

PRODUCTION OF BIO DIESEL FROM SILK COTTON SEED OIL USING HETEROGENOUS CATALYST

Submitted in partial fulfilment of the requirement for the award of

Bachelor of Technology Degree in

Chemical Engineering

By

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**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this project report is the bonafide work of Ramki J (39190025) and Gokul V (39190006) who carried out the project entitled "**PRODUCTION OF BIO DIESEL FROM SILK COTTON SEED OIL USING HETEROGENOUS CATALYST**" under our supervision from November 2022 to April 2023

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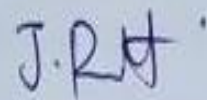
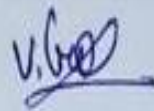
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DECLARATION

We Ramki J (39190025) and Gokul V (39190006) hereby declare that the Project Report entitled "**PRODUCTION OF BIO DIESEL FROM SILK COTTON SEED OIL USING HETEROGENOUS CATALYST**" done by me under the guidance of Mr Michael Rahul Soosai M.Tech (Internal) Sathyabama Institute Of Science and Technology, Chennai at is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in chemical engineering.

DATE: 21st April 2023

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ABSTRACT

This abstract presents the process of biodiesel production from silk cotton seed oil, which is a non-edible oil that has the potential to be used as a feedstock for biodiesel production. *Ceiba pentandra* (Silk cotton) seed oil was transesterified in two steps using an acid esterification and an alkali-catalyzed transesterification process with varying catalyst concentrations and methanol/oil ratios at temperatures of 50, 55, 60, and 65°C for one hour. The outcomes revealed an optimal percentage oil yield of 92.9% at 65°C. The findings also show that the biodiesel's properties. It is advised to use 4% of the catalyst for the transesterification of *Ceiba pentandra* seed oil because this concentration of the catalyst produced the highest production of biodiesel. The use of silk cotton seed oil as a biodiesel feedstock has environmental benefits as well. Biodiesel produced from this oil has lower emissions of particulate matter, carbon monoxide, and sulfur oxides compared to conventional diesel, resulting in reduced air pollution. Furthermore, the use of non-edible feedstocks can help reduce the impact of biodiesel production on food prices and land use.

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LIST OF ABBREVIATIONS

MgSO ₄	Magnesium sulphate
FFA	Free Fatty Acid
CCD	Central Composite Design
ANOVA	Analysis of Variance
XRD	X Ray Diffraction
FESEM	Field Emission Scanning Electron Microscope
EDX	Energy Dispersion X-Ray Analysis
FT-IR	Fourier Transform Infrared Spectroscopy
GC/MS	Gas Chromotography Mass Spectroscopy

CHAPTER-1

INTRODUCTION

The efforts to investigate certain alternate sources of petroleum-based fuels have been prompted by the depletion of the world's petroleum reserves as a result of the rapidly increasing energy demands and environmental concerns. Because they can be burned to create a considerable amount of energy, fuels are very important. Fossil fuels make up a large portion of the energy that is now used in the world. 80 percent of the world's energy challenge are met by fossil fuels. Vegetable oils, for example, can be used as renewable fuels. Vegetable oils provide a number of advantages over other energy sources, such as alcohols, including a larger energy content. Vegetable oils have recently gained popularity due to their favourable effects on the environment and their production from renewable resources. Vegetable oils contain 90% of the energy in diesel. Vegetable oils are currently more affordable than petroleum fuel, but they still require additional R&D to be developed and are not yet economically feasible. Vegetable oils can be used in CI engines by modifying the fuel and engine. Engine alter include heated fuel lines, a bifold fuel booster modification process, and the blending of diesel and vegetable oil. The transesterification procedure conclusion in the mono-alkyl esters of fatty acids that make up biodiesel. Heterogeneous catalysts may be reused, produce very little water, and use very little energy. The brake power and torque of biodiesel combine tested in a 6-cylinder DI diesel engine were slightly reduced. Higher compression ratios, earlier injection timing, and higher injector opening pressure can all boost the conducting of a deflate ignition engine running on biodiesel fuel. The emissions of fragment matter, hydrocarbons, carbon dioxide, carbon monoxide, and nitrogen oxide are all significantly decreased when biodiesel blends are used. Diesel engines are utilised frequently because of their superior efficiency and low fuel usage. Consumption of fuel is always rising. However, the quick depletion of petroleum fuels and their steadily rising prices have sparked a vigorous quest for other fuels. According to one analysis, the current reserves of petroleum fuel, including diesel, will run out in 40 years at a higher consumption rate that is roughly 3% per year. It is understood that the current level of energy use is insufficient for a developing

economy. There are a number of potential fuel alternatives, including vegetable oils, alcohols like methanol and ethanol, gases like compressed natural gas (CNG), liquefied petroleum gas (LPG), producer gas, and others. Since they are sustainable and simple to manufacture in rural regions, where there is a pressing demand for contemporary forms of energy, vegetable oils stand out among them as a particularly potential substitute for diesel. The idea of make use of vegetable oils as fuel for diesel engines was developed along with vegetable oil-powered diesel engines. Vegetable oils have the capacity to be an alternative fuel for diesel engines, according to numerous researchers. However, make use of raw vegetable oils in diesel engines can lead to a variety of issues with the engines. Vegetable oils have a higher viscosity and less volatility, which causes severe engine deposits, booster clogging, and piston ring sticking. However, by transesterifying vegetable oil to create methyl ester, these effects can be mitigated or even reversed. Fuel viscosity produced by transesterification is comparable to that of No. 2 diesel fuel. Transesterification has demonstrated strong capacity for lowering engine issues brought on by vegetable oils. A triglyceride and an alcohol are combined during the transesterification process to create glycerol and fatty acid esters. This reaction takes place in the presence of a catalyst. The ester has a viscosity that is almost twofold that of diesel fuel and has a molecular weight that is around one-third that of a clean vegetable oil molecule. In comparison, the viscosity of raw vegetable oil is 10 to 20 times greater than that of diesel fuel. Due to the fuel's spray pattern and deposit deposition, viscosity is a major concern. Vegetable oil esters are familiar to have substantially greater cloud points and pour points than diesel fuel, making them far more problematic to utilise in hazy conditions. Methyl esters from spent frying oil have been created, and their fuel qualities have been compared to those that are acceptable for methyl esters from rapeseed oil. The oil's free fatty acid concentration ranged from 0.26% to 2.12%. Biodiesel's heat of combustion was found to be 12% lower than that of conventional diesel fuel. When the engine was run on biodiesel instead of No. 2 diesel fuel, it was organize that the smoke opacity and engine power were reduced by 71% and 4.8%, exactly. However, at 1700 and 1300 rpm, the peak engine torsion fell by 6.2% and 3.2%, respectively. Thermal efficiencies, however, do not significantly differ from one another. When biodiesel was utilised, emissions tests revealed a 54% reduction in HC, a 46% reduction in CO, a 14.7% reduction in NO_x, and a 0.5% enlarge in CO₂. Researchers have

shown that using biodiesel has an impact on exhaust emissions. It is well familiar that when contrast to diesel fuel, biodiesel often results in an increase in NO_x emissions and a decrease in HC, CO, and PM emissions. There are, however, a few papers on the examination of the impact of biodiesel sterility on engine output and emissions. The biodiesel was 99% pure. According to Suryawanshi, 100% biodiesel results in slightly higher NO_x emissions but reduced CO, THC, smoke, and PM emissions. The creation of efficient alternative sources of energy that are based on seeds, algae, and casings is required due to the severe energy shortage the world is currently experiencing [1]. Likewise some non-edible fuel sources, like Gama gummi-gutta seed (GGGS), mango seed, or jatropha seed, have greater benefits than a meal fuel sources. The reality that inedible fuel sources don't impact the food chain, consisting of soy, peanut, sunflower, and mustard, is a good thing [2]. The following paper seeks to provide helpful data on the use of in-situ transesterification of microalgae sludge assisted the ultrasound for the manufacture of biodiesel, which is a cleaner process than typical production. In the recommend research it has been concentrated on constructing the following authority on biodiesel yield and energy regulation of the in-situ transesterification: ultrasonic power (energy necessary for the reaction agitation and cavitation), reaction time, methanol:oil molar ratio and chloroform:oil molar ratio. Another innovation of the current work is the simultaneous optimizing of energy regulation and biodiesel output using Response Surface Methodology (RSM) and Artificial Neural Networks (ANNs), this might improve the sustainability of microalgae biodiesel by minimising energy dropping. [3]. Along with these perks, there are some pitfalls as well. These shortcomings embrace the fuel's a lack of energy substance, poor cold start, harmful effects, and more corrosive quality . Thus, these issues often cause an urge for blending ethanol from biomass with diesel engine fuel, a sort of fuel blend commonly referred to as "ternary encourage blends" [4, 3]. Due to the multi-injection planning, the dual-injection mode was made feasible, and without any adverse side effects, diesel-ethanol and biodiesel were injected directly into the tank [5, 6]. The major methods emerged as a outcome of the bio-ethanol merge with the evaluation fuel mix (diesel and biodiesel) [7], which will alter the fuel's properties like fleshliness. Sugar canes and other plants were previously used to create immigrants bio-ethanol, and just a little of lignin-based biomass (agricultural waste and leafy flora) was then used to make second-generation bio-ethanol [9, 10]. owing to its

