PROJECT REPORT ON

PRODUCTION OF BIO-DIESEL FROM WASTE COOKING OIL

SUBMITTED BY-

	COLLEGE ROLL NO	. ASTU ROLLNO.
ANGKITA KAKATI	**19164**	**190610010003**
ANWESSA KASHYAP	**19116**	**190612810001**
JURAID AHMED	**19256**	**190610010033**
GOURANGON GOGOI	**19268**	**190610010025**

7 th SEMESTER

Under the guidance of
Prof. Tapan Jyoti Sarma

DEPARTMENT OF CHEMICAL ENGINEERING
ASSAM ENGINEERING COLLEGE
JALUKBARI, GUWAHATI - 781013
SESSION-2022-23

PRODUCTION OF BIO-DIESEL FROM WASTE COOKING OIL

SEVENTH SEMESTER B.TECH PROJECT

Submitted in partial fulfillment of The Requirements of the Degree of

BACHELORS OF TECHNOLOGY

In
CHEMICAL ENGINEERING

Of

ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY

By

ANGKITA KAKATI (ROLL NO-19/164)
ANWESSA KASHYAP (ROLL NO- 19/116)
JURAID AHMED (ROLL NO – 19/256)
GOURANGON GOGOI (ROLL NO – 19/268)

DEPARTMENT OF CHEMICAL ENGINEERING
ASSAM ENGINEERING COLLEGE,
JALUKBARI, GUWAHATI- 781013
SESSION-2022-23

CERTIFICATE

DEPARTMENT OF CHEMICAL ENGINEERING

ASSAM ENGINEERING COLLEGE

GUWAHATI – 781013

This is to certify that the project titled "**PRODUCTION OF BIO-DIESEL FROM WASTTE COOKING OIL**" submitted by the following students of 7th semester of Chemical Engineering Department.

1. ANGKITA KAKATI (ROLL NO-19/164)
2. ANWESSA KASHYAP (ROLL NO- 19/116)
3. JURAID AHMED (ROLL NO – 19/256)
4. GOURANGON GOGOI (ROLL NO – 19/268)

is a bona fide work carried out by them required in partial fulfilment for the award of the degree of Bachelor of Technology in Chemical Engineering of Assam Science and Technology University, Guwahati, which may be accepted.

Date

Dr. Bandana Chakrabarty	Prof. Tapan Jyoti Sarma
Head of the Department,	Associate Professor,
Department of Chemical Engineering	Department of Chemical Engineering

ACKNOWLEDGEMENT

First and foremost, we would like to take the opportunity to extend our heartfelt gratitude to our respected Head of the Department, Dr. Bandana Chakrabarty and the Department of Chemical Engineering, Assam Engineering College for providing us with the opportunity to carry out the 7th semester project.

We would also like to thank our respected project guide, Prof. Tapan Jyoti Sarma for his relentless support and guidance throughout the entire duration of the project work. Without their assistance, it would not have been possible to complete our project work successfully. We would also like to appreciate and acknowledge the efforts of the fraternity of the labs of the Department of Chemical Engineering, Assam Engineering College, Guwahati.

We also extend our gratitude to our team members for cooperating with each other throughout the project work and in accomplishing the report successfully within the given period of time. Last but not the least, we would like to whole heartedly thank our parents and family whose love and unconditional support, both on academic and personal front, has enabled us to see the light of this day.

ANGKITA KAKATI (ROLL NO-19/164)

ANWESSA KASHYAP (ROLL NO- 19/116)

JURAID AHMED (ROLL NO – 19/256)

GOURANGON GOGOI (ROLL NO – 19/268)

ABSTRACT

Increased energy consumption and the depletion of petroleum reserves have pushed up oil prices globally. The diminishing petroleum reserves are a problem inherent in this type of fossil energy, since the dawn of human civilization we have relied on plans for survival and other daily utilities. Plants are the primary constituents of petroleum crude products like petrol, diesel by the process of dia-genesis and surprisingly biodiesel and eco-friendly clean alternative diesel fuel can also be obtained from oils and fats of plants like Sunflower, Clonola or Jatropha. The mentioned natural oils when processed after using chemically show salient similarities to petroleum derived diesel. This process of preparation of biodiesel is called trans-esterification and the obtained biodiesel can directly blend with petroleum derived diesel after fractional distillation. First the waste cooking oil is put into a tank for settling and processing. After that the samples are heated and mixed with Ethanol and Potassium Hydroxide and heated. This results in formation of two main by-products, Biodiesel and Glycerine. Glycerine is much denser than biodiesel and can be easily separated in the settling vessel. The obtained by-products are then sent for production quality test and registration. The processed Bio-diesel is now blended with petroleum derived diesel in experimental amounts to find the best composition and the processed Glycerine is used to make Soaps for daily use. The main advantages of Biodiesel are its non toxicity and biodegradability. It produces approximately 80 percent less carbon dioxide emission and almost 100 percent less sulphur dioxide emission. It is more lubricating than petroleum derived diesel and hence increases the life cycle of the engine or generator. The Soaps can be blended with many fragrances and ingredients for customized uses.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

21st century has been facing many problems like energy sustainability, environmental problems and rising fuel prices. Conventional fuels are known for polluting air by emissions of sulfur dioxides, carbon dioxides, particulate matter and other gases. This has resulted to increased research in alternate fuels and renewable source of energy. Moreover, energy consumption of the world is ever increasing; this has caused the fuel resources dwindle. The transport sector worldwide has considerably increased the fuel consumption reaching 61.5% of the total, especially in the last decade. Recent research expects that the amount of petrol in the world can be used merely for next 46 years. Hence, interest in research for an effective substitute for petroleum diesel is increasing. Currently, India produces only 30% of the total petroleum fuels required for its consumption and the remaining 70% is imported, which costs about Rs. 80,0000 million per year. It is evident that mixing of 5% of biodiesel fuel to the present diesel fuel can save Rs.40, 000 million per year.

Over last few years, Biodiesel (fatty acid methyl esters) has become the part of the equation in the 1990's as the effects of global warming began to get political acknowledgement, because of its benefits over petroleum diesel like significant reduction in greenhouse gas emissions, non-sulfur emissions and non-particulate matter pollutants, low toxicity, biodegradable and is obtained from renewable source like vegetable oils, animal fat etc. Biodiesel is superior to fossil diesel fuel in terms of exhaust emissions, cetane number, and flash point and lubricity characteristics, without any significant difference in heat of combustion of these fuels. Moreover, biodiesel returns about 90% more energy than the energy that is utilized to produce it. Biodiesel mixed with conventional diesel in some proportions can be used to run any existing conventional compression ignition engine and does not require any modifications to be done to the engine.

Due to benefits like renewable in nature, low cost and green house gas reduction potential, biodiesel is nowadays incorporated all over the world especially in developed countries like USA, France, Brazil in different proportions with diesel. It is also estimated that India can supplement 41.14% of its total diesel fuel consumption, if resources like waste cooking oil and other bio wastes were used as raw material for biodiesel production.

Biodiesel can be processed from different mechanisms. Some of them are

1. Direct use or blending in diesel fuel, 2. Micro emulsions in diesel fuel, 3. Thermal cracking of vegetable oils 4. Trans-esterification.

In this review, transesterification is focused. Transesterification is the most common process, in this process an ester compound is exchanged by an alcohol in the alkyl group. Biodiesel can be defined as fatty acid methyl esters (FAME) derived from the Transesterification of triglycerides vegetable oils or animal fats) with alcohol and suitable catalyst. Biodiesel is used as mix constituent of petroleum diesel in proportions for running a diesel engine, since using neat biodiesel has some engine issues. Production rate, yield, product quality were the key performance indicators assessed. Biodiesel can be produced from different triglyceride sources such as vegetable oils (that can be edible, non-edible or waste oils), animal fats (mostly edible fats or waste fats) and microalgae oil. The crops identified for biodiesel are corn, sunflower, palm, olive, canola, soybean, rape and peanut oils, and animal-based lipid (e.g. butter).Waste animal fat is also is identified to be a good feedstock for biodiesel.

Economic feasibility of biodiesel depends on the availability of low-cost feed stocks. The key issue for large scale application of biodiesel as compared to petroleum diesel is the high cost of biodiesel which is mainly concerned with cost of feedstock oils as both the edible and non-edible oils are limited. Moreover, it has been reported that nearly 70-95 % of the total production cost is related to the cost of raw materials. This issue can be overcome by the use of WASTE COOKING OIL (WCO) as raw material which can effectively reduce the feedstock cost to 60-70% .Likewise, the cost of catalyst also affects the overall production cost. Several studies have been made to use waste materials for low cost catalyst preparation to develop sustainable biodiesel production process.

Waste cooking oil refers to the used vegetable oil obtained from cooking food. Repeated frying for preparation of food makes the edible vegetable oil no longer suitable for consumption due to high free fatty acid (FFA) content. Waste oil has many disposal problems like water and soil pollution, human health concern and disturbance to the aquatic ecosystem, so rather than disposing it and harming the environment, it can be used as an effective and cost efficient feedstock for Biodiesel production as it is readily available. Furthermore, Animal fats with high acid value and fat-containing floating sludge discharged in water systems are subject to environmental concern due to their high pollutant potential and it is a challenge for wastewater treatment plants to purify it. Therefore, conversion of low quality lipid-rich sources from slaughterhouses into commercial grade biodiesel is an opportune strategy for minimizing environmental damages while it can help meeting the energetic challenge. WCO collected can also be used to prepare soaps and additive for lubricating oil. Many researchers have successfully converted used vegetable oil into biodiesel. Vegetable oil contains saturated hydrocarbons (triglycerides) which consist of glycerol and esters of fatty acids. Used vegetable oil (UVO) is a by-product from hotels, fast food restaurants and shops selling fritter and by-product of an operating vegetable oil refinery. For serving better quality food, they usually throw this waste cooking without any treatment. Distillate that is produced by deodorization of palm oil (DDPO) is also a promising and cost effective feedstock.

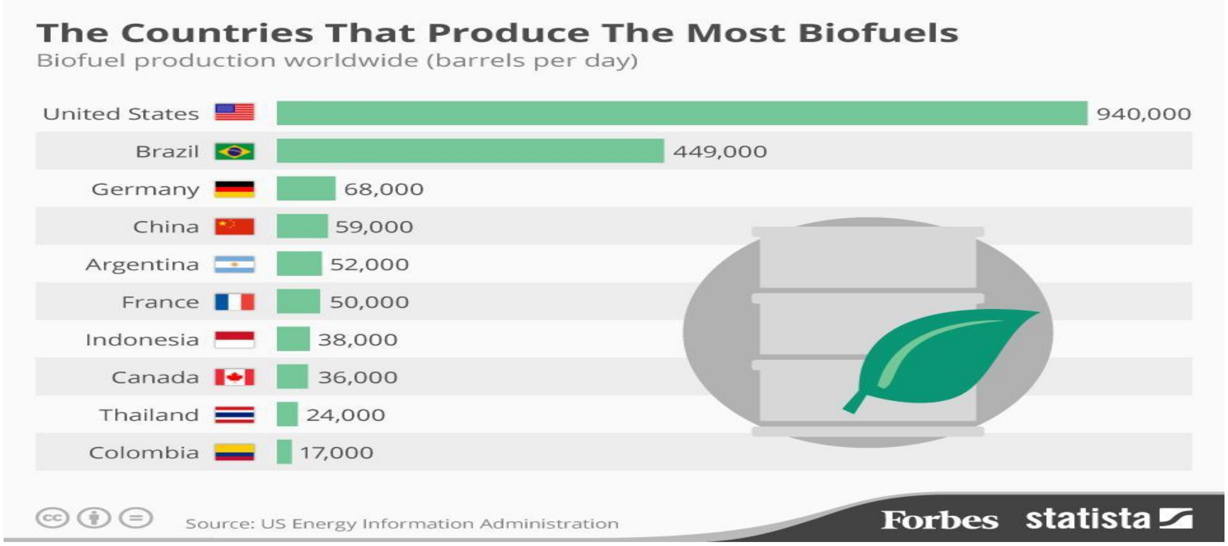
UCOs have different properties from those of refined and crude vegetable oils. The chemical and physical properties of WCO are different from those of fresh oil since some changes due to chemical reactions - such as hydrolysis, oxidation, polymerization, and material transfer between food and vegetable oil occur during the frying process.

The properties of WCO can change depending on the frying conditions, such as temperature and cooking time. Indeed a vegetable oil subjected to thermal stress such as during frying can completely vary its chemical and physical original characteristics. The cooking process causes the vegetable oil, Triglyceride to break-down to form, Diglyceride, Monoglyceride, and free fatty acids (FFAs).The amount of heat and water in the frying increases the hydrolysis of triglycerides, and therefore it causes a growth of the Free Fatty Acids (FFAs) in the WCO. Moreover, because of oxidation and polymerization reactions, there is an increase in the viscosity and the saponification number of the WCO when compared with the original oil .Furthermore the transport of matter and heat between the frying food and the vegetable oil occurs and causes a higher content of water in the WCO .During the transesterification reaction, the presence of water in the WCO samples often lead to hydrolysis, whereas high FFA content and high saponification number can lead to saponification reactions. The information on the physical–chemical properties of the many biodiesel sources available is a key issue to decide on investments for the development of crop production, processing, quality control, and engine adequacy.

In a study on the fatty acid profiles, it was concluded that the vegetable oil contains acids like Myristic (Tetradecanoic), Palmitic (Hexadecanoic), Stearic (n-Octadecanoic), Oleic , Linolenic, Arachidic and other special fatty acids. Among these oleic and linolenic were identified to be in major amounts. The most used vegetable oils for frying purposes are generally olive, sunflower and peanut ones. As for these oils, the fatty acid composition is dominated by oleic and linolenic fatty acids in addition to smaller quantities of stearic and palmitic acids. Another study concluded that to obtain a better yield of product (above 90%) , the concentrations of palmitic, oleic and linolenic acids should be about 37, 50 and 12% v/v and more. In terms of concentrations of triglyceride, diglyceride and monoglyceride, an investigation shows that used a WCO with FFA (wt/wt%) 8.42 and Acid value (mg KOH g−1) 16.6 , had Triglyceride concentration (%) of 84, Diglyceride concentration (%) of 7.0 Monoglyceride concentration (%) of 0.3. The characteristics of second UCO were found to have similarity to UCO but the FFA value is found to be higher in the second UCO.As the time spent for the frying of oil is increased, the product yield is decreased.

