel.

The effect of an alcohol-based biodiesel/diesel fuel mixture on the emission of hydrocarbons is significantly increased. It is observed from our test results that the engine efficiency decreases when there is increase in hydrocarbon emission. In the case of a Higher alcohol/biodiesel/diesel blend, it can have stronger combustion and is very clear that it can restrict the unburned fuel stuck in a specific engine position. From our test output, blend C30D69Hp5 exhibited a higher emission of HC due to cetane number variation, whereas when it comes to blend C15D84Hp5 it emits much lesser amount of HC when compared to petroleum diesel.

- According to the test result, Maximum CO emissions for all fuel samples tested were found to be at the peak engine load of 100%. At this load, the CO emission of pure diesel fuel was estimated at 0.029 %, while the carbon footprint of canola biodiesel was reported at 0.05 %. In other words, the minimum CO emission of canola biodiesel blends compared to diesel fuel to the atmosphere was observed at 0.004 % of 0 % engine load. Owing to the above observation, we can conclude that C15D84Hp5 emits less amount of carbon monoxide when compared to other biodiesel/diesel and 1-heptanol blends.
- The C20D79Hp5 blends portrays least NO_x emission at 25% engine loads when compared to all other diesel/biodiesel and 1-heptanol blends. However, the C20D79Hp5 blends emits maximum NO_x emission at 100% engine loads when compared to diesel/biodiesel and 1-heptanol blends.
- The CO₂ emissions for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were estimated to be 3.89%, 6.59%, 5.47%, 6.24%, 6.27% and 5.12% respectively at maximum load operating conditions, whereas C10D89Hp5 emits less carbon-di-oxide at 0%, 75% and 100% engine loads when compared to all other diesel/biodiesel and 1-heptanol blends.
- O₂ emissions for diesel fuel, C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 were found to be 11%, 13.24%, 11.13%, 11.58%, 15.89%, 13.95%, respectively, at 100% of engine load. The amount of O₂ emissions increased with the addition of biodiesel and 1-heptanol, as alcohol and biodiesel have an excess oxygen content at different fractions in their atomic structure. The addition of higher alcohols such as 1-heptanol to

the biodiesel/diesel fuel blend by 5 per cent and the creation of ternary blend has boosted O₂ emissions

According to all the experimental results of the current experimental work, the different blends C10D89Hp5, C15D84Hp5, C20D79Hp5, C25D74Hp5 and C30D69Hp5 could be tested with a single-cylinder, four-stroke, CI diesel engine without any changes to the research engine. 1-heptanol is a strong oxygenated additive due to the many important advantages described above. In further studies, the other higher alcohols (octanol, hexanol, decanol, etc.) can be used in the diesel engine as a fuel additive. Alternative fuels such as alcohol and biodiesel have an immense capacity to solve energy and environmental challenges related to conventional fuels. So similar research can also be conducted with various other parameters of engine, like Varying compression ratio, engine speed, etc.

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