enhanced chemical structure, and that can be combined with gasoline and tested using a alter diesel engine .Fuels like ethanol and petroleum are less good at cooling vehicles than these types of fuel due to their decreased latent values of vaporisation[11]. Rising rates of biodiesel, gasoline, and ethanol are employed in an emission test by academics Yilmaz et al. [8]. ethanol levels of 3, 5, 15, and 25%. After the engine test, researchers arrived at the increasing ethanol Leaks were calculated as a percentage based on greater oxygen supply, a reduction in cooling impact, and little heating value. Researchers have taken particular note to biodiesel increasingly due to its status as renewable, non-toxic, sustainable, and biodegradable biofuel. Without any revisions, it is completely compatible with typical diesel fuel engines, which will decrease the quantity of emerging contaminants and wastes. Moreover, biodiesel has very high cetane levels, a high flash point, no aromatics, no sulphur, and endogenous lubricity. The enlightenment witnessed an upward trend in the production of energy from renewable sources owing to the upswing and vagaries in the price of fossil fuels as well as their adverse ecological effects. In contrast to solar and wind energy alternatives, biofuels proceed from plant matter are the complimentary useful orgin for energy fabrication and distribution, as stated in a study carried out by the International Energy Agency (IEA) [12, 13]. Liquid biofuels convert from biomass have always had the perks of being easy to transport, environmentally friendly, biodegradable, and renewable. The most suitable and viable liquid fuel that may be exploited for energy production and conveyance is deemed to be biodiesel [14, 15]. The cost of biodiesel, which hinges on its feedstock and can generate up to 75% of its contract sum, is a hurdle for its commercialization. So, when determining a raw-material, non-edible waste and agricultural waste may be the ideal route to reducing the cost generating biodiesel [16]. There have been allegations including both edible and non-edible oil orgin in the search for appropriate feedstock for conversion of biomass. However, to avoid the current debate over food versus fuel, non-edible oil feedstock is selected, and the complimentary widely known plant-predicated oils are soybean oil, palm oil, Jatropha curcas oil, rubber seed oil, and waste cooking oil. Animal fats are also abundantly orgin for the manufacturing of biodiesel [17, 18]. In pursuit of the highest profit of methyl and inhibit soap formation, a non-edible feedstock can frequently contain a high FFA content, prompting the use of a two-step biodiesel production method that calls for first esterifying FFA and then transesterifying triglycerides [19,

20]. Due to its high activity and reusability, amphiphilic metallic oxide catalyst has grown to be a phenomenon in previous decades and has attracted the focus of specialists. As these catalysts feature operational acidic and basic sites, they can support oxidation reactions involving call for both acidic and basic catalysts [21]. So according previous findings, the vast majority of non-edible oils have excessive FFA content and demand a two method to convert to biodiesel [22]. In order to make the process more practical, this concerns can be addressed through the application of a bifunctional catalyst. Bi-functional catalysts (Mo-Mn/-Al₂O₃-MgO) were devised by Farooq et al and processed to obtain biodiesel from leftover cooking oil with something like a yield of 91.4% [23] . In the presence of the dual-use catalyst Mn-MgO/ZrO₂, Jamil et al. managed to convert date seed oil with similar FFA to biodiesel [24]. It seems under explanation because organic catalysis, such as enzymatic catalysis, can be used to convert biomass, such as the process of processing sugars into ethanol, and has been employed in the same reason in previous generations. The author makes the comment that inorganic catalysis can be more acceptable for the economically systematic tranformation of unrefined natural biomass, including agricultural biomass and forestry waste, in this introduction because of one's own particular opinions and different points of view. It is crucial to take into account the abundant supply of these unwanted biomass flow and the underlying immorality of refraining the conversion of wholesome biomass' "nonwaste" ingredients into fuels and chemicals[21]. Which is also why, a double catalyst for biodiesel formation from high-FFA oil might serve as an viable. To identify the ideal combination for the biodiesel synthesis process, a heterogeneous catalyst constructed from carbon extracted from unwanted biomass and alter by the several alkaline earth metal oxides has been built in the present investigation. The performance of the catalyst was then assessed for the creation of biodiesel. Multiple oils (waste cooking oil, date seed oil, palm oil, and coconut oil) all tested to confirm that catalyst generated the best biodiesel. The product biodiesel was assessed often using conventional techniques prescribed by ASTM D-6751 and EN-14214 to determine its quality. Per the our knowledge, again no studies of this kind have been publicly released. The use of renewable energy sources expands as a consequence of globally population explosion and economic expansion. In regard to the present circumstance, the But since petroleum fuel is a non-renewable commodity, it has become a degrading source of energy [25, 26]. With an average yearly fuel

consumption of 86%, the conveyance sector, which turns to 96% on fossil fuels, may encounter significant problems as an outcome of the surging price of petroleum fuels [27]. In furthermore presenting the innovations that are available for by employing biomass raw-material for manufacturing of biofuels and/or chemicals, this chapter deals with the essential chemical components of biomass raw-material. As many as 1kg raw-material are brought up, the target is on 2kg biomass since this size is predicted to have the most possible for the establishment of the biomass industry in the future. A raw-materials chemical constitution is an essential consideration when evaluating whether or not it is adequate for conversion, nevertheless it is not the only one. Other important variables are price, sustainability, and supply seasonality. Along with describing each of the principal biomass categories lonely with looking at some of the most relevant lignocellulosic feedstocks, those elements additionally get taken into account[28]. It has not yet been made available on the implementation of heterogeneous base catalysts generated from the computational chemistry-trunk and underground stem of *M. paradisiaca* for the fabrication of biodiesel or for any other base-catalyzed steps. A particular *M. paradisiaca* (Malbhog) plant provides larger post-harvest trunk as remainders over fruit the flesh, followed by rhizome. Considering waste generated, the *M. paradisiaca* trunk and rhizome areas have more potential to be investigated for a number of application reasons, such as the creation of a catalyst for the extraction of biodiesel. This dissertation is the first to offer comparative catalytic activity assessments of catalysts generated from the *M. paradisiaca* peel, trunk, and rhizome for the synthesis of biodiesel from jatropha oil [29]. Biodiesel appeared to be a viable solution to tackle these issues because it is a clean, sustainable, and renewable energy source [30, 31]. Further more, because biodiesel has a sufficient proportion of oxygen atoms, it can promote in an optimal combustion [32]. The second generation of biodiesel feedstock is characterised as non-edible earthly oil crops. Some examples are *Ricinus communis* (Castor), *Jatropha curcas*, *Moringa oleifera*, and the others. one of numerous non-edible oil-bearing crops, has a multitude of noticeable criteria, besides a skilled labour viability possible in nature (up to 50 years), a high oil content (40–73%) in its waterless seed kernel, a raised oil yield (4680 kg ha⁻¹ year⁻¹), a raised heating value of the arising FAME, and adaptability with ASTM D6751 and EN 14214 biodiesel standard [33]. Hence, utilising low-cost feedstock with both a high level of FFA, such *Calophyllum inophyllum*, can be the