1.1 NEED FOR ALTERNATIVE SOURCES OF ENERGY

Due to urbanization, industrialization the need for conventional energy has rise immensely in this few years and we need to find an alternative in order to sustain. The conventional energy requirement has a direct impact on our fossil fuels which this is getting depleted day by day the energy that we use is applied for running household, industries transport education, healthcare, hospitality etc. Therefore, biodiesel is a very good option as a source which can be used as an alternative 40 conventional energy an hence it is renewable. Disposal of waste oil to the environment causes pollution such as soil pollution, water pollution, land pollution etc and as a result it indirectly or directly affects the health of aquatic animals, plants, human health. The waste cooking oil that is being used in the shops, canteens, restaurants for making food can be reused and can be converted into useful products. Those waste cooking oil can we convert it into biodiesel and glycerin and it can be used in the market after purification and as a result it will contribute to the economy of our society. The countries that produce most of the bio-fuels are United States Brazil Germany China Argentina France Indonesia Canada Thailand Colombia. So the increasing demand for bio-fuels is taking an uplifting era.



The rapid increase in the demand of energy has caused worry about its supply. The main sources of energy are conventional sources. They are non-renewable and exhaustible sources. By the year 2030-35 if any alternative sources of energy do not substitute or supplement them, sources of energy like Petroleum and Natural gas are under threat of vanishing. Therefore we should concentrate on alternative and non-conventional and renewable energy sources. Main alternative source of energy are as follows:

Some of the alternative fuels available are as follows:

1. Compressed Natural Gas (CNG): It is a mix of hydrocarbon found under-ground in which there is 80% to 90% methyl gas. It produces very low pollution in comparison to petrol and diesel this is the most important benefit of CNG.

2. Gasohol: It is another alternative fuel in which petrol is mixed in the alcohol obtained from sugarcane juice. Increasing loss in petroleum in India and pollution can be checked by using Gasohol.

3. Bio-diesel: It is ultra low Sulphur diesel, which is also an alternative fuel produces even low pollution comparing to CNG & Hydrogen fuels &Solar batteries.

Main characteristics of alternative fuels:

1. Alternative fuels are not available readymade.
2. It requires technological up gradation.
3. These fuels are generally modern in their use.
4. These fuels have not gained much importance in use that of yet.

Advantages of alternative fuels:

1. These are generally renewable and non-exhaustible.
2. They are available domestically and don't require to depend on imports.
3. These fuels are less expensive comparatively.
4. These fuels produce less pollution.
5. Bio-diesel will give an economically viable option to farmers.
6. Hydrogen has the largest calorie value.

Disadvantages of alternative fuels:

1. Technological up gradation is required for this.
2. Huge investment is required to change today's petrol and diesel running vehicles to adopt such technologies.
3. Cultivation of Jatropha and other types of biodiesel will require land which is very necessary for food crops cultivation.
4. Hydrogen is explosive and problem of storage is there also.

Solar, wind, tidal, geothermal etc. are gradually been adapted and adopted as alternative source of energy are being developed and the cost are adequately reduces as well. These energy sources have the advantage of generally producing energy in a non-polluting form and they are renewable by nature also. Luckily India has vast potential to harness solar and wind energy. North-west part and Eastern and Western coastal areas of India have great potential of wind energy. India has also wide potential of solar energy due to its vast sunny territory. Many rivers provide facilities for development of hydel-energy.

Bio-fuels are of different types.

a. Solid: Wood, dried plant material, and manure

b. Liquid: Bio-ethanol and Biodiesel

c. Gaseous: Biogas

Categories of Bio-fuels are:

1. First Generation bio-fuels: These are produced using traditional technologies from food sources including sugar, starch, vegetable oil, or animal fats. Bio-alcohols, biodiesel, vegetable oil, bio-ethers, and biogas are examples of common first-generation biofuels.

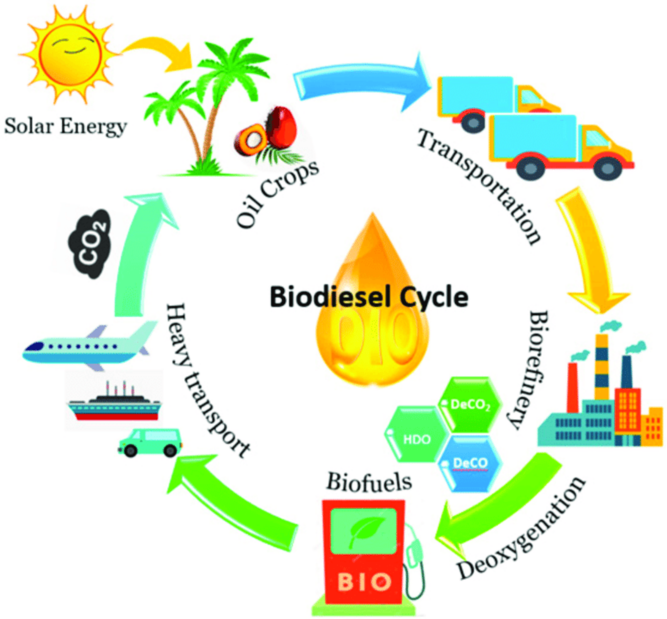
2. Second Generation biofuels: These are made from non-food crops or by-products of food crops that are considered wastes since they cannot be eaten, such as fruit peels, husks, stems, and wood chips. Such fuels are created through thermo-chemical reactions or biochemical conversion processes. Examples include biodiesel and cellulose ethanol. Although these fuels have no impact on the food economy, they are difficult to produce. Additionally, it is claimed that when compared to first-generation biofuels, these biofuels release fewer greenhouse emissions.

3. Third Generation biofuels: These are produced from micro-organisms like algae. Example:- Butanol. Algae can be cultivated on land and in water that is not suited for food production, which relieves pressure on already-depleted water supplies.

4. Fourth Generation Biofuels: Crops that have been genetically modified to absorb large amounts of carbon are cultivated and harvested as biomass in the creation of these fuels. The crops are then converted into fuel using second-generation techniques.

Some popular bio-fuel Crops are:

1. Jatropha 2. Sugar beet 3. Sorghum 4. Pongamia/Karangia



Major Types of Bio-fuels are:

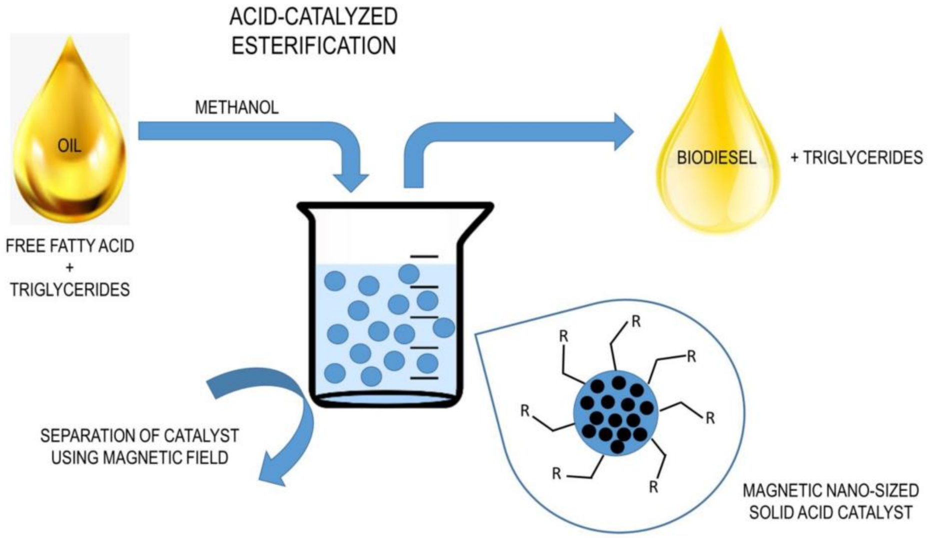
1. Bio-ethanol: It is derived from corn and sugarcane using a fermentation process. About two-thirds of the energy in one liter of gasoline can be found in one liter of ethanol. It enhances fuel combustion and reduces carbon monoxide and sulphur oxide emissions when combined with gasoline. Flexible fuel vehicles (FFVs) have an internal combustion engine and are capable of operating on gasoline and any blend of gasoline and ethanol.

2. Biodiesel: It is derived from vegetable oils like soybean oil or palm oil, vegetable waste oils and animal fats by a biochemical process called "Transesterification." It produces very less or no amount of harmful gases as compared to diesel. It can be used as an alternative to conventional diesel fuel.

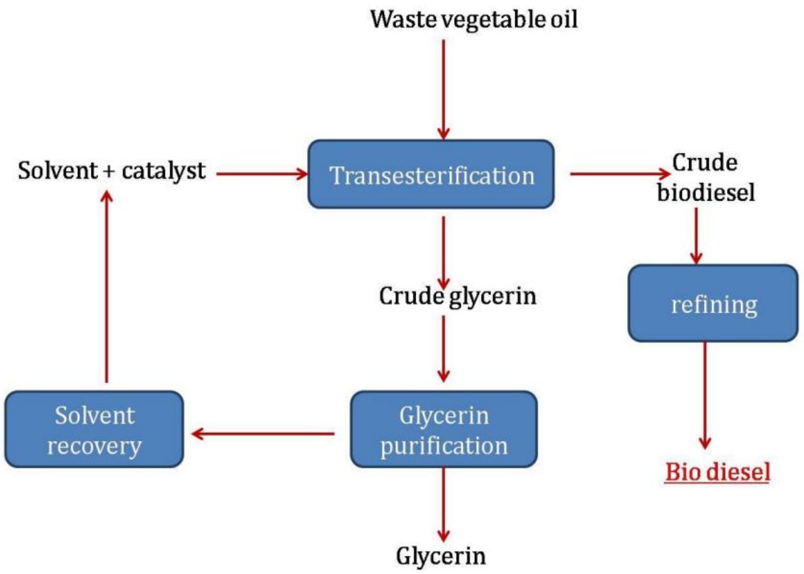
3. Biogas: It is created by the anaerobic breakdown of organic materials, such as sewage from people and animals. Methane and carbon dioxide make up the majority of biogas, while it also contains minor amounts of hydrogen, carbon monoxide, and hydrogen sulphide. Biogas is frequently utilized for heating, electricity generation, and transportation.

4. Bio-butanol: It is produced in the same way as bio-ethanol i.e. through the fermentation of starch. Butanol has the highest energy con content of all the gasoline substitutes. It can be used to cut emissions from diesel. It serves as a solvent in the textile industry and is also used as a base in perfumes.

5. Bio-hydrogen: Bio-hydrogen, like biogas, can be produced using several processes such as pyrolysis, gasification, or biological fermentation. It can be the perfect alternative to fossil fuels.



1.2 PRODUCTION OF BIO-DIESEL



The production of majority of biodiesel today is done through homogeneous alkali catalyzed transesterification of edible vegetable oils. Homogeneous catalysts are soluble during the reaction; they may be liquid or gaseous. They are of two types: Acidic and Alkaline. Acidic catalysts like H_2SO_4 are used usually for Esterification while Alkaline catalysts like NaOH and KOH are used for transesterification. The benefits of homogenous catalysts are

(i) They can catalyze reaction at lower reaction temperature and atmospheric pressure;

(ii) High conversion can be achieved in less time,

(iii) Easy availability and its low cost.

This process permits a good product quality in a relatively shorter reaction time. In transesterification reaction, the triglyceride component of oil reacts with the alcohol in the presence of NaOH or any other catalyst to give ester and glycerol. In general, there are three systems of transesterification with vegetable oil or an animal fat as a starting material, they are homogeneous, heterogeneous systems and enzymatic, based on the catalyst employed in the process. Used vegetable oil is reacted with alcohol. In most of the cases methanol is used because of better efficiency. However ethanol and isopropyl alcohol can also be used, Ethanol is used for animal fats. It has been reported that, transesterification process depends upon many parameters which are reaction temperature and pressure, reaction time, rate of agitation, type of alcohol used and molar ratio of alcohol to oil, type and concentration of catalyst used and concentration of moisture and free fatty acid in the feed stock waste oil. The optimal values of these parameters largely depend on the physical and chemical properties of the feedstock oil for attaining higher conversion.

The effective use of Alkaline homogenous catalyst is limited only for refined vegetable oil with less than 0.5 wt.% FFA or acid value less than 1 mg KOH/g. Moreover, the removal of these catalysts after the reaction is complete needs the washing of biodiesel with water which might result in loss of Fatty acid alkyl esters, energy consumption and generates large amount of waste water. This also increases the overall cost of biodiesel production as it is difficult to recover the catalyst which may cause reactor corrosion. The triglyceride and alcohol should be anhydrous and a Low free fatty acid (FFA) content of raw material is necessary to avoid the soap production (by alkaline catalyst consumption) and low product yields.

Heterogeneous catalysts are the solids and are insoluble during the reaction .Most of them are metal oxides like KBr/CaO, chitosan, $SrFe_2O_4/SiO_2$-SO_3H and catalyst derived from chicken bones. Heterogeneous (solid) catalysts are preferred over homogenous as they can be reused, allow a better separation, better quality of the final products and are economical.

Solid base catalysts are considered to be promising catalysts for transesterification as they have advantages such as easy removal of catalyst from reaction mixture, can tolerate high FFA, no washing is required, easy regeneration, less corrosive character, and low in cost and it is a more environment friendly. However, there are also few disadvantages of the heterogeneous catalysts such as they require extreme reaction conditions (higher temperature and reaction times) for preparation compared to homogeneous process.