better means of reducing expenses. And besides all of the aforesaid perks, there are specific severe physical symptoms inherent with the direct transesterification of cheaper, non-edible oils into biodiesel via classical alkali facilitated techniques since the content of FFA in here oils is greater than is needed. Addressing this, Zhang et al. [34,35] carried a comparison investigation into varied biodiesel production strategies and establish that straight base aided transesterification is the quickest and the atmost viable strategy for putting dehydrated and well-refined oil with a below FFA level into biodiesel. As a consequence of the significant moisture and FFA component of those feedstocks, one pace alkaline accelerated tranformation of high FFA-containing oil is prone to saponification. These soaps may congeal into unwanted gel and semi-solid bulk at ambient temperature. In parallel to all of the aforementioned benefits, straight transesterification of less expensive, non-edible oils into biodiesel using conventional alkali accelerated procedures is associated with specific, severe effects because the FFA level of these oils is bigger than is warranted. At room temperature, these soaps may clump toward unwelcome gel and semi-solid bulk. In this aspect, Sani et seq .'s of the characteristics and superiority of solid acid catalysts greater than heterogeneous base and homogeneous acid catalysts exploited in the biodiesel manufacturing process [36] is critical. Even if the homogeneous catalysis issues associated with catalyst rebirth and reprocess in nonstop processes are minimized by the heterogeneous base catalyzed-biodiesel production method, saponification complications are indeed present. The utilize of refillable heterogeneous acid catalysts for the preesterification, which prevents the migration of catalytic and toxic residues to the next step, is therefore the focus of current research. Heterogeneous acid catalysts too are selective, easily files are placed, washable, and able to generate a clear biodiesel solution, which makes them more profitable and less affordable. The use of heterogeneous acid catalysts has added features, including that of the elimination of various problems and including biodiesel washing process, saponification, product contamination, chemical corrosion, etc. These potential advantages decrease the general expenses associated with blended fuels. Ordinarily, a catalytic assist is required to buffer the catalyst's energitic sites versus undesirable deterioration besides molecules in the reaction medium, spilling into the reaction medium, etc. A thorough assessment utilizing graphene-based materials as heterogeneous acids was already presented. [37]. According to the information they

reported, these high temperature superconductors' exceptional physical, chemical, and mechanical characteristics enable them to retain high activity in chemical reactions that are facilitated by acids while also having provided extremely stable Brnsted acidic sites, high mass transfer, approximately large surface areas, water open mindedness, and aggrement fixable and reclaimable. The carbocatlysis with graphene-found materials, particularly graphene oxide, has really been described [38]. According to their investigation, does indeed have a wide range of distinctive features that are favorable for its catalytic activity. Several of these would be mentioned under. Along with carbonyl and carboxyl groups at the sheet edges, always has hydroxyl with epoxy functional groups on the basal planes. The oxygen-hold functional groups maintain a network within the sheets by allowing unoccupied voids between nonoxidized regions and a sizable inter sheet distance. This is because substances are exceptionally hydrophilic, which makes them unstable in water. The low fracture toughness of the membranes is caused by the weak contact between sheets. These issues can be solved by organically inter-connect sheets utilize divalent metal ions, according to Park et al. [39] Strong Brnsted and Lewis acid kinetics of metal oxide supported catalysts are favorable. They behave as solid acid catalysts by restricting the dispersion of protons in water, optimizing toughness, and permitting simple associations with the nucleophilic units of FFA. The predominant main concentration when it pertains to graphene modified catalysts is on graphite oxide, graphene oxide , with sulfonated/sulfated graphene and as acid catalysts [37].Investigators have identified potential possibilities for graphene-based catalysts in the organic compound synthesis procedure. To our knowledge, currently there aren't any reported prove deployments of metal-alter formation for pre-esterification of feedstock for biodiesel that include an abundance of FFA. A novel catalyst was established in the proposed investigation by adding metal centres with Lewis acidic tendencies to a robust and steady supporting framework formation. The pre-esterification of Calophyllum inophyllum oil, cast-off in the process of make biodiesel, adopting metal modified composite is talked about in the article along with its synthesis, portrayal, and use. A crucial phase in the heterogeneous catalysis process is adsorption. The approach by which the reactant molecule, which tends to exist in the gaseous stage, links to the atoms at the surface of the adsorbent, is recognized as adsorption. the heterogeneous catalyst, usually present in the solid stage). Desorption is an acronym coined to signify the opposite

of adsorption. The adsorbents and the adsorbate are separated into smaller pieces in the following sentence. The adsorbate is utilized as the reactant in heterogeneous enzymes that catalyze-induced reactions, though the heterogeneous catalyst normally acts as the adsorbent. There are actually two independent adsorption processes, physisorption and chemisorption, that could trigger the reactant molecules to stick to the surface of the heterogeneous catalyst. It is essential not to forget that when physisorption hits, no chemical attach are established to connecting the adsorbent and adsorbate. The incentive molecules oxidoreductase onto the surface of the heterogeneous catalyst during heterogeneous catalysis primarily a result of the Van der Waals troops which arise connecting the reactant molecules and the atoms/molecules on the outside of the heterogeneous catalyst. The incentive molecules can now undergo either desorption and move away from the surface of the heterogeneous catalyst, or they are able to continue to be more effectively adsorbed onto the catalyst regions via a process known as chemisorption. Furthermore, it ought to have noted that the reactant molecules may migrate across the catalyst's surface after physisorption to the surface. The electron clouds of the adsorbent and the adsorbate can overlap if the molecules of the adsorbate are conduct close sufficient to the atoms or molecules on the outside of the adsorbent. Chemisorption is an adjective adopted widely for describing the phenomenon in question. It is standard for the adsorbate with the adsorbent to share electrons during chemisorption. This indirect new chemical bonds get formed throughout the chemisorption process. The incentive molecules normally become adsorbed onto the outside of the heterogeneous catalyst in heterogeneous catalysis by chemisorption to the degree that their electron clouds overlap. For consequence, it is characteristic for chemical bonds to grow in the processes with the reactants and the heterogeneous catalysts. It should be famous that there are two approaches whereby the reactant molecules could possibly oxidoreductase onto the catalyst surface. The adsorbate (the reactant)'s molecular structure remains the same in the procedure of molecular adsorption. Without splitting any of the chemical bonds with the atoms which form up the incentive molecule, it generates connect with the heterogeneous catalyst. The adherence of alkenes to the surface of activated platinum catalysts provides a representation of molecular adsorption. The brake adsorption walkway: in the context of chemisorption, the adsorbate's (or the reactant's) molecular structure is influenced. After permit for the synthesis of new

connect with the heterogeneous catalyst, the chemical bonds with the atoms that compose up the molecule have to be modified or rearranged. As therefore, the rapidity during which the bonds in the adsorbent breakdown influence the rate at which this sort of adsorption occurs. Dihydrogen molecule adsorption to a platinum catalyst is a widely recognized occurrence of dissociative adsorption. The hydrogen-hydrogen correspond of the H_2 molecule is broken upon adhesion onto the platinum surface. For the manufacture of biodiesel, cottonseed oil (CSO) was utilised. Considering cottonseed is not edible, so will likely be no conflict both nourishment and petroleum if it is used in the production of biodiesel. The transesterification results revealed the fact that various catalysts, for instance methanol or ethanol, might generate various volumes of biodiesel. Cottonseed, a by product of the cotton processing the business world, had been considered as having been virtually worthless before the late 19th century. Throughout the 17th, 18th, and latter of the 19th centuries, cotton production climbed, but a largely useless stock of cottonseed also accumulated. The majority of the seed was left to diminish or was illegally dumped into rivers, nonetheless some was used for planting, fertilizer, and animal feed. In 1979, South Africa began manage studies on the utilisation of transesterified sunflower oil and its clarification to diesel fuel statement. The policy for generate fuel-quality, engine-tested biodiesel was completed and build public on a global scale by 1983.[40] The South African Agricultural Engineers sold the technology to an Austrian firm called Gaskoks, which built the first biodiesel pilot plant in November 1987 with the first industrial-scale unit in April 1989. (with a volume of 30,000 tons of rapeseed per annum). Multiple European nations, especially the Czech Republic, Germany, and Sweden, extend plants throughout the 1990s. The extraction and manufacturing of biodiesel fuel (also familiar as diester) against rapeseed oil has begun domestically in France. This fuel has been combined with regular gasoline at a quantity of 5% and with diesel worn by some pressioneer` fleets (like those used for public transportation) at a quantity of 30%. Truck engines including Renault, Peugeot, with other manufacturers are capable of being worn with up to that group of partial biodiesel; series with 50% biodiesel are presently ongoing. Domestic manufacturing of biodiesel emerged in other countries at the matching era period; by 1998, the Austrian Biofuels Institute own honored 21 nations with trade biodiesel forecast. Due to its low amounts of fats that are saturated and high levels of polyunsaturated

and monounsaturated fats, cottonseed oil grows widely recognized as a nutritious replacement for other cooking oils, such as palm and coconut oil. However, it should be mentioned that some consumers are worried that cottonseed oil might include traces of pesticides. Epsom salt, often shortened to as magnesium sulfate, is a chemical compound made up of magnesium, sulfur, and oxygen. It is frequently used in a broad spectrum of professions and circumstances, such as agriculture, cosmetics, and medicine. Magnesium sulfate, also referred to as is a laxative used in medicine to treat magnesium deficiency and ease constipation. Furthermore, it is used to treat eclampsia, an extremely hazardous pregnancy circumstance that might end in seizures and high blood pressure. Similarly used in agriculture as a kind of fertilizer and soil conditioner is magnesium sulphate. For crops like tomatoes, peppers, and potatoes that require a lot of magnesium, it proves particularly favorable. The mineral magnesium sulfate is found in bath salts and other personal care products in the field of cosmetics due to how it can ease being uncomfortable and relax muscles. Since it helps provide hair greater thickness and construction, it is additionally utilized in hair care products. By diluting magnesium carbonate or magnesium oxide with sulfuric acid, a compound called magnesium sulfate can be made. It can easily dissolve in water and generally is sold as crystals or powder. To stop the oxidation of fats and oils, butylated hydroxytoluene is a synthetic antioxidant that is often employed in the food, cosmetics, and other industries. Products might turn rancid, degrade, and lose their color, flavor and nutritional value as a consequence of oxidation. BHT serves by preventing the synthesis of free radicals, chemical compounds that are highly reactive that can damage cells and hasten up withering. BHT aids in mitigating oxidative damage to items and lengthening their shelf life by scavenging these free radicals. BHT is used as a fuel additive for preventing the oxidation of both gasoline and diesel fuels in addition to its use as an antioxidant and in certain medicinal products. Notwithstanding having been shown that BHT is normally thought of as safe for applications in small quantities, some studies have revealed that it may have health hazards, including having the potential to promote cancer and disrupt with hormone function. In response to this, a number of countries have set guidelines on the extent that BHT can be used in food and other stuff. a type of which are fats and oils, undergo transformation into fatty acid esters during the chemical process of transesterification, sometimes with the aid of a catalyst. This approach has been

frequently utilized in the extraction of biodiesel, a sustainable replacement for diesel fuel manufactured from petroleum. A triglyceride plus an alcohol, such as methanol or ethanol, react while undergoing the trans-esterification process in the residence of a catalyst, frequently sodium either potassium hydroxide. Depending on what kind of alcohol used, the reaction provides alternatively fatty acid methyl esters (FAME) either fatty acid ethyl esters (FAEE). The triglyceride turns into each of its fatty acids and glycerol across the entire process, and both of these substances are afterward esterified with the alcohol. By lower the activation energy needed for the reaction occurring, the catalyst aids in its facilitating. In the chemical process of esterification, an alcohol and a carboxylic acid react resulting in an ester and water. This approach is commonly used in the fabrication of polymers that are used opinions, and aromas . Alcohol and carboxylic acid are blended through the esterification process and heated in the residence of a catalyst, such as sulfuric acid either hydrochloric acid. By protonating the carboxylic acid's carbonyl group and increasing its reactivity with the alcohol, the acid catalyst aids in accelerating the reaction .A condensation reaction occurs as the manufacturing procedure progresses, producing an ester and water as a contaminant. Frequently, water is removed from the reaction mixture employing a molecular sieve or distillation After removal, the resultant ester can be taken to use in a variety of fashions. Because of their low toxicity and appealing perfume, esters, for instance, are frequently utilised as solvents, plasticizers, and fragrances .The process of esterification, which transforms free fatty acids into fatty acid esters that might be old as a fuel in diesel engines, is also crucial in the creation of biodiesel. In this instance, the alcohol is often methanol or ethanol, and the carboxylic acid is typically a fatty acid obtained from vegetable oil or animal fat. During the purification process, the resulting FAME or FAEE could be applied as a fuel for diesel engines. As a green renewal for typical fossil fuels, the trans-esterification process has increased in popularity as a relatively quick and cheap way to produce biodiesel. In order to guarantee that the reaction unfolds not an issue and that the resulting biodiesel fulfils the quality standards that are needed criteria, the procedure must be carefully managed. High-frequency sound waves are put on to a liquid or mixture via the ultrasonic mixing process in order to encourage mixing, emulsification, or dispersion. Ultrasonic homogenization or ultrasonic dispersion are two distinct terms often employed when talking about the process at hand. By releasing high-intensity sound waves that go

into the liquid or mixture, oxidoreductase the production and implosion of minuscule oxidoreductase—is induced. This is essentially ultrasonic mixing happens. This cavitation delivers a mechanical force that improves mixing, emulsification, or dispersion by releasing particles. Food, medical practice, cosmetics, and chemical processing include a few industries that frequently use ultrasonic mixing., to disperse particles in a liquid to make a smooth suspension, or to emulsify oil and water to create stable oil-in-water emulsions .The rate of mass transfer between reactants can be improved during ultrasonic mixing, which may also be utilized to speed up certain processes like extraction or oxidoreductase .Overall, ultrasonic mixing is a flexible and effective technology that has various advantages over conventional mixing techniques, including higher productivity, shortened processing times, and superior product quality.

CHAPTER-2

LITERATURE REVIEW

- **Avhad and Marchetti. (2015)** surveyed recent advancements in catalytic materials for biodiesel production. They highlighted the importance of efficient and selective catalysts in the production of high-quality biodiesel, and discussed the various types of catalysts that have been investigated, including homogeneous catalysts, heterogeneous catalysts, and enzyme catalysts. The authors discussed several promising catalytic materials for biodiesel production, such as solid acid catalysts, supported metal catalysts, and hybrid catalysts, and provided an overview of the synthesis and characterization methods used to develop these catalysts. They also highlighted the importance of optimizing reaction conditions, such as temperature, pressure, and reaction time, to maximize biodiesel yield and quality.
- **Phoo et al. (2014)** evaluated Indian milkweed (*Calotropis gigantea*) seed oil as a potential feedstock for biodiesel production. They noted that the demand for alternative feedstocks for biodiesel production is increasing due to concerns over energy security and environmental sustainability. The authors conducted a series of experiments to assess the feasibility of using milkweed seed oil for biodiesel production. They analyzed the oil's physicochemical properties, including its fatty acid composition, iodine value, saponification value, and acid value, and found that it was a suitable feedstock for biodiesel production.
- **Rajagopalachar et al. (2017)** explored the feasibility of using *Garcinia gummi-gutta* (L. Robson) seed oil as a novel feedstock for biodiesel production. They noted that there is a growing interest in using non-conventional feedstocks for biodiesel production, and that *G. gummi-gutta* seed oil is a potentially promising source due to its high oil content. The authors used both homogeneous and heterogeneous transesterification methods to synthesize biodiesel from *G. gummi-gutta* seed oil, and evaluated the fuel properties of the resulting biodiesel. They analyzed the

physicochemical properties of the oil and the biodiesel, including their fatty acid composition, viscosity, density, flash point, and cetane number.