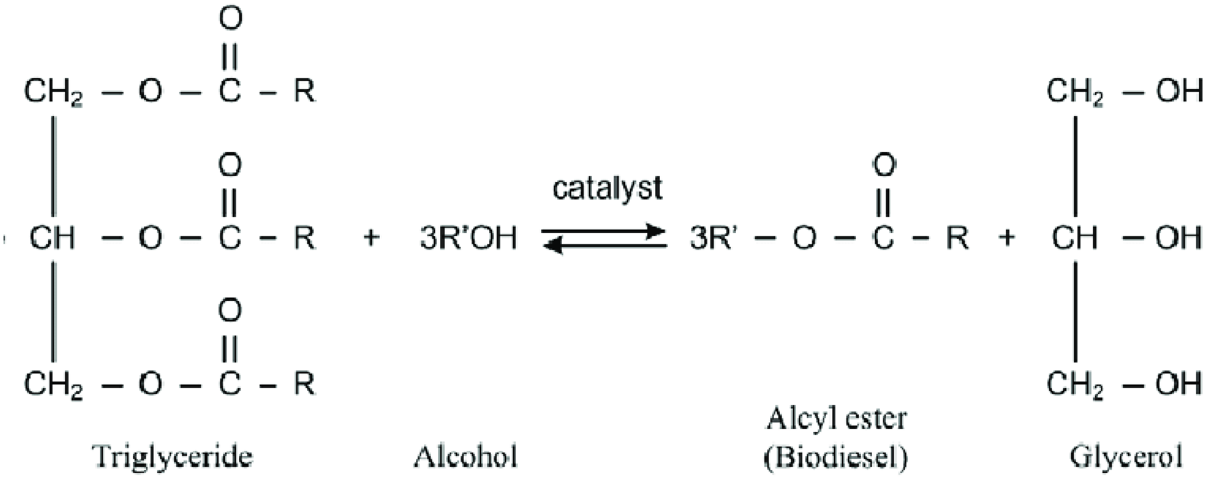
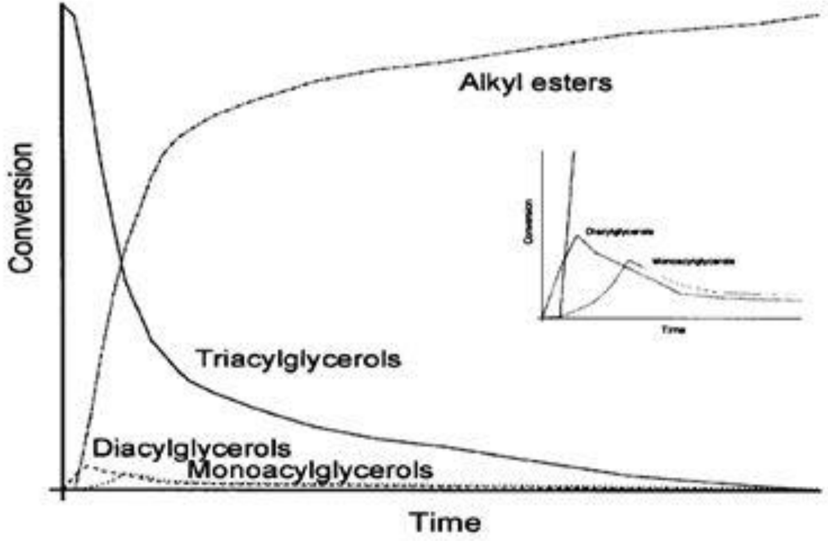


Fig 1. Trans-esterification reaction

Biodiesel produced by the process of transesterification has a much lower viscosity, making it capable of replacing petroleum diesel in diesel engines. The biodiesel production method applied worldwide at industrial level is the alcoholysis (transesterification) of triglycerides which are the main component of vegetable oils and animal fats. The above reaction is termed as trans-esterification.

Fig2. Equilibrium plot for trans-esterification reaction



The above picture depicts the Qualitative diagram of the conversion of vegetable oil to methyl and intermediate products during the course of the reaction.

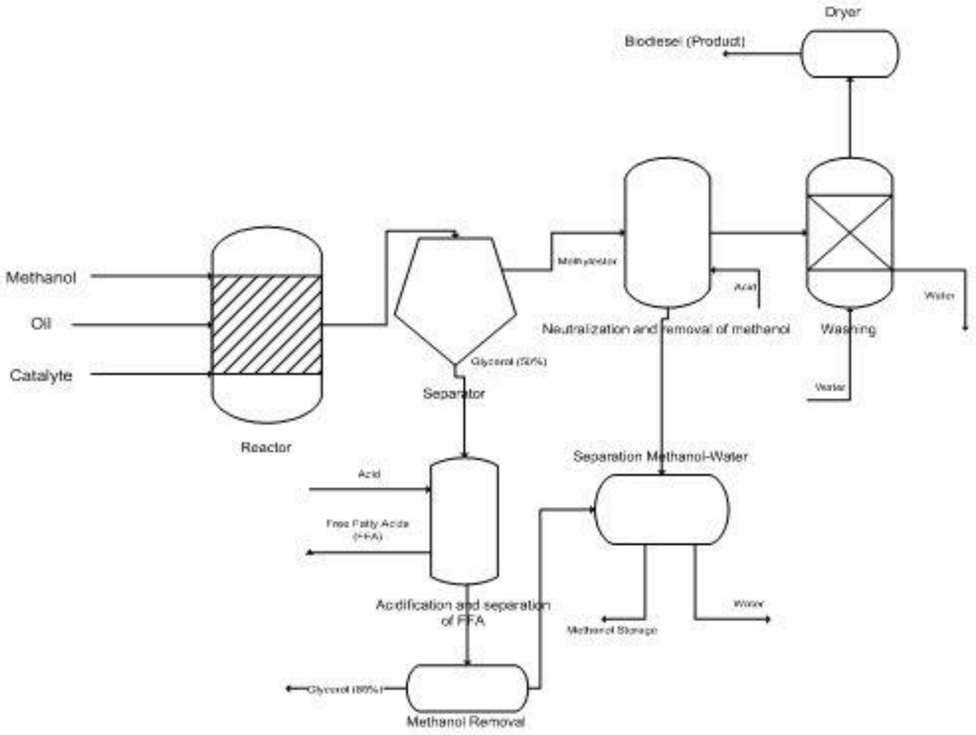


Fig 3. Flowchart for industrial production of bio-diesel.

Analyzing the process described in this flowchart, the catalyst and the oil are mixed in a reactor and stirred for one hour at 60 ° C approx. Smaller capacity plants often use non-continuous reactors (**batch reactors**), but most large plants (those generating more than 4 million liter/year) reactors are using **continuous and complete mixing**. The reaction generally includes two steps: in the first one,80% alcohol and the catalyst are added in the oil. Then, the reactor output stream is led to the removal of glycerin, before entering the remaining 20% of alcohol.

After the reaction, the **glycerol** is separated from the methyl esters. Due to the low solubility of the glycerol esters, their separation can be accomplished easily and quickly using a precipitating tank or a simple centrifugation. The amount of methanol that has not reacted, acts as a solvent thereby delaying the separation of glycerol and methyl. However, excess methanol is usually not removed from the reaction stream until a complete separation of glycerol and methyl esters has been achieved, because the direct reaction of transesterification of products (higher conversion). Often, after the completion of the transesterification, water is added to the reaction mixture to facilitate the glycerol separation.

Following the flowchart, after the glycerol separation, the mixture of the methyl esters is neutralized and then separated from impurities using vacuum distillation or evaporation, before washing with water. For the neutralization of biodiesel an acid is added, which neutralizes the residues of the basic catalyst and separates any soap residue that can be produced during the reaction. The soap reacts with the acid forming hydrophilic salts and fatty acids according to the following reaction:

$$\text{R-COONa} + \text{HAc} \rightarrow \text{R-COOH} + \text{NaAc}$$

The salts are removed during washing, while the free fatty acids remain in the biodiesel. The washing water is applied to remove any remaining catalyst, soap, salt, methanol and free glycerol from biodiesel. Neutralization before washing reduces the amount of water needed and minimizes the tendency to produce emulsions. After washing, the water left in the biodiesel is distilled off under vacuum.

The stream of glycerol is removed from the separator containing glycerol 50%. It also contains some of the excess methanol and most of the catalyst and soap. In this form, the glycerol has little value and its commercial potential is small. The existence of these impurities implies that glycerol must be treated as a hazardous waste. The first step to increase the purity of glycerol is the refinement where acid is introduced in the waste stream to convert soap into free fatty acids and salts. Free fatty acids are not soluble in glycerol and separated at the top of the mixture (upper layer) which can be removed and recycled. These fatty acids can be esterified and thus used as a biodiesel feedstock in the input stream of transesterification reaction. Even then, salts are still present within glycerol. When potassium hydroxide is used as a catalyst and phosphoric acid as a reagent for the neutralization reaction, then phosphates are produced and these can be used as fertilizer. After acidification and removal of free fatty acids, methanol impurities are also removed via an extraction process through vacuum or through another type evaporator. After that glycerol produced has an 85% approximate purity, which allows it to be sold in a glycerol refining plant. There, by further distillation under vacuum or an ion exchange process, its purity can be increased from 99.5 to 99.7%.

Methanol, which is removed from the methyl ester and glycerol streams will “collect” the water produced during the process, since it is fully water miscible. This methanol-water stream should be directed to a distillation column before methanol is led back into the process. This stage is more difficult if the alcohol used is ethanol or isopropanol, due to the azeotropic mixture which is created with water. In this case a molecular sieve is required so as to remove water.

1.3 FUTURE SCOPES OF BIO-DIESEL

With near record oil prices, the future of bio-fuels is of keen interest worldwide. Global bio-fuel production has tripled from 4.8 billion gallons in 2000 to about 16.0 billion in 2007, but still accounts for less than 3 percent of the global transportation fuel supply. About 90 percent of production is concentrated in the United States, Brazil, and the European Union (EU). Production could become more dispersed if development programs in other countries, such as Malaysia and China, are successful. The leading raw materials, or feed stocks, for producing biofuels are corn, sugar, and vegetable oils.

The outlook for global biofuels will depend on a number of interrelated factors, including the future price of oil, availability of low-cost feed stocks, and sustained commitment to supportive policies by governments, technological breakthroughs that could reduce the cost of second-generation biofuels, and competition from unconventional fossil fuel alternatives.

The current oil market is driven by strong demand-side factors. These factors include robust economic growth and rising oil demand from rapidly growing middle-income economies, where consumers are demanding a higher standard of living and exhibiting big appetites for energy. Profitability of Biofuels depends on the availability of low-cost feed stocks. Feedstock costs are the most significant cost of bio-fuel production, ranging from 37 percent for sugarcane-based ethanol in Brazil in 2003-04 to 40-50 percent for corn-based ethanol in the United States. Sugar beets represented 34 percent of the cost of sugar-based ethanol production in the EU. With rising commodity prices, these cost shares are even higher now. Another major cost component is energy, which may account for as much as 20 percent of bio-fuel operating costs in some countries.

The ratio of crude oil prices to feedstock prices offers a simple indicator of the competitiveness of bio-fuel made from various feed stocks. The ratio of crude oil to corn prices, for example, rose sharply after 2004 as oil and ethanol prices increased and corn prices were stable. But the ratio dropped sharply after September 2006, making biofuels less cost competitive. Biodiesel producers in Europe and Southeast Asia also faced declining competitiveness as soy and palm oil prices rose in 2006-07. World sugar prices, on the other hand, declined by 50 percent from 10-year highs in 2006, boosting relative prospects in Brazil’s ethanol sector. The sale or productive use of byproducts also contributes to a bio-fuel plant’s profitability. Dried distillers’ grain (DDG), a byproduct of corn ethanol production, can be used as a protein-rich livestock feed additive. Sales of DDG can add as much as 10-15 percent to ethanol producers’ incomes. Carbon dioxide, usually released into the atmosphere, is captured by some ethanol plants and sold for use in the food and beverage sector. Bagasse, the fibrous material left over from pressing sugarcane, can be burned to provide heat for distillation and electricity to power machinery or sold to local utilities. Glycerin, a byproduct of biodiesel production, has a wide number of pharmaceutical, food-processing, and feed applications.

Governments have introduced a variety of policy tools that reduce risk and uncertainty in response to investor and producer concerns about the double-edged uncertainty of volatile feedstock and energy input prices and bio-fuel output prices. The most common tool is a requirement to blend bio-fuel with its fossil fuel counterpart to provide a guaranteed market for biofuels. The nature of this requirement varies around the world in the extent to which it is mandatory, the phase-in period, the volume or blend percentage mandated, and whether a nationwide or regional strategy is used.

While biofuels share similar attributes with oil-based fuel, they are not perfect substitutes. Biofuels can be used in existing gasoline and diesel engines in blends of up to 10 percent in the case of ethanol and 20 percent for biodiesel with little or no engine modification. This compatibility contrasts with hydrogen fuel cell technology, which would require a radically different distribution system. However, ethanol has only two-thirds the energy content of gasoline, and biodiesel has 90 percent that of diesel. Thus, a car will get fewer miles per gallon the greater the bio-fuel blend. Shipping ethanol is more expensive; it cannot be transported by low-cost pipelines because of potential contamination from ethanol's tendency to absorb water and to dissolve impurities on the inside surfaces of multiproduct pipelines. Dedicated pipelines for ethanol are being considered in Brazil and the United States and may become economical with expanded production.

Rising crude oil import bills have pushed the Indian government to look for other alternatives fuel sources such as Ethanol and Biodiesel. Currently, the transport sector, railways and aviation are the major end-users of biodiesel in India. As per an FY2021 quarterly update, India's biodiesel market demand stood at 0.17 million tones despite major setbacks due to the pandemic induced disruption in supply chains. Initiation of the 2019 National Policy on Biofuels and the Food Safety and Standards Authority of India's (FSSAI) Repurposed Used Cooking Oil (RUCO) project have further encouraged legacy players and startups alike to jump on the bandwagon. With India's primary energy demand set to double by 2040, the use of alternative fuels such as Biodiesel is bound to grow as well. These fuels also help reduce the environmental impact as the end product is 95 per cent carbon-free on average. Used cooking oil, animal fats, imported crude vegetable oils and Jatropha seeds are used to produce alternative fuels such as Biodiesel. But with India only contributing to 1 per cent of the global bio-fuel production, alternative fuels are still a niche in our country.

However, biofuels have the potential to change India's energy spend and consumption. The demand is there but production and supply are not where it needs to be. However, major players like Biomax Fuels, Universal Biofuels and startups like Aris Bioenergy are hot on the trail. While the passenger vehicles sector rides its electric wave, the bio-fuel industry is building its own foundations with sustainable fuels that can serve India's energy requirements in real-time

CHAPTER 2

LITERATURE REVIEW

2.1) PRODUCTION OF BIODIESEL FROM WASTE FRYING OIL USING METHANOL ONLY.

In the study conducted by Zheng S. et al has analyzed the reaction kinetics based on acid-catalyzed trans-esterification of waste frying oil. They have found out that at the methanol/oil molar ratio of 250:1 at 70 ºC or in the range 74:1-250:1 at 80ºC, the reaction was known as the pseudo-first-order reaction. Higher yield of 99% was achieved both at 70 ºC and 80 ºC temperatures while stirring the mixture at rate of 400 rpm, using a feed molar ratio oil:methanol:acid of 1:245:3.8.

2.2) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL USING FERRIC SULPHATE CATALYZED METHANOLYSIS FOLLOWED BY POTASSIUM HYDROXIDE CATALYST.

In the study conducted by Wang Yong et al investigated a two- step catalyzed processes for the synthesis of bio-diesel by using WCO from Chinese restaurants. In the first step the reaction was carried out with ferric sulphate-catalysed metanalysis while potassium hydroxide catalysis was performed in the second step of the reaction. The authors concluded that compared to the one-step sulphur acid catalysis the two-step catalyzed process provided a simpler and more economic and efficient method to produce bio-diesel from waste cooking oil.

2.3) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL USING ONLY SULFURIC ACID AND MICROWAVE ASSISSTED TRANSESTERIFICATION USING BaO and KOH CATALYST.

In the study conducted by Prafulla D. Patil et al comparative study on biodiesel production from waste cooking oil using sulfuric acid (Two-step) and microwave-assisted transesterification (One-step) was carried out. The two-step transesterification process is being used to produce bio-diesel from mainly high free fatty acid waste cooking oil. The Microwave- assisted transesterification was done by using catalytic BaO and KOH. The study showed that that the microwave-heating method consumes less than 10% of the energy to achieve the same yield as the conventional heating method. Moreover, fuel properties of biodiesel produced were compared with ASTM Standards for biodiesel and regular diesel and it was seen that it has similar properties compared to conventional diesel with higher yield.