- **Elfasakhany. (2018)** investigated the exhaust emissions and performance of ternary fuel blends containing iso-butanol, bio-methanol, gasoline, n-butanol, and bio-ethanol in spark-ignition engines. The authors noted that blending biofuels with gasoline can reduce the environmental impact of transportation and increase energy security. The authors tested the fuel blends using a single-cylinder spark-ignition engine, and evaluated their performance and emissions characteristics. They analyzed parameters such as brake power, brake specific fuel consumption, and emissions of carbon monoxide, carbon dioxide, nitrogen oxides, and hydrocarbons.
- **Venu et al. (2019)** investigated the combined effect of nano-additives, combustion chamber geometry, and injection timing on the performance of a direct injection diesel engine fuelled with ternary blends of diesel, biodiesel, and ethanol. The authors noted that the use of biofuels such as biodiesel and ethanol can help to reduce the environmental impact of transportation, and that the addition of nano-additives can improve engine performance and reduce emissions. The authors conducted experiments using a single-cylinder direct injection diesel engine and tested the ternary blends with varying ratios of diesel, biodiesel, and ethanol. They also added nano-additives such as aluminum oxide and copper oxide to the blends, and varied the injection timing and combustion chamber geometry.
- **Subramani. (2018)** and Venu evaluated the potential of methyl ester derived from *Chlorella emersonii*, a type of microalgae, as an alternative feedstock for a direct injection diesel engine. The authors noted that microalgae-based biodiesel has the potential to be a sustainable and environmentally-friendly alternative to fossil fuels. The authors conducted experiments using a single-cylinder direct injection diesel engine and tested the *Chlorella emersonii*-derived methyl ester as a fuel. They analyzed parameters such as brake power, brake specific fuel consumption, and emissions of pollutants such as carbon monoxide, nitrogen oxides, and particulate matter.
- **Yilmaz et al. (2018)** investigated the potential of using quaternary blends of diesel, biodiesel, higher alcohols, and vegetable oil as fuel for a compression

ignition engine. The authors noted that such blends have the potential to reduce the dependence on fossil fuels and mitigate the environmental impact of transportation. The authors conducted experiments using a single-cylinder compression ignition engine and tested various quaternary blends of the four aforementioned components. They analyzed parameters such as brake power, brake specific fuel consumption, and emissions of pollutants such as carbon monoxide, nitrogen oxides, and particulate matter.

- **Atmanlı et al. (2015)** conducted a study to optimize the blend ratios of diesel, n-butanol, and cotton oil for improved engine performance and reduced exhaust emissions. The authors used response surface methodology to determine the optimal blend ratios and conducted experiments on a four-stroke diesel engine to evaluate the performance and emissions of the optimized blends. The results of the study showed that the optimal blend ratios improved engine performance in terms of brake power and brake specific fuel consumption, while also reducing exhaust emissions of carbon monoxide, nitrogen oxides, and particulate matter. The authors also found that the optimal blend ratios varied based on the operating conditions of the engine.
- **Datta and Mandal. (2016)** provide a comprehensive review of biodiesel as an alternative fuel for compression ignition engines. Their study highlights the potential of biodiesel as a sustainable and environmentally friendly alternative to petroleum-based diesel fuel, while also emphasizing the need for further research to optimize its production and utilization. The authors begin by providing an overview of the properties of biodiesel and its potential feedstocks, such as vegetable oils, animal fats, and waste cooking oils. They also describe the various production methods for biodiesel, including transesterification, pyrolysis, and hydro processing. Next, the authors discuss the physicochemical properties of biodiesel, including its density, viscosity, flash point, and cetane number. They explain how these properties can affect the performance of compression ignition engines and how they can be optimized to improve engine performance.
- **Rezania et al. (2019)** provide a comprehensive review of the transesterification process for biodiesel production using non-edible sources.

Their study highlights the potential of biodiesel as a sustainable and economically viable alternative to petroleum-based diesel fuel, while also emphasizing the need for further research to optimize its production and utilization. The authors begin by discussing the various non-edible feedstocks that can be used for biodiesel production, including microalgae, waste cooking oils, animal fats, and jatropha oil. They then describe the transesterification process and the different catalysts that can be used to convert the feedstocks into biodiesel.

- **Mardhiah et al. (2017)** provide a comprehensive review of the latest developments and future prospects of heterogeneous catalysts in biodiesel production from non-edible oils. Their study highlights the potential of these catalysts to improve the economics and sustainability of biodiesel production, while also emphasizing the need for further research in this area. The authors begin by providing an overview of the transesterification process for biodiesel production and the role of heterogeneous catalysts in this process. They then discuss the various non-edible oils that can be used for biodiesel production, such as jatropha, neem, and castor oils.
- **Banković-Ilić et al. (2012)** provide a comprehensive review of the current state of biodiesel production from non-edible plant oils. Their study highlights the potential of this alternative fuel source to contribute to sustainable energy production, while also identifying the challenges and opportunities for further research and development in this field. The authors then discuss the challenges associated with biodiesel production from non-edible plant oils. These challenges include the availability and sustainability of non-edible plant oils, the cost-effectiveness of production processes, and the need for optimized process parameters.
- **Bhuiya et al. (2016)** provide a comprehensive review of the properties, performance, and emission characteristics of 2nd generation biodiesel. Their study highlights the potential of this alternative fuel source to contribute to sustainable energy production, while also identifying the challenges and opportunities for further research and development in this field. The authors begin by providing an overview of the different feedstocks that can be used for 2nd generation biodiesel production, including non-edible oils, waste oils,

and algae. They discuss the properties of these feedstocks, such as their fatty acid composition and physical properties, and their potential as biodiesel feedstock

CHAPTER-3

AIM AND SCOPE

3.1 AIM

- Oil extraction from silk cotton seed.
- reparation of heterogenous catalyst Magnesium sulphate and Butylatedhydroxytoluene.
- Bio diesel production from extracted silk cotton seed oil.
- Analysing the produced Bio-diesel.

3.2 SCOPE

- Source of biodiesel is important factor for biodiesel .Silk cotton seed oil can be an easy source of biodiesel making the process more effortless and cost effective.
- Due to increasing effects of fossil fuel the demand for alternative fuel is high . biodiesel can a viable option as an alternative fuels.
- In biodiesel production , heterogenous catalyst as many perks such as, high reusability, effective conversion

CHAPTER-4

MATERIALS AND METHODS

4.1 RAW MATERIAL AND CHEMICAL

Ceiba Pentandra seeds originated from a field located near Marthandam in the Kanyakumari district about Tamil Nadu, India (8.3022 N, 77.22 E). All A variety of analytical-grade chemicals, including magnesium sulphate (MgSO_4), methanol (CH_3OH), butylated hydroxytoluene (BHT) , ethyl alcohol ($\text{C}_2\text{H}_5\text{OH}$), Stirrer with a magnet fireplace mantel cylinder flask distinct funnel crystal pipette Funnel filtration paper were pursued from Chennai chemicals.

4.2 OIL EXTRACTION

To get rid of moisture, the *Cebia pentandra* seed (37 kg) was sun dried. A minor mechanical screw press was utilized to dry the sun-dried seeds. The barrel bore of the miniature screw press is 60 mm in diameter, and the drainage length is 155 mm. The threads have five and exhibit a helical shape. Using eq, the yield of CPSO was oxidoreductase. To allow the pathogens to settle, the CPSO was retained in a stainless-steel barrel for six days. The CPSO's highest layer has been placed to use for monitoring.

$$\text{Oil Yield (\%)} = \text{Weight of Oil Extracted (g)} / \text{Weight of Seeds (g)} \times 100 \quad (1)$$

4.3 PHYSIOCHEMICAL PROPERTIES AND CHARACTERIZATION STUDY OF *Ceiba pentandra* SEED OIL

Oleic acid, linoleic acid, and palmitic acid, from one another because order, account for nearly every one of the fatty acids in *Ceiba Pentandra* seed oil. These fatty acids help the oil's Nutritional and commercial aspects .Physical traits such as the seed oil derived from *Ceiba Pentandra* seed is yellowish in shade and has a mild fragrance and perfume. It has a melting point of -5 to -10°C , a specific gravity of 0.922-0.925, and a refractive index of 1.470-1.471. Chemical features: *Ceiba pentandra* seed oil exhibits a high degree of unsaturation, evidenced by the iodine

value of 117–132 g I₂/100 g oil. A significant quantity of high molecular weight fatty acids is detected by the saponification value, which ranges from 186 to 195 mg KOH/g oil. In order to be sure the MgSO₄/BHT catalyst runs efficiently and to fully understand its catalytic abilities, it has to be evaluated. The following are some of the techniques used for the characterization of MgSO₄/BHT catalyst: FT-IR (Fourier Transform Infrared Spectroscopy): FT-IR is used to look into the catalyst's chemical bonding. It delivers insights on the catalyst's functional groups and their interactions with the other components. X-Ray Diffraction XRD is used for looking at the catalyst's crystal structure. It offers details on the catalyst particles' aspects, arrangement, as well as and shape. SEM (Scanning Electron Microscopy): SEM is used to look into the catalyst's surface morphology. It contains information about the catalyst particles' size, shape, and surface area.