2.4) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL USING ONLY SULFURIC ACID AND MIXTURE OF ETHANOL AND METHANOL.

In the study conducted by Issariyakul Titipong et al. [30] introduced the two-step process to trans esterify waste cooking oil, except that sulphuric acid was selected as acid catalyst and mixtures of methanol and ethanol were used for transesterification in order to get better solvent properties of ethanol and more equilibrium using methanol. More than 90% ester was obtained by using the two-stage method compared with yield by using single stage alkaline catalyst.

2.5) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL CATALYSTS PREPARED FROM RAW CHICKEN BONES FOR TRANSESTERIFICATION REACTION.

In the study conducted by Farooq Muhammad and Ramli Anita [37] prepared catalysts that was from the raw chicken bones for transesterification reaction of waste cooking oil to produce biodiesel. The study revealed that heterogeneous catalyst calcined at 900°C exhibits good catalytic activity in the transesterification of waste cooking oil, which provides maximum biodiesel yield of around 89.33% at 5.0 g of catalyst given with 15:1 methanol to oil molar ratio at a temperature around 65°C in reaction time of 4 h.

2.6) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL FROM ACID BASE AND BASE-BASE TRANSESTERIFICATION PROCESS USING HCL,KOH AND METHANOL.

In the study conducted by Bakir T. Emaad and Fadhil B. Abdelrahman [33] showed work on single step transesterification and two step transesterification which is known as the acid-base and base–base catalyzed transesterification process for production of biodiesel from chicken fried oil which is the WCO. For this purpose, hydrochloric acid and potassium hydroxide with methanol was used and the results showed that two step base catalyzed transesterification was way better compared to other methods.

2.7) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL FROM ACIDIC AND BASIC CATALYSIS AND, GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTOR (GC–FID).

In the study conducted by Canesin Antonio Edmilson et al. [36] produced biodiesel from Residual oils and it the viability and degradation level of production process was also checked. Residual soybean oils were used in the production of biodiesel. They used the four transesterification methods by using acidic and basic catalysis and gas chromatography with flame ionization detector (GC–FID). They concluded that the use of acidic catalysis at a lower temperature was the most efficient in the biodiesel production process.

2.8) EVALUATION OF BIODIESEL PRODUCED FROM WASTE COOKING OIL REGARDING CO EMISSION RELATED TO CETANE NUMBER.

In the study conducted by Mohanty et al. [35] observed that from Waste cooking oil CO emissions increases with increase in engine load. Moreover it was also found that volume of CO initially decreases but at full load it increases which indicates better burning conditions at higher temperature supported by improved spraying qualities with unchanging charge preparations of biodiesel. The emissions of unburnt hydrocarbon for biodiesel exhaust is lower than that of diesel fuel but the increased gas temperature and higher cetane number of biodiesel can be responsible for this decrease.

2.9) EVALUATION OF BIODIESEL PRODUCED FROM WASTE COOKING OIL WITH REGARD TO BLENDS B20 AND B50.

In the study conducted by Lin Fen-Ya et al. [31] used waste cooking oil to prepare bio-diesel and a study was conducted in which the exhaust tail gas of bio-diesels was compared when the engine was operated using different types of fuels such as bio-diesel, bio-diesel/diesel blends, and normal diesel fuels. Among the collected data, the authors found that B20 and B50 were the optimum fuel blends.

2.10) PRODUCTION OF BIODIESEL FROM WASTE COOKING OIL WITHOUT CATALYST.

In the study conducted by Saka and Kusdiana [168] has studied the transesterification reaction of rapeseed oil in supercritical methanol with free catalyst. This process was performed in a vessel preheated at 350 oC in 42:1 molar ratio of oil to methanol with pressure interval between 45–65 MPa and by setting an interval time of supercritical from 10–240 s. The results concluded that in a maximum reaction time of 240 s, this process was able to convert all the triglycerides into ester. In one more work of Kusdiana and Saka [169] investigated various supercritical alcohols of methanol, ethanol, 1-propanol, 1-butanol and 1-octanol to study the transesterification of triglycerides at 302 °C. The results showed that transesterification was faster for alcohols with shorter alkyl chains and provides better yield.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 SAMPLE COLLECTION

For the process of experimentation and testing, we have collected samples of WASTE COOKING OIL from-

1. Hostel mess present in our college campus
2. Eateries and small stalls in Sundarbari, Guwahati (at max 3 stalls)
3. Eateries and small stalls in Ganeshguri, Guwahati (at max 4-5 stalls)

Over a period of 10-15 days we have collected around 2-3 liters of WASTE COOKING OIL which we have divided into different samples and have carried out the experimental procedure for the production of bio-diesel. The details of the collected samples are given below in a tabular form.-

TABLE1. COLLECTION OF WASTE COOKING OIL

SL.NO.	SAMPLE (WASTE COOKING OIL)	TYPE OF OIL	PLACE OF COLLECTION	DATE OF COLLECTION	QUANTITY (L)
1	S1	Mustard oil	Hostel 3 mess	24.10.2022	0.3
2	S2	Mustard oil	Hostel 3 mess	25.10.2022	0.2
3	S3	Mustard oil	Hostel 1 mess	26.10.2022	0.04
4	S4	Mustard oil	Hostel 8 mess	24.10.2022	0.5
5	S5	Mustard oil	Hostel 8 mess	25.10.2022	0.4
6	S6	Palm oil	Sundarbari stall	27.10.2022	0.25
7	S7	Palm oil	Sundarbari stall	31.10.2022	0.3
8	S8	Palm oil	Ganeshguri stall	28.10.2022	0.4
9	S9	Refined oil	Ganeshguri stall	05.11.2022	0.25
10	S10	Refined oil	Ganeshguri stall	07.10.2022	0.5
11	S11	Mustard oil	Hostel 3 mess	10.10.2022	0.05
12	S12	Mustard oil	Hostel 8 mess	08.10.2022	0.03

As the above table depicts, we have labeled each sample on the basis of date of collection, place of collection and type of oil used during the process of cooking. However most of the samples went rancid due to negligence and did not produce results. During the process of experimentation we have successfully made use of 6 out of the 12 samples collected. The next table clearly shows the samples that were used in the experiment.

TABLE2. SAMPLES USED IN EXPERIMENTAL PROCEDURE

SL. NO.	SAMPLE (WASTE COOKING OIL)	QUANTITY (L)	SAMPLE USED FOR EXPERIMENT	DIVISION OF SAMPLE	QUANTITY TAKEN FOR EXPERIMENT
1	S1	0.3	Yes	S1.a S1.b	100ml 100ml
2	S2	0.2	Yes	S2	200ml
3	S3	0.04	No	-	-
4	S4	0.5	Yes	S4	500ml
5	S5	0.4	No	-	-
6	S6	0.25	Yes	S6	200ml
7	S7	0.3	Yes	S7	200ml
8	S8	0.4	Yes	S8	200ml
9	S9	0.25	No	-	-
10	S10	0.5	Yes	S10.a S10.b S10.c	100ml 100ml 100ml
11	S11	0.05	No	-	-
12	S12	0.03	No	-	-

As **TABLE 2** depicts, we started with 300ml of S1 sample and divided it into two parts as S1.a & S1.b taking 100 ml each. Similarly we have taken 200ml of S2. We could not proceed with S3 sample due to lack in quantity. After collecting 500ml of S4, we have proceeded with experimentation. However, S5 was a failure. 200ml of S6, S7 and S8 were used for experimentation. To proceed with blending, we took 300ml of S10 and divided it in to three batches of 100ml labeled as S10.a, S10.b and S10.c. S11 and S12 were very less in quantity and could not be used for experimentation.

From the above sample collection process, we have come to the conclusion that around 5-6 liters of waste cooking oil is generated from our college campus and also 2-3 liters from small stalls and eateries in town area in around 20-25 days. If a bigger survey area is taken under consideration, then around 10-15 liters of waste cooking oil will be generated within a month. Due to time constraint, we adhered ourselves to our college campus and surrounding areas.

3.2 EXPERIMENT

3.2.1 CHEMICALS USED

For proceeding with the laboratory procedure, we have taken the following chemicals –

1. Waste cooking oil sample
2. Ethanol
3. Methanol
4. Aniline
5. KOH pellets
6. NaOH pellets
7. Water

3.2.2 APPARATUS USED AND EXPERIMENTAL SETUP

For proceeding with the laboratory procedure, we have made use of the following apparatus

1. Burette
2. Centrifuge machine
3. Beaker (100ml, 200ml, 500ml)
4. Separating funnel
5. Conical flask
6. Funnel
7. Aniline point apparatus
8. Cleveland apparatus
9. Redwood viscometer apparatus
10. Specific gravity bottle
11. Thermometer
12. Measuring cylinder
13. Filter paper
14. Magnetic stirring apparatus
15. Round bottom flask (500ml)
16. Condenser
17. Fractionating head
18. Pipes
19. Electric heater

3.2.3 EXPERIMENTAL PROCEDURE

i. Production of biodiesel:

The first step of our biodiesel process is the collection of used cooking oil. A large amount of oil comes from commercial fryers at local restaurants, food processors, and any business that serves food, as well as home kitchens. All kinds of cooking oil can be used, including soy, vegetable, canola, and animal fats. The next step is refinement. Used oil is usually full of impurities, such as meat scraps, water, crumbs of breading, and other leftovers. These contaminants must be filtered out, so they don't interfere with the conversion process.

The chemical reactions of trans-esterification and esterification involves vegetable or animal fats and oils being reacted with short-chain alcohols (typically methanol or ethanol). Base catalyzed trans-esterification reacts lipids (fats and oils) with alcohol (typically methanol or ethanol) to produce biodiesel and an impure co-product, glycerol.

The following procedure was followed in the laboratory while preparing bio-diesel from waste cooking oil samples:

1. We have taken 100 ml of waste cooking oil and heated it to 60 degrees Celsius.
2. In the meantime we take one gram of potassium hydroxide and 20 ml of ethanol and make a solution.
3. We add this solution to the waste cooking oil and maintain a constant temperature of 60 degree Celsius for almost an hour.
4. We pour the solution into a burette and let it settle for almost 24-48 hours.
5. Finally, we find that there are 2 separate layers that have been formed and this can be separated with the help of a separating funnel. The upper layer consists of biodiesel and lower layer consists of glycerol.
6. The bio-diesel produced is then used for various testing.

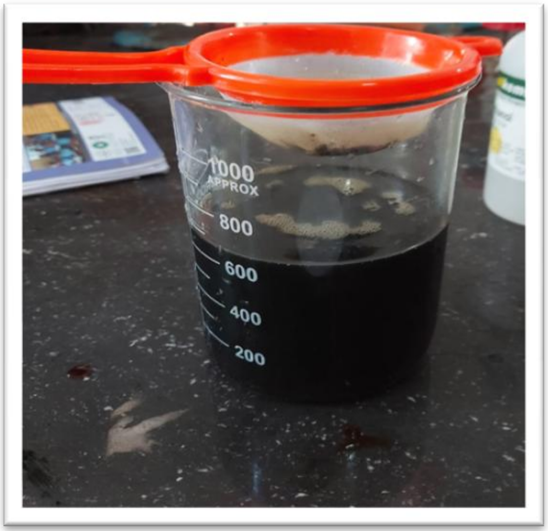


FIG4. WASTE COOKING OIL SAMPLE

FIG 5. KEEPING THE SAMPLE FOR 24-48 HRS FOR SEPARATION INTO TWO LAYERS

Fig 6. Glycerol separation

ii. Purification of bio-diesel produced through distillation

After the standard testing is over, distillation is employed to purify the samples of bio-diesel. After distillation, the samples are again tested through standard testing methods. For this purpose we have employed two types of distillation as mentioned below:

I. Steam distillation:

1. Steam distillation is carried out by passing dry steam through the material whereby the steam volatile compounds are volatilized, condensed and collected in receivers.
2. The condensed liquid phase contains vaporized water vapor with required compounds, and they are placed in a condensation flask that is placed nearby.
3. The vapors are condensed after the distillation process.

Fig 7. Steam distillation

II. Fractional distillation

Fractional distillation separates hydrocarbons using their different boiling points. The steps of the process are:

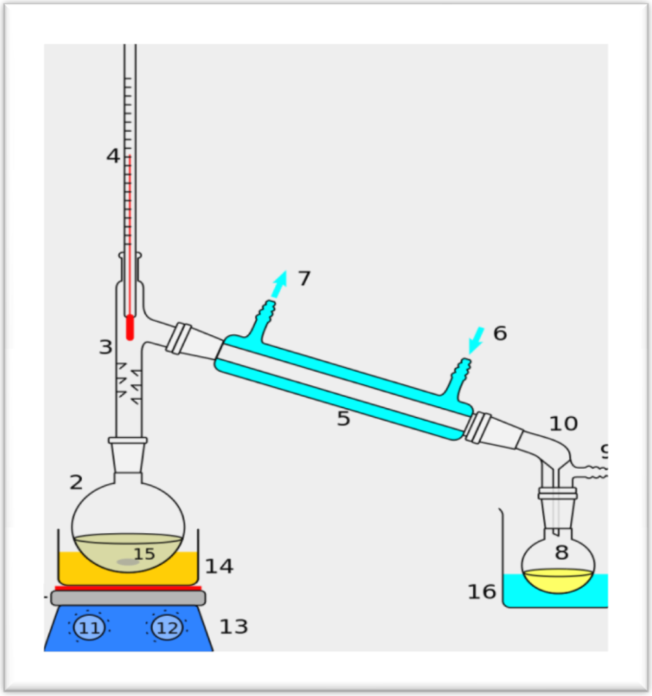
1. Evaporation of the more volatile component followed by evaporation of the next more volatile component. This process is based on the relative volatilities of mixture of liquids taken.
2. Condensation in a condenser which takes place by contact of the vapors with a cooling liquid, in most cases water, thereby condenses the vapors.
3. Collection of the hot liquid that comes from the condenser and then again doing the process for the next liquid.
4. There is a reflux operation going on inside the head of the distillation still, wherein the vapors of the less volatile liquid unable to enter into the condenser returns back to the still. Such a process maintains product purity and temperature at which such a process is going on.

Fuels (e.g. petrol, diesel) are a common end product.