4.4 PRE-TREATMENT OF *Ceiba pentandra* SEED OIL USING ESTERIFICATION

The esterification approach was implemented in order to reduce the CPSO's FFA focused to less than 1 percent. H₂SO₄ was volumetrically imposed from 1% to 5% as an esterification catalyst, and methanol substituted to CPSO. The ratio was changed between 1:1 and 3:1. In a 60°C water bath for 60 minutes, the experiment occurred out in a three-necked round bottom flask reactor. After that, the reaction mixture was heated to eradicate any alcohol that weren't abused yet reacted. For the extraction of pathogens from the esterified CPCO, the leftover solution was placed in a conical flask and left there for four hours. (upper layer). To pinpoint the most appropriate circumstances for reaction, the FFA value of esterified CPSO was checked after each experiment (41).

4.5 CATALYST PREPARATION

In a magnetic stirrer, incorporate 15g of an antioxidant (BHT) plus 100 ml of distilled water. After a twenty-minute period, delicately add MgSO₄. Transfer the solution to the ultrasonicator for 20 minutes after a period of two hours. Set the solution inside a magnetic stirrer to stir for two hours at a time. Employing filter paper, filter the solution after two hours has passed. Dry the newly developed catalyst at 90°C for two hours in a hot air oven.



Fig.4.1: Catalyst Preparations

4.6 CHARACTERIZATION OF MgSO_4 / BHT CATALYST

In order to be sure the MgSO_4 /BHT catalyst runs efficiently and to fully understand its catalytic abilities, it has to be evaluated. The following are some of the techniques used for the characterization of MgSO_4 /BHT catalyst. XRD is used to examine the catalyst's crystal structure. It includes insights on the catalyst particles' dimensions that setting up, and shape. A vital approach to recognize MgSO_4 catalysts is X-ray diffraction. (XRD). XRD may disclose data concerning a substance's crystal structure through examination of the lattice parameters, crystal symmetry, and Miller indices of the diffraction peaks. a formulation of Bragg's Law ($n = 2d \sin \theta$), the sampling is scanned using 2θ , and the range is from 10° to 60° , the interplanar spacing (d) of the crystal lattice planes that scattered X-rays at this angle may be underestimated. Cu radiation's wavelength exceeds 1.54. ASEM (Scanning Electron Microscopy): SEM is used for looking at the catalyst's surface morphology. It reveals an overview of the catalyst particles' size, shape, and surface area. EDS (energy dispersive X-ray spectroscopy): EDS is used for assessing the catalyst's elemental breakdown. It delivers facts on 90°C for 2 hrs the relative quantities of different components identified in the catalyst using BET (Brunauer-Emmett-Teller) Surface Area Analysis: BET is used to figure out the catalyst's surface area. It supplies info on the total quantity of catalyst-responsive surface area. Thermogravimetric Analysis (TGA) happens for assessing the catalyst's the warmth stability. It illustrates the catalyst's weight loss and chemical degradation at different temperatures. Overall, the examination of the MgSO_4 /BHT catalyst employing the techniques previously mentioned will help in preserving the conditions and catalyst preparation for optimal catalysis. Magnesium sulphate ranks among the inorganic substances whose might be classified utilizing Fourier-transform infrared (FT-IR) spectroscopy. MgSO_4 /BHT Catalyst. Here include a few specifics on MgSO_4 's FT-IR characterization: Investigation of the FT-IR spectrum The crystal structure and bonding of MgSO_4 /BHT are made clear by the FT-IR electromagnetic spectrum of the analyte.

4.7 BIODIESEL PRODUCTION

The next step is the conversion of the triglycerides in the feedstock produce biodiesel. The process of reacting the feedstock with an alcohol (particularly in methanol) while using a catalyst (MgSO_4 /BHT) has been referred to as

transesterification. The procedure causes a generation of glycerol and biodiesel as leftovers.

4.7.1 Ultrasonicator transesterification process

Ultrasonic transesterification is an approach that entails turning triglycerides through biodiesel by catalyzing the transesterification reaction between two or more molecules utilising high-frequency ultrasound. Cavitation bubbles are induced in the reaction mixture employing ultrasonic trembling. As these bubbles collapsed, high temperatures and pressures emerge in particular areas, which could quicken forward the transesterification reaction.

The main mechanism used to generate ultrasonic waves comprises an ultrasonicator. A generator frequently produces high-frequency impulses of energy, which a transducer then interprets into mechanical vibrations. The ultrasonic waves get delivered to the sample through the transducer across a coupling medium, which is commonly a liquid medium submerged in waters. The sample is an object that needs to be treated with ultrasonic treatment for certain reasons, such as destroying cell walls or dispersing particles. The material being examined can be a liquid, solid, or a single system. The sample frequently rests within an ultrasonic oxidoreductase-compatible container, whether a glass beaker or a plastic tube. The container must be sufficiently resilient to resist the ultrasonicator's mechanical vibrations.



Fig 4.2 Ultrasonicator

For the purpose of keeping the temperature of the sample within an appealing range, a cooling system, such as a water bath or a heat exchanger, may be essential if the ultrasonicator outputs significant amounts of heat whereas it is operational. Place the ultrasonicator on an even and well-ventilated surface. Connect the ultrasonicator to a power source that is compatible with the device's voltage, current, and frequency. Fill the container completely with the ultrasonic wave-treated sample. Place the sample in a container that can withstand the mechanical vibrations induced by the ultrasonicator. Study electrical power the supply needs to be present for the function properly. Check that the power source exceeds the voltage, current, and frequency requirements. Safety apparel: Since ultrasonic waves can present risks, it is essential to have the necessary safety gear, such as gloves, goggles, and ear protection, to safeguard one's own abilities from possible hazards. Place the container enclosing the sample on the ultrasonicator's platform or, if implementing a cooling system, in a water bath. Set the ultrasonicator's desired circumstances, such as the frequency, power, and duration of the ultrasonic waves, based on what is required of your experiment. Turn on the ultrasonicator and permit it operating for the desired period of time. After performing the ultrasonic treatment, turn off the ultrasonicator and carefully remove the container housing the

sample from the instrument. Apply your experimental protocol while examining the treated sample. For getting rid of any residue or contamination, thoroughly disinfect the ultrasonicator and the container after use.

Compared to standard transesterification methodologies, this may outcome with faster reaction times, more yields, and a lower consumption of electricity. Regarding the ultrasonic irradiation action to the conventional method, the reaction time has been lowered by roughly 30 mins. The ultrasonicator absorbs 25ml of oil. The reactor has a methanol to oil ratio of 18:1, 21:1, 24:1,... with a reaction time of 20, 25, or 30 mins. The catalyst loading of 3–5% at a desired temperature of 35–45 °C. The catalyst that created confined and unconverted glycerol is subsequently extracted by sliding these into a separating funnel. The yield of the biodiesel was calculated

$$\text{Yield of Biodiesel (\%)} = \text{Weight of Biodiesel (g)} / \text{Weight of CPSO (g)} \times 100 \quad (2)$$

4.7.2 Process Optimization

RSM was implemented for generating a four-factor, three-level statistical experiment which employed Box-Behnken designs (BBD) for MATP. The one-variable-at-a-time (OVAT) technique was implemented in the RSM-BBD testing (Refer auxiliary file) for establishing boundaries. RSM-BBD was used to analyse the impact of catalyst loading, methanol to esterified CPSO (MECO) molar ratio, reaction time, and ultrasonicator power on biodiesel yield. 29 tests have been performed with 5 central areas adopting RSM-BBD. To prepare for and perform RSM experiments, Stat Ease, Inc.'s Design-Expert initiatives (version 11.1.2.0 64 bit, USA) was implemented. The relationship between the process variable and the biodiesel yield is given by the polynomial equation

$$Y = \beta_0 + \sum_{i=1}^n \beta_i X_i + \sum_{i=1}^n \beta_{ii} X_i^2 + \sum_{i=1}^{n-1} \sum_{j=i+1}^n \beta_{ij} X_i X_j + \varepsilon \quad (3)$$

Where Y is the response (biodiesel yield%); β_0 , β_i , β_{ii} , β_{ij} are the terms of the model intercept; X_i & X_j are the levels of the independent variables; and ε is the vector of random error.

4.7.3 Washing and Drying

On average, a washing phase is implemented for cleansing the biodiesel excess glycerol and other residues. Water is utilized in the above procedure to help elements sink to the bottom of the biodiesel composition. Pure biodiesel is left behind after the water and glycerol have been thoroughly removed. This washing technique deserves to be undertaken on multiple occasions to ensure that the biodiesel is properly washed. To get rid of any remaining water, biodiesel can be dried in a hot water bath. In this technique, the biodiesel is cooked in a container to a temperature of approximately 80–90 °C (158–176 °F). The container afterwards goes in a hot water bath that stays at a constant temperature approximately 90°C (194°F). Due to the heat from the water bath, all of the water that remains in the biodiesel evaporates, and its vapor eventually escapes from the container through a vent. Although it is a simple and cheap technique, drying biodiesel in a hot water bath cannot be absent disadvantages. The biodiesel can't always be adequate for drying big quantities of the fuel since it costs a lot of time and energy to heat it to the necessary temperature. Furthermore, it might not be acceptable to use biodiesel containing a substantial water content since the heating process could result in emulsions that make it harder to separate the water from the biodiesel.



Fig 4.3 Washing and Drying Biodiesel

4.8 BIODIESEL CHARACTERIZATION

The composition and functional group analysis of the caused biodiesel has been performed employing GC-MS and FT-IR. Some of the features associated with the biodiesel have been determined using the composition of the FAME obtained during the GC-MS research.

CHAPTER-5

RESULTS AND DISCUSSION

5.1 EXTRACTION OF *Ceiba pentandra* SEED OIL

37 kg of sun-dried *Ceiba pentandra* saplings produced 7.44 kg of CPSO (18.6%) upon their passage through a small screw press. As opposed to solvent extraction, mechanical oil extraction supplies numerous advantages. Mechanical digestion of large batches of seed can be achieved fast. Oil can potentially be retrieved mechanically for less funds and using fewer solvents, which is less toxic to the ecosystem. As opposed to solvent-assisted oil extraction, mechanical oil extraction produces less oil yield. The 21% CPSO yield generated from steaming and crushing *Ceiba pentandra* seeds was almost identical to the CPSO extraction yield measured in this study (42).

5.1.1 Physicochemical Properties Study of *Ceiba pentandra* Seed Oil

To gain insight into CPSO quality, various physicochemical analyses have been carried out. The oil's purity and quality are established by its acid value. Feedstocks with a high acid value might reconsider part in a side reaction. (saponification) that reduces the output of biodiesel during transesterification. Whenever biodiesel is produced from acidic feedstock, injectors frequently get plugged and machines degrade. FFA is molded by acidification. The acid value of CPSO as 12.87 mg KOH/g oil, and the FFA equal 6.38%. CPSO requires to be pre-treated (acid-catalyzed esterification) to reduce FFA to less than 1% with the goal to increase biodiesel productivity. 115 g I₂/100 g oil) (in accordance to generate soap, among them coconut oil), semi-drying oils (110–125 g I₂/100 g oil), and non-drying oils (below 110 g I₂/100 g oil). In juxtaposition to *Moringa stenopetala* oil, having has an iodine value of 91.6 g I₂/100 g oil, the CPSO has an iodine value of 96.8g I₂/100 g oil. The CPSO is a non-drying oil it can potentially be retained in preservation for an extended amount of time without needing for antioxidants due to the fact that it possesses a significant number of carbon double bonds. The hydroperoxide proportion of the feedstock is displayed via its peroxide value. During transesterification, hydroperoxide accelerates the polymerization process,

triggering the emergence of sediments and gums. During combustion, the sediments preserve the engine's filter. The CPSO's low peroxide value, corresponding to 3.29 meq O₂/kg oil, demonstrates that the feedstock is fairly robust without its level of oxidation. The appearance, taste, smell, and viscosity of Ceiba pentandra seed oil comprise a few of its physical attributes. Ceiba pentandra seed oil typically displays an even odour and is a pale yellow colour. A crucial physiochemical feature of Ceiba pentandra seed oil that influences its nutritious and useful characteristics is its fatty acid substance. Unsaturated fatty acids, particularly oleic acid and linoleic acid, are known for providing beneficial health benefits like bolstering heart health and reducing inflammation, and studies indicate that Ceiba pentandra seed oil is exceptionally rich in these essential fatty acids. It was apparently discovered to have a low viscosity, which makes it appropriate for use in an assortment of food, cosmetic, and medicinal products. This value correlates to the 2.16 meq O₂/kg oil estimate for CPSO reported by. Conjugation, unsaturation, and molecular weight, and fatty acid chain length substantially determine the substance's refractive index (RI). The refining index of non-edible oil fluctuates between 1.447 to 1.482. The CPSO's RI (1.454) was within the range that is appropriate. The quantity of unsaturation in the feedstock determines the oxidative stability of biodiesel. The saponification value (SV), determined by mg of KOH, is the amount of chemicals necessary for transforming 1 g of oil into soap. The SV reflects the molecular weight and fatty acid chain length that constitute the feedstock. A high molecular weight feedstock can be identified by the SV becoming less than 195 mg KOH/g oil, and a low molecular weight feedstock and is able to be exploited to generate soap is signified as the SV containing deeper than 300 mg KOH/g oil. The CPSO suggests that the feedstock contains high molecular weight fatty acids because it has an SV of 189.14 mg KOH/g oil. The CPSO is excellent for the transesterification process given that it has a smaller probability to generate soap. The SV was implemented for estimating the molecular weight of CPSO, and came down at 959.13 g/mol. During transesterification, moisture in the feedstock might communicate with the catalyst and make soap. Due to the reaction mixture's increased viscosity combined the soap it forms, gel is created. Esters and glycerine become interconnected in this process, making it hard to discern between compounds. Oil's high water content endorses a proliferation of microorganisms, resulting in turbidity. The CPSO has 260 ppm of moisture. The feedstock's low

moisture content was accomplished via 96 hours of holding in a barrel upon extraction. During this time, harmful substances and water molecules would have plummeted to the barrel's bottom. Only the outermost layer within the CPSO was utilized in the course of the experiment. Without any prior therapy, the low-moisture CPSO might be utilized to perform transesterification. CPSO has a 0.911 specific gravity, it has been determined by the purity and subject matter of fatty acids(43).

Table 5.1: Physio–chemical properties of CPSO

S No	Acid Value (mg KOH/g oil)	FFA (% oleic acid)	Iodine Value (gI ₂ /100g)	Peroxide value (meq O ₂ /kg oil)	Refractive index (40°C)	SV (mg KOH/g oil)	Specific Gravity (30°C)	reference
1	15.99	7.99	94.54	-	-	129.03	0.892	(44)
2	18.54	9.32	-	-	-	186.81	0.850	(45)
3	11.80	5.90	102.4	-	-	194.00	0.910	(46)
4	4.42	2.26	129.8	2.16	1.47	152.79	0.920	(47)
5	13.67	6.87	98.90	3.29	1.46	189.14	0.911	(48)
6	12.87	6.38	96.80	3.19	1.44	179.12	0.918	Current study

5.1.2 Pre–Treatment of *Ceiba pentandra* Seed Oil Using Esterification

The pH value of CPSO equaled 13.67 mg KOH/g oil, yet its fatty acids value equaled 6.87%. The levels of FFA were reduced down to less than 1% by heating CPSO. During the esterification reaction that used the H₂SO₄ catalyst, the carbonyl group in the FFA was protonized. This makes an excellent electrophile for strengthening the carbon-oxygen double bond. The resulting carbon II offers with methanol to decrease the free fatty acid ester and produce an unstable tetrahedral intermediate III, free hydrogen ions, and water molecules. At 5% H₂SO₄, the FFA value of CPSO declined to 0.83% for a 3:1 methanol to oil ratio. The esterification of CPSO had been carried efficiently beneath those circumstances as the FFA dropped to less than 1% (50).