Fig 8. Fractional distillation

We were successful in completing the distillation process with fractional distillation as it gave us results. The procedure followed is showed in the diagram and the apparatus used consists of the following parts-

1. Heat source
2. Still pot



3. Still head
4. Thermometer
5. Condenser
6. Cooling water in
7. Cooling water out
8. Distillate flask
9. Gas inlet
10. Still receiver
11. Heat control
12. Stirrer control
13. Stirrer plate
14. Heating bath
15. Stirrer bar
16. Cooling bath

Fig 9. Fractional distillation diagram

We have taken three samples of bio-diesel for fractional distillation process and for each case following quantity has been maintained:

Amount of bio-diesel taken in still- 70ml

Amount of distillate collected- 10ml

Amount of bio-diesel left in still after distillation- 55ml

iii. Process of blending biodiesel & diesel

Bio-diesel is rarely used in pure form as it can lead to maintenance and performance issues without engine modifications. Bio-diesel has similar engine power, ignition, torque, and yield as diesel but the consumption can increase slightly more than diesel. The following procedure was employed during bio-diesel & diesel blending.

1. For the process of blending, we have taken 200ml market-grade diesel as our basis.
2. Then we mixed (manual stirring), in volume proportions the pure biodiesel that we produced.
3. We have formulated four samples namely- i. B5- 5% blend
   ii. B7.5 -7.5% blend
   iii. B10- 10% blend
   iv. B15- 15% blend

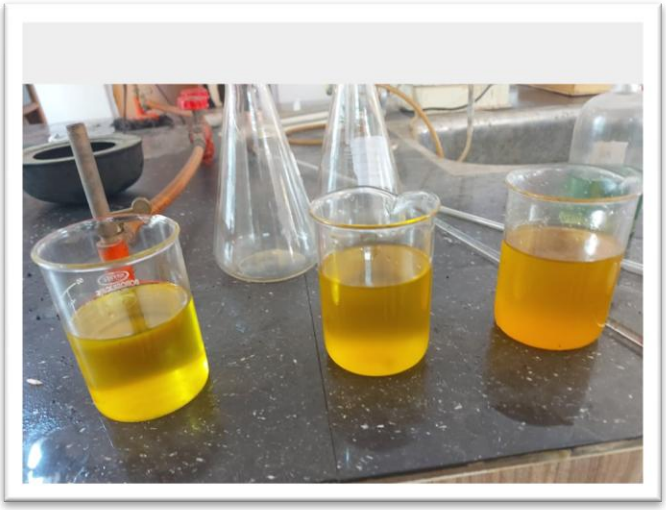


Fig 10. Bio-diesel blends, from left, B5, B10, B15

3.2.3 STANDARD TESTS FOR BIO-DIESEL

There are many standard tests for diesel fuel which are conducted for bio-diesel as well. We undertook the following tests to find out the characteristics of bio-diesel processed in laboratory.

1. FIRE POINT: The fire point of a fuel is the lowest temperature at which the vapor of that fuel will continue to burn for at least five seconds after ignition by an open flame of standard dimension. Apparatus used includes PENSKY MARTENS OPEN CUP APPARATUS & ABEL FLASH POINT APPARATUS.

2. FLASH POINT: Flash point of a material is the lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapors in a quantity such as to be capable of forming an ignitable vapor/air mixture. Apparatus used includes CLEVELAND OPEN CUP apparatus. It can be used for determination of both flash & fire point.

Fig 11. Cleveland fire and flash point apparatus

3. VISCOSITY: Viscosity is the resistance of a fluid (liquid or gas) to a change in shape or movement of neighboring portions relative to one another. REDWOOD VISCOMETER is used for determination for viscosity.

Fig 12. Redwood viscometer apparatus

4. ANILINE POINT: The aniline point of oil is defined as the minimum temperature at which equal volumes of aniline and oil are miscible.

Fig 13. Aniline point apparatus

5. CETANE NUMBER: Cetane number is a measurement of the quality or performance of diesel fuel.

CN = 0.72 Diesel index X 10

6. DIESEL INDEX: An empirical measure of the ignition quality of a diesel fuel defined in terms of the API gravity and aniline point of the fuel.

   Diesel index = (API X Aniline point)/ 1000

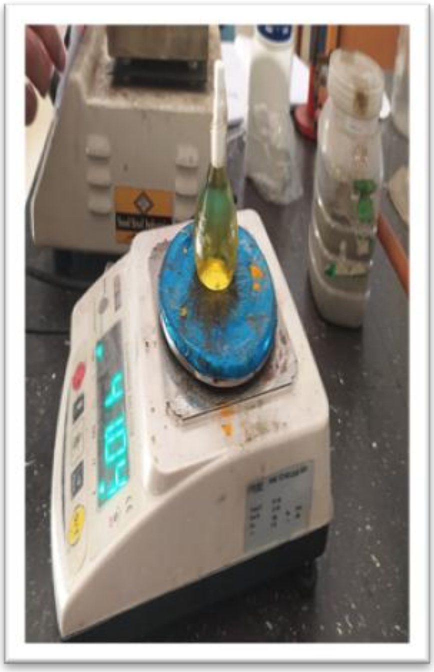


Fig 14. Specific gravity apparatus

7. POUR POINT: The temperature at which the test fluid can be poured under the prescribed test conditions. It is a measure of the tendency of a fuel to become more viscous and resist flowing when cold.

8. CLOUD POINT: It is the minimum temperature at which the first crystal formation starts i.e. clod formation starts.

   Both cloud and pour points are determined using CLOUD & POUR POINT apparatus.

FIG 15.Cloud point

FIG 16 .Pour point

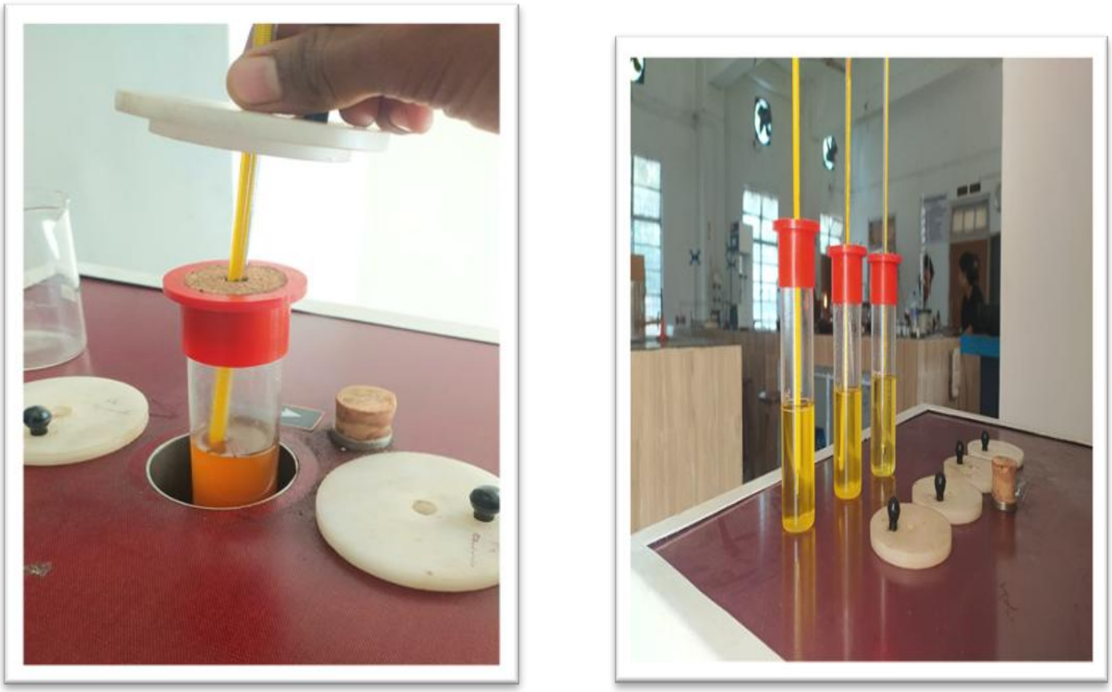


FIG 17. Pour point and cloud point for different blend

9. CARBON RESIDUE: It is an indication of the fuel to decompose and form carbonaceous material that can plug diesel fuel injection nozzles. It is determined using RAMSBOTTOM CARBON RESIDUE apparatus.

   After the blending process, we have done these nine standard tests for the four samples of blend. The observations and results of each test conducted for each sample is discussed in detail in **CHAPTER 4.**

3.3 SOAP PRODUCTIONS FROM GLYCEROL

The byproduct glycerol is obtained as the bottom viscous layer from the biodiesel and glycerol mixture. Glycerol plays a very important part in the cosmetic industry as it is an excellent moisturizing agent. The purification of glycerol is done through "VACCUM DISTILLATION" which is crystal clear in appearance.

From the glycerol that was separated, we made two items- Hand wash & organic soap.

The point to be noted here is that when left in a beaker for storage, the highly viscous glycerol becomes foul and does not form proper soap.

1. HANDWASH

5 ml of purified glycerol was taken in a beaker. A solution of 7ml of 40% NaOH solution was mixed with it. The mixture was then slightly heated for about 10 minutes and allowed to cool. After 48 hours, a viscous liquid was obtained which was used as a handwash.

2. ORGANIC_SOAP

We took 25 ml of glycerol in a beaker and to it we added 35 ml of 40% NaOH solution. Again it was heated for about 10 minutes. During the heating, the other ingredients were added to it whist continuously stirring the mixture. The mixture was allowed to cool and poured into a mold and kept isolated for almost 2days. The resulting product was a beautiful bar of organic soap.

Ingredients added-

- Aloe vera extract (5g)
- Niacinamide (3-5 drops)
- Vitamin E capsules (3)
- Neem extract (6 ml)
- Menthol (10 drops
- Green coloring 94 drops)

FIG 18. Organic soap from glycerol

CHAPTER 4

RESULTS AND DISCUSSIONS

After the successful completion of entire experimental procedures and tests, we have put forward all the data in tabular form and in graphical form. The following annexure depicts the calculated and collected data. With the tables, we have also added graphs showing deviations from standard values. At the end of each comparison, results are given

To make it more understandable and clear, we have separated the entire data analysis into three annexure. This are-

1. **ANNEXURE-I-** ANALYSIS AND COMPARISON OF STANDARD DATA AVAILABLE ON DIESEL AND BIO-DIESEL.

2. **ANNEXURE –II-** ANALYSIS AND COMPARISON OF EACH SAMPLE OF BIO-DIESEL PROCESSED WITH STANDARD DIESEL.

3. **ANNEXURE-III-** ANALYSIS AND COMPARISON OF BIO-DIESEL BLENDS WITH STANDARD DIESEL.

.

In the first annexure, we have taken standard values available for diesel available for BS-IV and BS-VI and standard data available for bio-diesel from major producing countries like USA & Europe. Finally, we have combined all the standard data in a single table showing the variations clearly. To make it more clear, we have added graph showing the variations.

We have divided the second annexure in to two parts- before and after distillation. In part I, we have taken standard values of BS-IV diesel and calculated and observed values of bio-diesel that we have processed in lab before distillation. After distillation, we again proceeded with all the experimental tests for the distilled samples. Finally, we have added graphs distinguishing the deviations from the standard values for both the parts. For the case of distillation process, we proceeded with fractional distillation process which gave us results. The other processes of steam and differential distillation ended up in a failure. The details on the experimental procedure are given on **CHAPTER 3**.

In the third annexure, again we have compared the standard values of BS-IV diesel with the four blends. Additionally, we have provided graphs for the variations among the blends and the variations with the standard values available.

ANNEXURE-I

ANALYSIS AND COMPARISON OF STANDARD DATA

TABLE 3. STANDARD DATA AVAILABLE FOR DIESEL

SL.NO.	PARAMETERS	AUTOMOTIVE DIESEL	
		BS-IV*	BS-VI**
1	FLASH POINT	66 ^{o}C	Min 55^{o}C
2	FIRE POINT	93.3^{o}C	90.5^{o}C
3	DENSITY	(at 15^{o}C) 815-845kg/m^{3}	(at 15^{o}C) 820-860kg/m^{3}
4	KINEMATIC VISCOCITY	2.0-4.5	2-4.5
5	POUR POINT	-3^{o}C	-3^{o}C
6	CETANE NUMBER	51	51
7	DIESEL INDEX	1.26	1.32
8	CARBON RESIDUE	0.30g	0.30g
9	ANILINE POINT	71^{o}C	74^{o}C
10	SULPHUR CONTENT	50mg/kg	10mg/kg

*BS-IV (IS 1460-2017) - standard findings from MRPL, Mangalore

**BS-VI, standard findings from BPCL, Mumbai

TABLE 4. STANDARD DATA AVAILABLE FOR BIO-DIESEL

SL. NO.	PARAMETERS	BIO-DIESEL *	BIO-DIESEL **
1	**FLASH POINT**	93°C	97°C
2	**FIRE POINT**	100°C & greater	100°C & greater
3	**DENSITY (at 15°C)**	820-845 kg/m^3	860-900 kg/m^3
4	**KINEMATIC VISCOCITY**	1.9-6.0	3.5-5.0
5	**POUR POINT**	-3-10°C	-4-12°C
6	**CETANE NUMBER**	47	51
7	**DIESEL INDEX**	1.26	1.43
8	**CARBON RESIDUE**	0.0040g	0.0036g
9	**ANILINE POINT**	59°C	59°C
10	**SULPHUR CONTENT**	0.05%	0.05%

*BIO-DIESEL (ASTM D6751-07b) –American standard bio-diesel defined as mono alkyl esters of long chain fatty acids derived from vegetable oils and animal fats. The type of alcohol is not specified

**BIO-DIESEL (EN 14214:2012) – European standard bio-diesel is more restrictive and applies only to mono alkyl esters made with methanol (FAME). The minimum ester content is specified at 96.5%. Te addition of components that are not fatty acid methyl esters is not allowed.

TABLE 5. COMPARISON OF STANDARD VALIUES OF DIESEL AND BIO-DIESEL

SL. NO.	PARAMETERS	AUTOMOTIVE DIESEL		BIO-DIESEL *	BIO-DIESEL **
		BS-IV	BS-VI		
1	**FLASH POINT**	66 ^{o}C	Min 55^{o}C	93^{o}C	97^{o}C
2	**FIRE POINT**	93.3^{o}C	90.5^{o}C	100^{o}C +	100^{o}C +
3	**DENSITY (at 15^{o}C,kg/m^{3})**	815-845	820-860	820-845	860-900
4	**KINEMATIC VISCOCITY**	2.0-4.5	2-4.5	1.9-6.0	3.5-5.0
5	**POUR POINT**	-3^{o}C	-3^{o}C	-3-10^{o}C	-4-12^{o}C
6	**CETANE NUMBER**	51	51	47	51
7	**DIESEL INDEX**	1.26	1.32	1.26	1.43
8	**CARBON RESIDUE**	0.30g	0.30g	0.0040g	0.0036g
9	**ANILINE POINT**	71^{o}C	74^{o}C	59^{o}C	59^{o}C
10	**SULPHUR CONTENT**	50mg/kg	10mg/kg	0.05%	0.05%

In the next page, there are graphs showing variations in the standard values among the fuels.

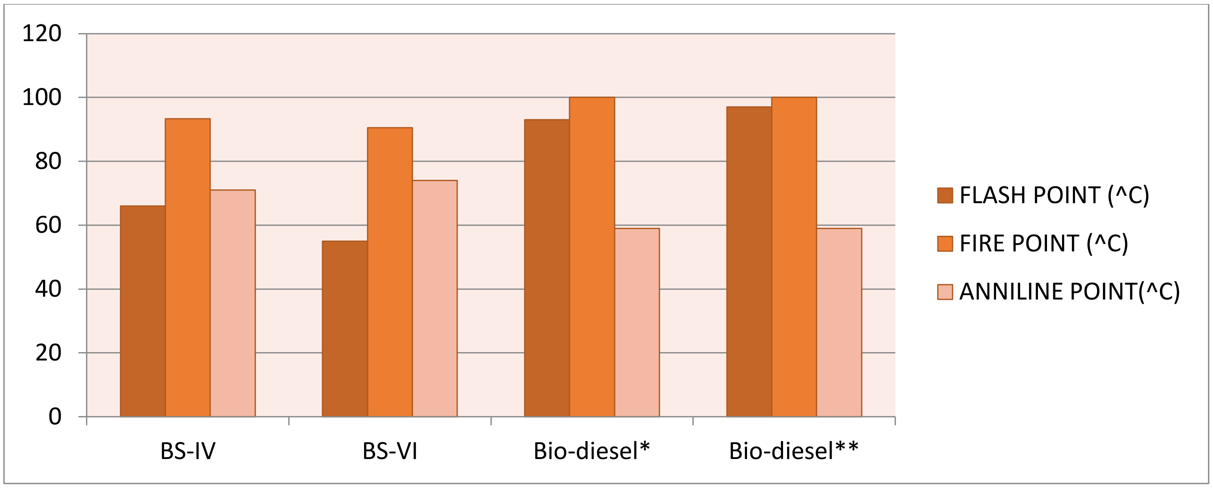


Fig19. Graph showing variations in flash point, fire point and aniline point

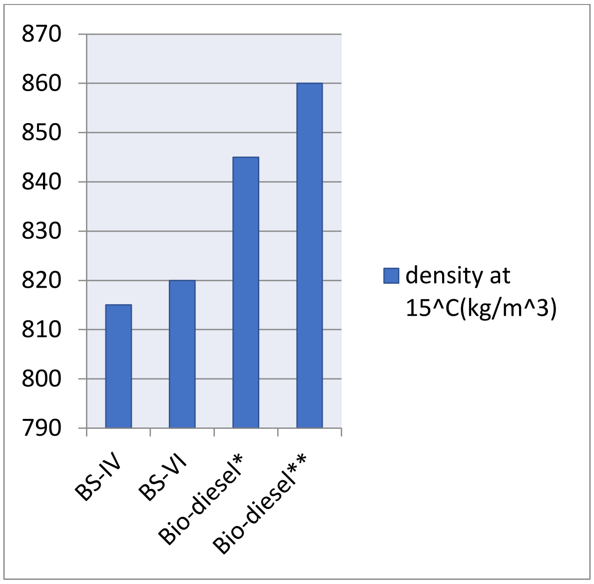


Fig20. Graph showing variations in density

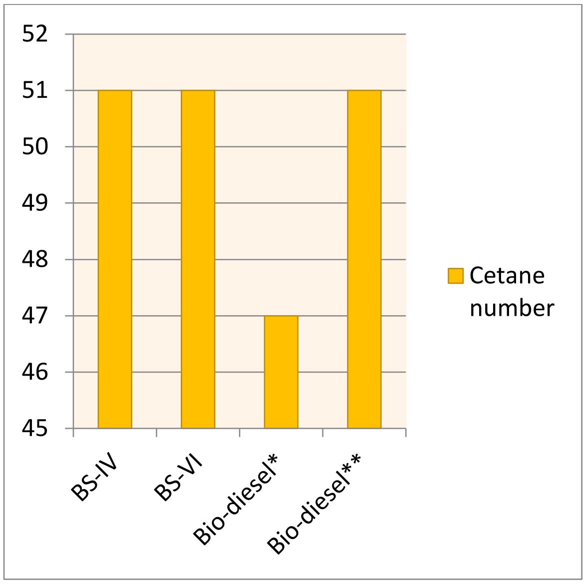


Fig21. Graph showing variations in cetane number

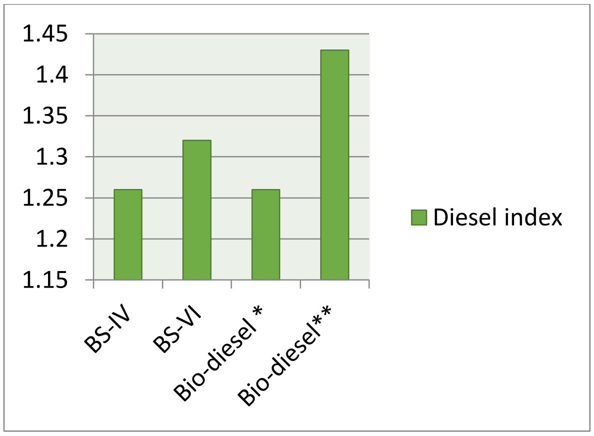


Fig22. Graph showing variation in diesel index

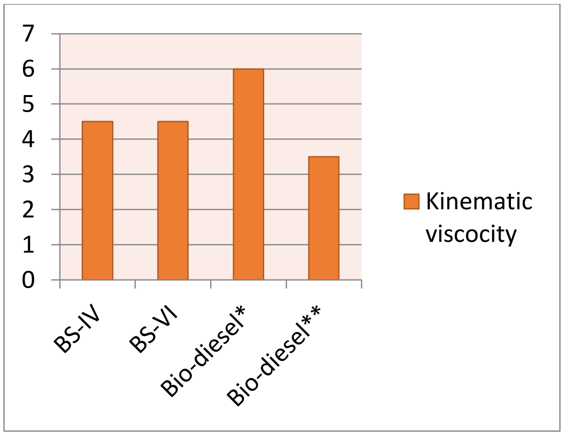


Fig23. Graph showing variation in viscosity

ANNEXURE II

ANALYSIS AND COMPARISON OF DATA OF BIO-DIESEL SAMPLES PROCESSED IN LAB

PART 1- DATA ANALYSIS OF BIO-DIESEL BEFORE DISTILLATION PROCESS

1. SAMPLE S1-

i) S1.a - 100 ml of WASTE COOKING OIL from hostel 3

Chemicals used: 20ml ethanol, 1.4g of KOH

OBSERVATIONS:

TABLE 1.1a: WEIGHT OF ITEMS TAKEN

CATEGORY	ITEM	WEIGHT(g)
Waste cooking oil	**Weight of beaker (g)**	140.13
	Weight of sample and beaker (g)	240.13
	Net sample weight (g)	100
Bio-diesel	**Weight of beaker (g)**	140.13
	Weight of sample and beaker(g)	225.13
	Net sample weight(g)	85

Weight of glycerol = Weight of sample and beaker- weight of beaker = 17.85g

TABLE 1.2a: COMPARISONS WITH STANDARD DIESEL

SL. NO.	PARAMETER	DIESEL (BS-IV)	S1.a	DEVIATION
1	FLASH POINT	66 ^{o}C	92^{o}C	~40%
2	FIRE POINT	93.3^{o}C	98^{o}C +	~5%

3	**DENSITY**	815-845kg/m^3	819.2 kg/m^3	-0.7%
4	**VISCOCITY**	2.0-4.5	4.3	-4.4%
5	**CLOUD POINT**	-3^{o}C	-3.4^{o}C	~13%
6	**POUR POINT**	-3-15^{o}C	-8.3^{o}C	~44%
7	**ANILINE POINT**	71^{o}C	57^{o}C	~19%
8	**DIESELINDEX**	1.26	1.31	~4%
9	**CARBON RESIDUE**	0.30g	0.0045g	98.5%

ii) S1.b - 100 ml of WASTE COOKING OIL from hostel 3

Chemicals used: 21ml ethanol, 1.5g of KOH

OBSERVATIONS:

TABLE 1.1b: WEIGHT OF ITEMS TAKEN

CATEGORY	**ITEM**	**WEIGHT(g)**
Waste cooking oil	**Weight of beaker (g)**	140.13
	Weight of sample and beaker (g)	240.13
	Net sample weight (g)	100
Biodiesel	**Weight of beaker (g)**	140.13
	Weight of sample and beaker(g)	225.13
	Net sample weight(g)	85

Weight of glycerin formed = (Weight of sample and beaker – weight of sample) = 25-30g

TABLE 1.2b COMPARISONS WITH STANDARD DIESEL (BS-IV)

SL. NO.	PARAMETER	DIESEL (BS-IV)	S1.b	DEVIATION
1	**FLASH POINT**	66 ^{o}C	92-93^{o}C	~40%
2	**FIRE POINT**	93.3^{o}C	110^{o}C+	~5.3%
3	**DENSITY**	815-845kg/m^{3}	824.8 kg/m^{3}	~1.2%
4	**VISCOCITY**	2.0-4.5	4.25	~ -5%
5	**CLOUD POINT**	-3^{o}C	-3.3^{o}C	~10%
6	**POUR POINT**	-3-15^{o}C	-8.5^{o}C	~ -43%
7	**ANILINE POINT**	71^{o}C	61^{o}C	~19%
8	**DIESEL INDEX**	1.26	1.29	~2.3%
9	**CARBON RESIDUE**	0.30g	0.0043g	96.5%

2. SAMPLE S2

500 ml of WASTE COOKING OIL from hostel 3

Chemicals used: 100ml ethanol, 3.5g of KOH

OBSERVATIONS:

TABLE 2.1: WEIGHT OF ITEMS TAKEN

CATEGORY	ITEM	WEIGHT(g)
	Weight of beaker (g)	539

Waste cooking oil	**Weight of sample and beaker (g)**	994.34
	Net sample weight (g)	455.34
Biodiesel	**Weight of beaker (g)**	539
	Weight of sample and beaker(g)	971.45
	Net sample weight(g)	432.45

Weight of glycerin – (Weight of sample and beaker- weight of beaker) =50-70g

TABLE 2.2- COMPARISONS WITH STANDARD BIO-DIESEL

SL.NO.	**PARAMETER**	**DIESEL (BS-IV)**	**S2**	**DEVIATION**
1	**FLASHPOINT**	66 °C	95°C	~43%
2	**FIRE POINT**	93.3°C	100°C+	~5.3%
3	**DENSITY**	815-845kg/m^3	822.3 kg/m^3	~1.3%
4	**VISCOCITY**	2.0-4.5	4.16	~ -4.5%
5	**CLOUD POINT**	-3°C	-3.4°C	~13%
6	**POUR POINT**	-3-15°C	-8.6°C	~ -41.2%
7	**ANILINE POINT**	71°C	59°C	~21%
8	**DIESEL INDEX**	1.26	1.3	~2.1%
9	**CARBON RESIDUE**	0.30g	0.0045g	94.5%

3. SAMPLE S3

200 ml of waste cooking oil from hostel 3

Chemicals used: 1.4 g NaOH, 45 ml methanol

Bio-diesel was not formed due to-

1. Magnetic stirrer was used during heating which did not initiate proper mixing i.e. apparatus failure.
2. The optimum temperature of around 60°C was not reached and hence, reaction did not occur.

4. SAMPLE S6

200 ml of waste cooking oil from Sundarbari stall

Chemicals used: 2.6g NaOH, 45 ml methanol

Bio-diesel was not formed due to-

1. Reaction parameters were not met as mentioned in above case.
2. Further centrifugation could not separate the reaction mixture into different layers.

5. SAMPLE S7

200 ml of waste cooking oil from Sundarbari stall

Chemicals used: 2g NaOH, 45 ml methanol

Bio-diesel was not formed due to-

1. Reasons as mentioned in above cases.

6. SAMPLE S10

100 ml of waste cooking oil from Ganeshguri stall

Chemicals used: 1g KOH, 20ml ethanol

OBSERVATIONS:

TABLE 3.1WEIGHT OF ITEMS TAKEN

CATEGORY	ITEM	WEIGHT(g)
Waste cooking oil	**Weight of beaker (g)**	140.13
	Weight of sample and beaker (g)	240.13
	Net sample weight (g)	100

Biodiesel	**Weight of beaker (g)**	140.13
	Weight of sample and beaker(g)	225.13
	Net sample weight(g)	85

Weight of glycerin = (Weight of sample and beaker- weight of beaker) =18-20g

TABLE 3.2 COMPARISONS WITH STANDARD BIO-DIESEL

SL.NO.	PARAMETERS	DIESEL (BS-IV)	S10	DEVIATION
1	FLASH POINT	66 ^{o}C	93^{o}C	~41%
2	FIRE POINT	93.3^{o}C	110^{o}C	~5.5%
3	DENSITY	815-845kg/m^{3}	826.2 kg/m^{3}	~1.7%
4	VISCOCITY	2.0-4.5	3.6	-~4.4%
5	CLOUD POINT	-3^{o}C	-3.6^{o}C	~14%
6	POUR POINT	-3-15^{o}C	-8.7^{o}C	~ -41.5%
7	ANILINE POINT	71^{o}C	58^{o}C	~19%
8	DIESEL INDEX	1.26	1.35	-2.6%
9	CARBON RESIDUE	0.30g	0.0043g	94.8%

After the completion of analysis and comparison of each sample with standard diesel, we have tabulated all the samples together to find out which one was the best processed. In the next table, we have tabulated all the samples together and have put forward a histogram showing the variations among them.

TABLE 4 COMPARISONS AMONG ALL THE SAMPLES OF BIO-DIESEL

SL.NO	**PARAMETER**	**SAMPLE S1.a**	**SAMPLE S1.b**	**SAMPLE S2**	**SAMPLE S10**
1	**FLASH POINT**	92°C	92-93°C	95°C	93°C
2	**FIRE POINT**	98°C +	110°C+	100°C+	110°C
3	**DENSITY**	819.2 kg/m^3	824.8 kg/m^3	822.3 kg/m^3	826.2 kg/m^3
4	**VISCOCITY**	4.3	4.25	4.16	3.6
5	**CLOUD POINT**	-3.4°C	-3.3°C	-3.4°C	-3.6°C
6	**POUR POINT**	-8.3°C	-8.5°C	-8.6°C	-8.7°C
7	**ANILINE POINT**	57°C	61°C	59°C	58°C
8	**DIESEL INDEX**	1.31	1.29	1.3	1.35
9	**CARBON RESIDUE**	0.0045g	0.0043g	0.0045g	0.0043g

From the above table we can conclude that sample S10 was better in its properties compared to the rest of the samples formed. In the next page, we have put forward graphs as mentioned beforehand.

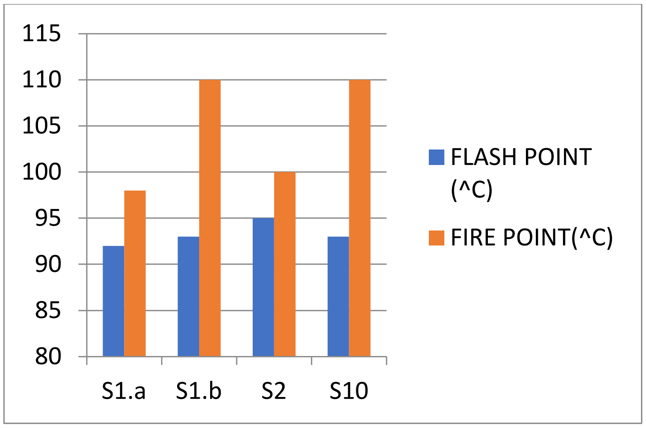


Fig 24. Variation in flash and fire point

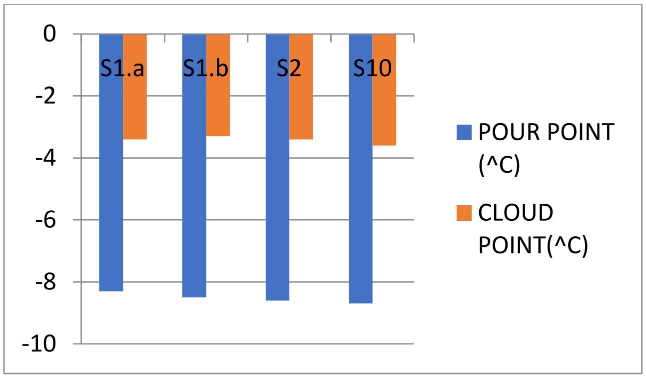


Fig 25. Variation in cloud and pour point

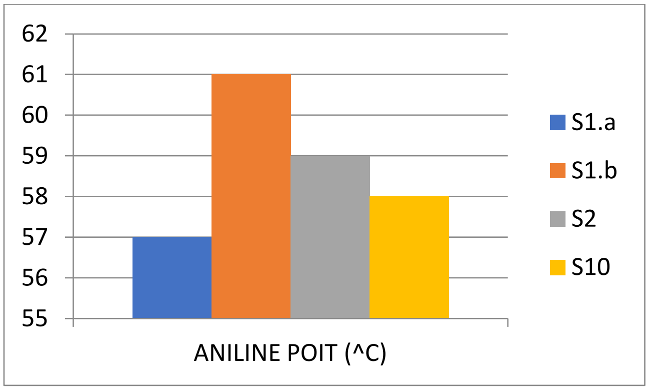


Fig 26. Variation in aniline point

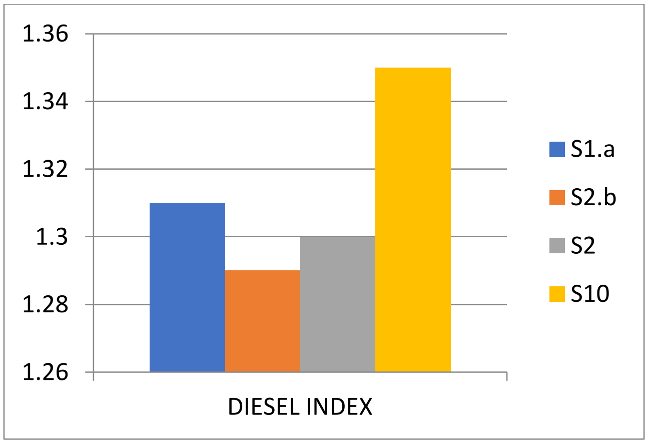


Fig 27. Variation in diesel index

PART 2- DATA ANALYSIS OF BIO-DIESEL AFTER DISTILLATION PROCESS

We employed a laboratory level distillation apparatus to fractionate our biodiesel. The more volatile components like unreacted ethanol, water etc were collected and measured. After the entire process was over, we again proceeded for the analysis of the distilled biodiesel samples.

We have done the process of distillation for three samples of bio-diesel and those are-

1. SAMPLE S1.a
2. SAMPLE S1.b
3. SAMPLE S2

FIG28. FRACTIONAL DISTILLATION APPARATUS

The apparatus used consists of the following parts-

17. Heat source
18. Still pot
19. Still head
20. Thermometer
21. Condenser

22. Cooling water
23. Distillate flask
24. Still receiver
25. Heating bath
26. Cooling bath

OBSERVATIONS:

For each case,

Amount of bio-diesel taken in still- 70ml

Amount of distillate collected- 10ml

Amount of bio-diesel left in still after distillation- 55ml

TABLE 5: COMPARISONS BEFORE AND AFTER DISTILLATION

SL.NO.	PARAMETER	BEFORE DISTILLATION (SAMPLE S1.a)	DISTILLED SAMPLE S1.a	DISTILLED SAMPLE S1.b	DISTILLED SAMPLE S2
1	**FLASH POINT**	92^{o}C	102^{o}C	101^{o}C	97^{o}C
2	**FIRE POINT**	98^{o}C +	116^{o}C	116^{o}C	116^{o}C
3	**DENSITY**	819.2 kg/m^3	834.5kg/m^3	832.6kg/m^3	821.5kg/m^3
4	**POUR POINT**	-3.4^{o}C	-3.9^{o}C	-4.1^{o}C	-4.1^{o}C
5	**CLOUD POINT**	-8.3^{o}C	-7.1^{o}C	-7.1^{o}C	-7.3^{o}C
6	**CARBON RESIDUE**	0.0045g	0.0034g	0.0033g	0.0032g
7	**DIESEL INDEX**	1.31	1.35	1.35	1.35
8	**ANILINE POINT**	57^{o}C	55^{o}C	55^{o}C	55^{o}C

The entire comparison and analysis amongst the samples before and after distillation are shown in a histogram.

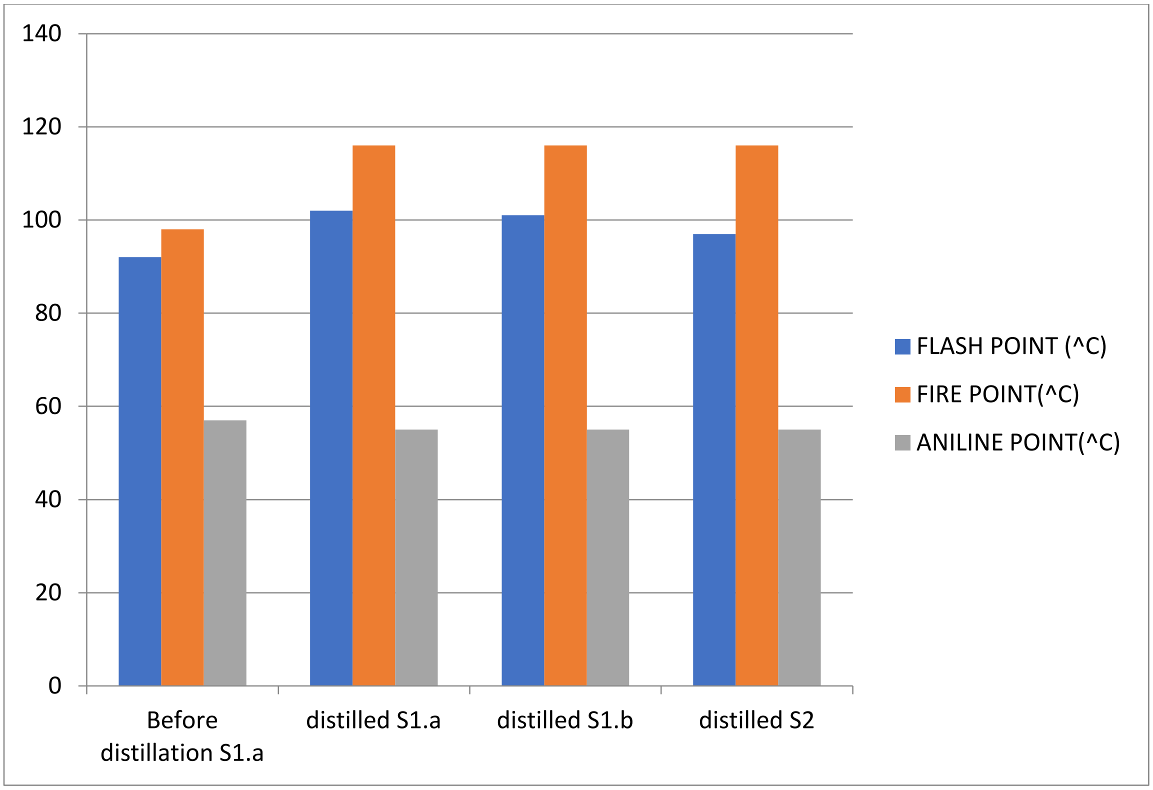
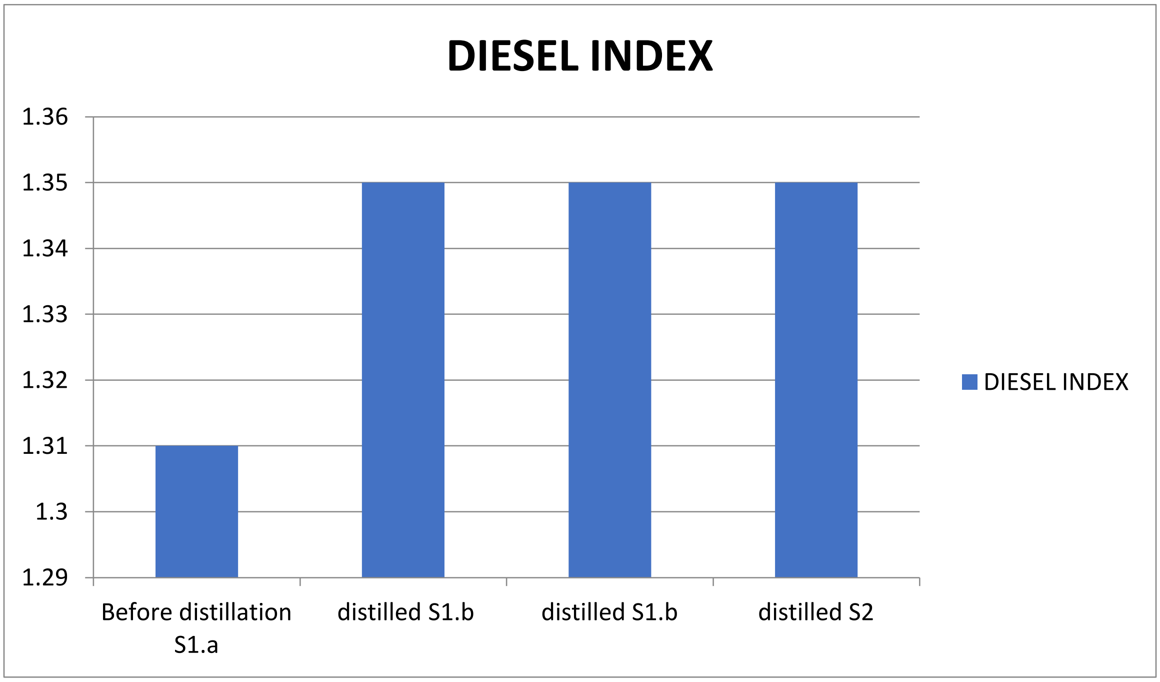


Fig 29. Variations in flash point, fire point and aniline point

Fig 30. Variation in diesel index



For comparison with the after distillation samples, we have taken the observed and calculated values of sample **S1.a** as the reference, given in table 4. We can see that the properties of the samples of bio-diesel have significantly improved upon distillation. . Again we have comparisons between standard diesel and the distilled samples given in table 5.

TABLE 6: COMPARISONS OF DATA WITH STANDARD DIESEL

SL.NO.	**PARAMETER**	**DIESEL (BS-IV)**	**DISTILLED SAMPLE S1.a**	**DISTILLED SAMPLE S1.b**	**DISTILLED SAMPLE S2**
1	**FLASH POINT**	66 °C	102°C	101°C	97°C
2	**FIRE POINT**	93.3°C	116°C	116°C	116°C
3	**DENSITY**	815-845kg/m^3	834.5kg/m^3	832.6kg/m^3	821.5kg/m^3
4	**CLOUD POINT**	-3°C	-3.9°C	-4.1°C	-4.1°C
5	**POUR POINT**	-3-15°C	-7.1°C	-7.1°C	-7.3°C
6	**CARBON RESIDUE**	0.30g	0.0034g	0.0033g	0.0032g
7	**DIESEL INDEX**	1.26	1.35	1.35	1.35
8	**ANILINE POINT**	71°C	55°C	55°C	55°C

ANNEXURE III

DATA ANALYSIS OF BIO-DIESEL-DIESEL BLENDS

As mentioned earlier, three batches of 100ml of sample **S10** was taken and used in the process of blending. The three blends were then further tested. The following procedure was followed:

1. For the process of blending, we have taken 200ml market grade diesel as our basis.
2. Then we have mixed (manual stirring), in volume proportions the pure biodiesel that we have produced.
3. We have formulated three samples namely- i. B5-5% blend
   ii. B10-10% blend
   iii..B15-15% blend

Given below are the analyses of the various blends along with standard data of diesel (BS-IV)

1. SAMPLE 1- 5% BLEND (B5)

CALCULATIONS:

Basis =200ml of diesel

Now, 5% of 200 ml =0.05× 200 =10 ml

Therefore, we blend 10 ml of biodiesel in, 200-10=190 ml of diesel.

TABLE 7: COMPARISONS WITH DIESEL (BS-IV)

SL.NO.	PARAMETER	DIESEL (BS-IV)	B5
1	**FLASH POINT**	66 ^oC	96^oC
2	**FIRE POINT**	93.3^oC	100^oC+
3	**POUR POINT**	-3-15^oC	-16^oC
4	**DENSITY**	815-845kg/m^3	418 kg/m^3
5	**CLOUD POINT**	-3^oC	-2.8 ^{o}C
6	**CARBON RESIDUE**	0.30g	0.0040g
7	**ANILINE POINT**	71^oC	72^oC

8	**DIESEL INDEX**	1.26	1.23
9	**CETANE NUMBER**	51	53

2. SAMPLE 2- 10% BLEND (B10)

CALCULATIONS:

Basis =200ml of diesel

Now, 10% of 200 ml = 0.10× 200 =20 ml

Therefore, we blend 10 ml of biodiesel in, 200-20=180 ml of diesel.

TABLE 8: COMPARISONS WITH DIESEL

SL.NO.	**PARAMETER**	**DIESEL (BS-IV)**	**B10**
1	**FLASH POINT**	66 ^{o}C	82^{o}C
2	**FIRE POINT**	93.3^{o}C	100^{o}C+
3	**DENSITY**	815-845kg/m^{3}	415.7 kg/m^{3}
4	**POUR POINT**	-3-15^{o}C	-19^{o}C
5	**CLOUD POINT**	-3^{o}C	-4.6 ^{o} C
6	**CARBON RESIDUE**	0.3g	0.0043g
7	**ANILINE POINT**	71^{o}C	76^{o}C
8	**DIESEL INDEX**	1.26	1.56
9	**CETANE NUMBER**	51	56

3. SAMPLE 3- 15% BLEND (B10)

CALCULATIONS:

Basis =200ml of diesel

Now, 15% of 200 ml =0.15× 200 =30 ml

Therefore, we blend 10 ml of biodiesel in 200-30=170 ml of diesel.

TABLE 9: COMPARISONS WITH DIESEL

SL.NO.	PARAMETER	DIESEL (BS-IV)	B10
1	FLASH POINT	66 ^{o}C	75^{o}C
2	FIRE POINT	93.3^{o}C	100^{o}C
3	DENSITY	815-845kg/m^{3}	432.5 kg/m^{3}
4	POUR POINT	-3-15^{o}C	-23^{o}C
5	CLOUD POINT	-3^{o}C	-7.9 ^{o} C
6	CARBON RESIDUE	0.3g	0.0046g
7	ANILINE POINT	71^{o}C	78^{o}C
8	DIESEL INDEX	1.26	1.53
9	CETANE NUMBER	51	54

After complete comparison and analyses, we have found that the blend B5 and B10 has better properties. Hence, to further enhance our findings, we took a 7.5% blend i.e in between 5% and10% blend to compare our findings. The results of the B7.5 blend are as follows-

4. SAMPLE 4- 7.5% BLEND (B10)

CALCULATIONS:

Basis =200ml of diesel

Now, 7.5% of 200 ml =0.075 × 200 =15 ml

Therefore, we blend 10 ml of biodiesel in, 200-15=185 ml of diesel.

TABLE 10: COMPARISONS WITH STANDARD RESULTS

SL.NO.	PARAMETER	DIESEL (BS-IV)	B7.5
1	**FLASH POINT**	66°C	95°C
2	**FIRE POINT**	93.3°C	100°C +
3	**DENSITY**	815-845kg/m^3	412.5 kg/m^3
4	**POUR POINT**	-13°C	-18°C
5	**CLOUD POINT**	-3°C	-5.9 ° C
6	**CARBON RESIDUE**	0.3g	0.0046g
7	**ANILINE POINT**	71 °C	76°C
8	**DIESEL INDEX**	1.26	1.33
9	**CETANE NUMBER**	51	58

After completion of the analysis of blends, we have put forward a comparison amongst all the blends to give an overall view of the characteristics.

TABLE 11: COMPARISONS AMONG ALL THE BLENDS

SL.NO.	PARAMETER	B5	B7.5	B10	B15
1	**FLASH POINT**	96°C	96°C	82°C	75°C
2	**FIRE POINT**	100°C +	100°C +	100°C+	100°C+
3	**POUR POINT**	-16°C	-18°C	-19°C	-23°C

4	**CLOUD POINT**	-2.8 ^{o}C	-3.9 ^{o}C	-4.6 ^{o}C	-7.9 ^{o}C
5	**CARBON RESIDUE**	0.0040g	0.0046g	0.0043g	0.0046g
6	**ANILINE POINT**	72^{0}C	76^{o}C	79^{0}C	76^{o}C
7	**DIESEL INDEX**	1.23	1.33	1.56	1.53
8	**CETANE NUMBER**	53	58	56	54

From the above table we conclude that, blends between B5 and B10 provide the best characteristics.

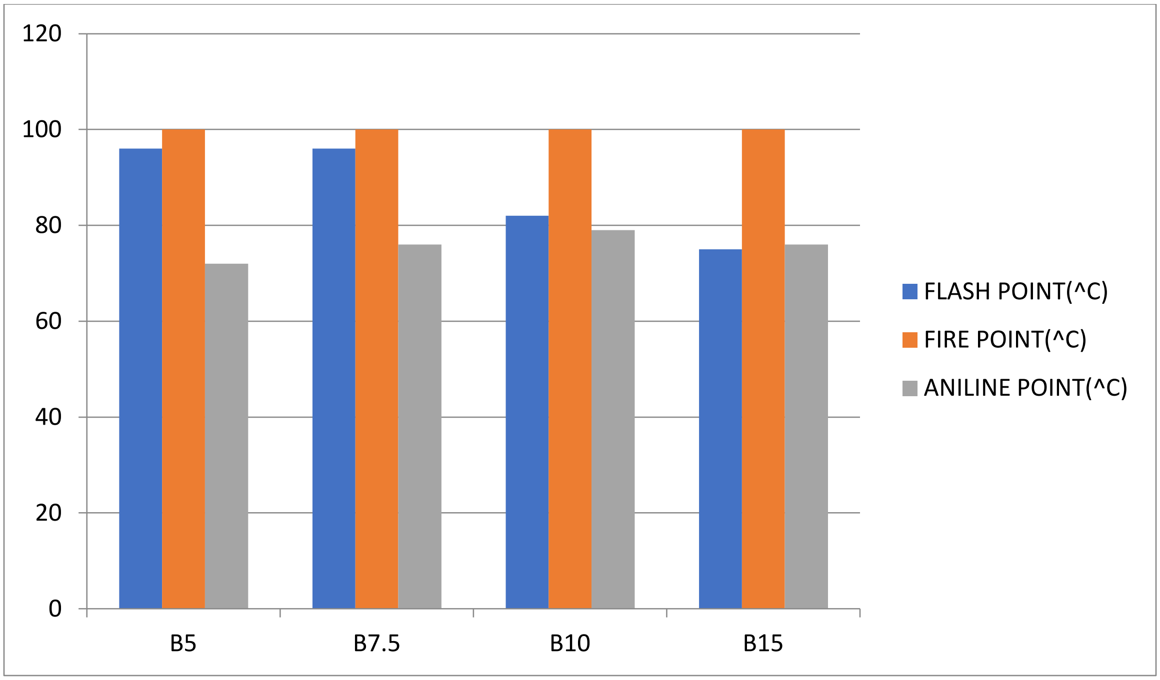


Fig 31. Variations in flash, fire and aniline point among the blends

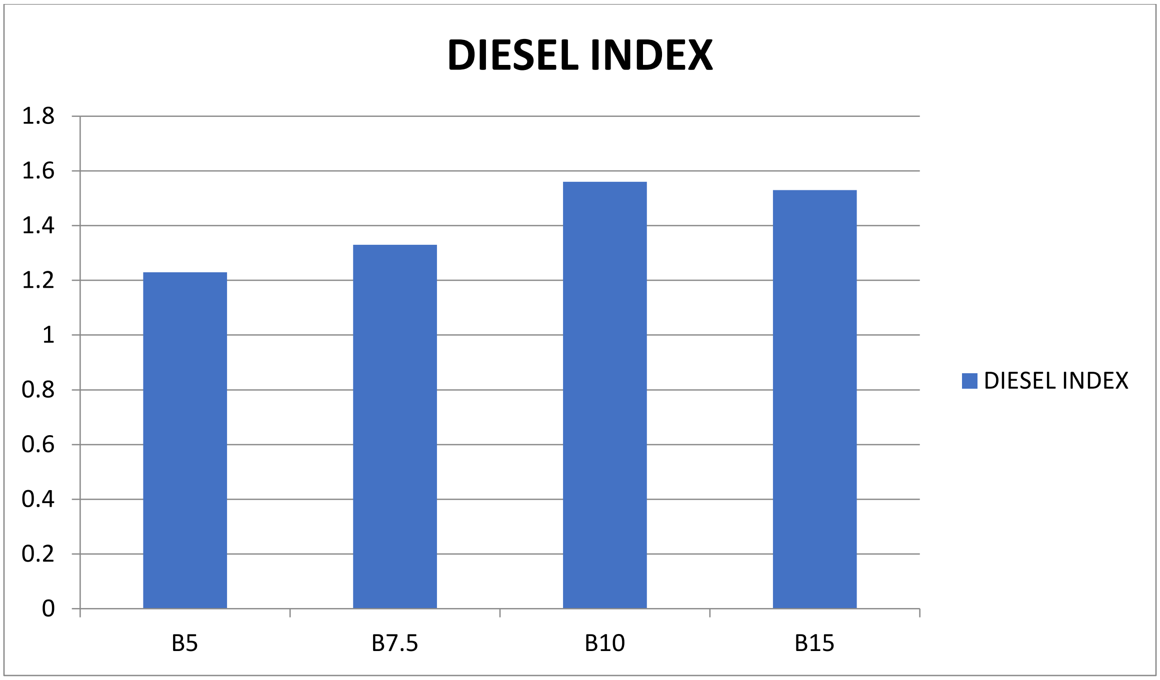


Fig 27. Variations in diesel index

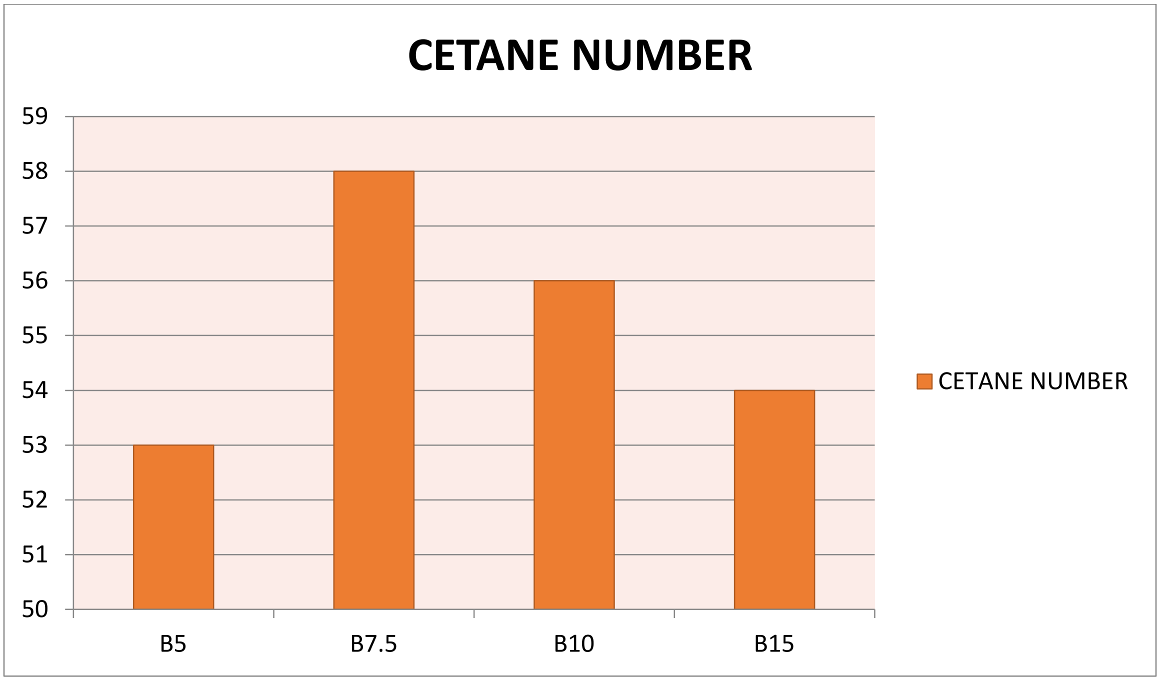


Fig28. Variations in cetane number

CONCLUSION

Bio-diesel produced from waste cooking is a very fruitful process of utilizing waste and helps in waste management of edible oil. However the main challenge lies in utilizing bio-diesel as an alternative for hydrocarbon fuels. There are standard procedures of blending in use and direct use of biodiesel. The quality characteristics of bio-diesel obtained in this work were in good agreement with standard diesel specification and bio diesel specification. If sufficient time and amount of waste cooking oil is taken, then following process can be completed and data can be further analyzed-

1. Pure biodiesel application in a diesel or hydrocarbon engine. Also more variation in blend volumes with more tests can be produced and applications on a engine as fuel can be done.
2. The glycerol obtained should be purified through VACCUM DITILLATION and further both organic and inorganic filler like orange peel extract, paraben etc can be employed for the process of soap making.
3. Fractional distillation for pure bio-diesel can be done in automatic modes.

Hence, we can conclude that biofuels are the one of the many options of energy crisis going on currently. Proper research and data representation can facilitate the process of this entire research initiative.

REFERNCE

[28] S. Zheng, M. Kates, M.A. Dube, D.D. McLean. Acid-catalyzed production of biodiesel from waste frying oil. Biomass and Bioenergy 2006;30:267–272.

[29] Yong Wang, Shiyi Ou, Pengzhan Liu, Zhisen Zhang. Preparation of biodiesel from waste cooking oil via two-step catalyzed process. Energy Conversion and Management 2007;48:184–188.

[30] Issariyakul, T., Kulkarni, M.G., Dalai, A.K., Bakhshi, N.N. Production of biodiesel from waste fryer grease using mixed methanol/ethanol system. Fuel Process Technol 2007;88:429-436.

[31] Ya-fen Lin, Yo-ping Greg Wu, Chang-Tang Chang. Combustion characteristics of waste-oil produced bio-diesel/diesel fuel blends. Fuel 2007;86:1772-1780.

[32] Hossain A.B.M.S. and Boyce A.N. Biodiesel production from waste sunflower cooking oil as an environmental recycling process and renewable energy. Bulgarian Journal of Agricultural Science. 2009;15: 312-317.

[33] Bakir T. Emaad, Fadhil B. Abdelrahman. Production of biodiesel from chicken frying oil. Pak. J. Anal. Environ. Chem. 2011;12: 95-101.

[34] Patil D. Prafulla, Gude Gnaneswar Veera, Reddy K. Harvind, Muppaneni Tapaswy and Deng Shuguang . Biodiesel production from waste cooking oil using sulfuric acid and microwave irradiation processes. Journal of Environmental Protection. 2012;3107-113.

[35] Suvendu Mohanty, Dr. Om Prakash. Analysis Of Exhaust Emission Of Internal Combustion Engine Using Biodiesel Blend. International Journal of Emerging Technology and Advanced Engineering 2013;3(05):731-742.

[36] Edmilson Antonio Canesin, Cláudio Celestino de Oliveira, Makoto Matsushita, Lucia Felicidade Dias, Mayka Reghiany Pedrao, Nilson Evelazio de Souza. Characterization of residual oils for biodiesel production. Electronic Journal of Biotechnology 2014;17:39-45.

[37] Farooq Muhammad and Ramli Anita. Biodiesel production from low FFA waste cooking oil using heterogeneous catalyst derived from chicken bones. Renewable Energy. 2015;76:362-368