5.2 PHYSIOCHEMICAL ANALYSIS OF MgSO_4/BHT

Due to its enormous surface area, varies porosity, and distinct metal-ligand connection variations, magnesium sulphate (MgSO_4/BHT) comprises a particular kind of crystalline product that is growing popular as a catalyst. Theoretical and chemical knowledge are needed to appreciate the makeup, chemical houses, and functionality of MgSO_4/BHT catalysts. Catalyst character development is an essential component in developing and research of catalyse.

5.2.1 FESEM-Field Emission Scanning Electron Microscope

FESEM, occasionally referred to as field emission scanning electron microscopy, is a valuable imaging methodology to illustrate the surface morphology and microstructure of materials at a high magnification. The structure of MgSO_4/BHT at the micro- and nanoscale is capable of being evaluated with FESEM. MgSO_4/BHT FESEM are instruments that can utilized to investigate the size, shape, and distribution of the crystals that make up the substance. Furthermore, it might give insights concerning a material's porosity and surface area, which constitute crucial considerations when establishing its probable uses. The material's shortcomings or impurities that may impact its performance and the characteristics can be identified by employing FESEM. MgSO_4/BHT catalysts are distinguished by their high porosity and surface area, outstanding thermal stability, chemical endurance, and computational chemistry which renders them potential catalysts for an assortment of industrial applications. MgSO_4/BHT catalysts frequently make a desirable material for catalytic applications because they exceed customary catalysts in terms of catalytic activity, selectivity, and efficiency. MgSO_4/BHT catalysts are able to be used in a number of industrial processes, but additional research is needed to fully exploit their capabilities.

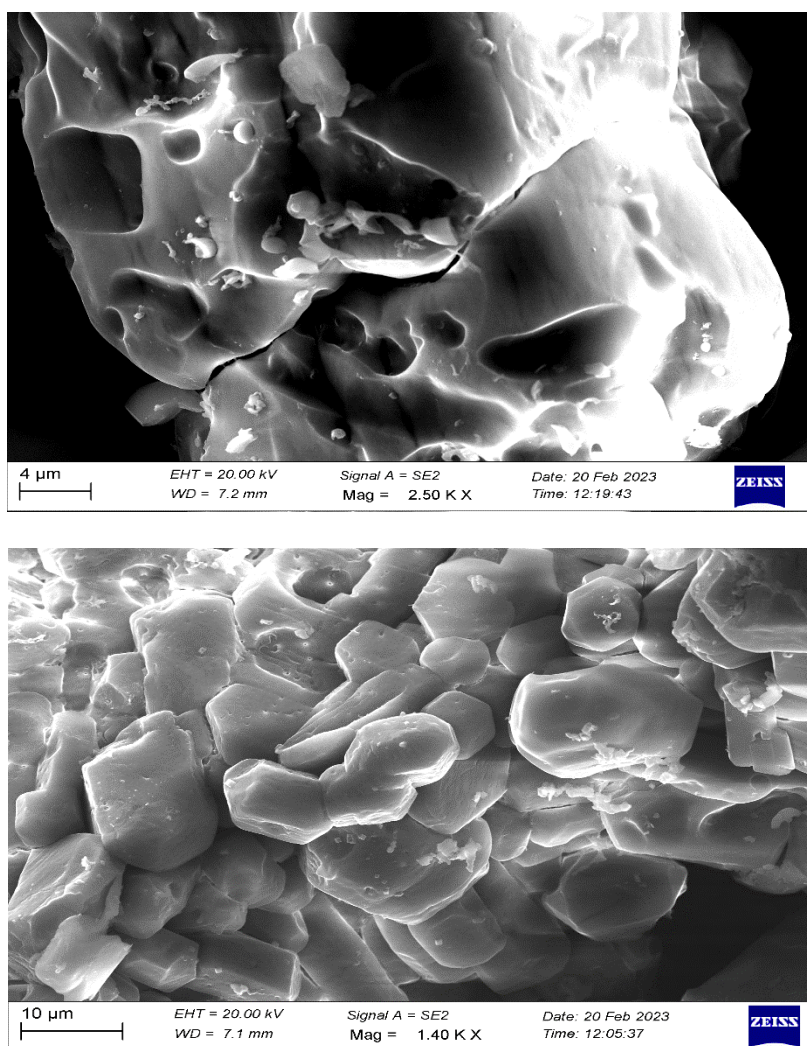


Fig 5.1 FESEM Images

MgSO₄ /BHT surface characteristics, size, and morphology may all be seen in FESEM pictures. MgSO₄ /BHT may be found in a variety of forms, and their morphology can be examined using FESEM pictures of pellets and powder. For instance, a MgSO₄ /BHT pellet's morphology may be revealed by a pellet FESEM picture, which can be used to assess the material's packing density and particle size distribution. On the other hand, a powder FESEM picture may display the size distribution and morphology of each individual MgSO₄ /BHT particle in the powder. Both of them will gives better yield. But we used pellet in packed bed column for easy handling and removable that will help to stop leaching into the product.

5.2.2 Energy Dispersive X-Ray Analysis

An approach termed energy dispersive X-ray (EDX) analysis leverages the X-rays that a sample announces after being bombarded by high-energy electrons or X-rays to detect and estimate the compounds that make up the sample. This approach is widely utilised in materials science, biology, and geology, and is frequently used together with scanning electron microscopy. (SEM).

The outcome of the EDX spectrum contains useful information concerning the chemical make-up of the sample and can be used to identify individual elements or compounds which are present in observe a Mg and other atoms are present in the graph up front. The peaks in the EDX spectrum, which

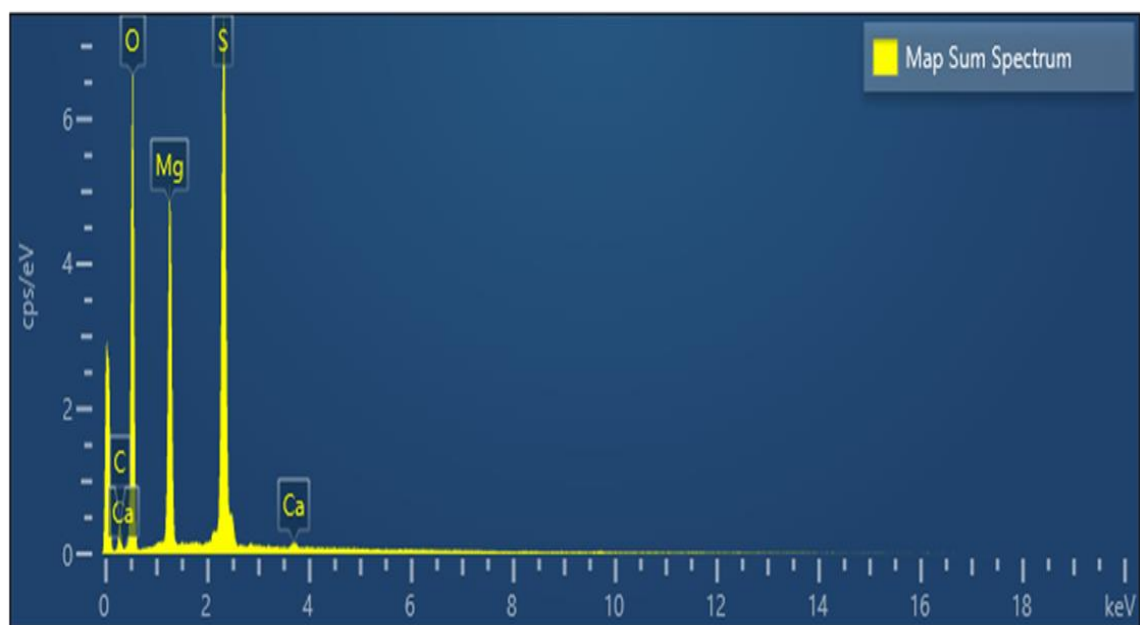


Fig 5.2 EDX image

Correspond to the particular X-rays that each element manufactures, can be utilized to determine the relative abundance of each element in the sample.

5.3 OVAT EXPERIMENTS

(One variable at a time)

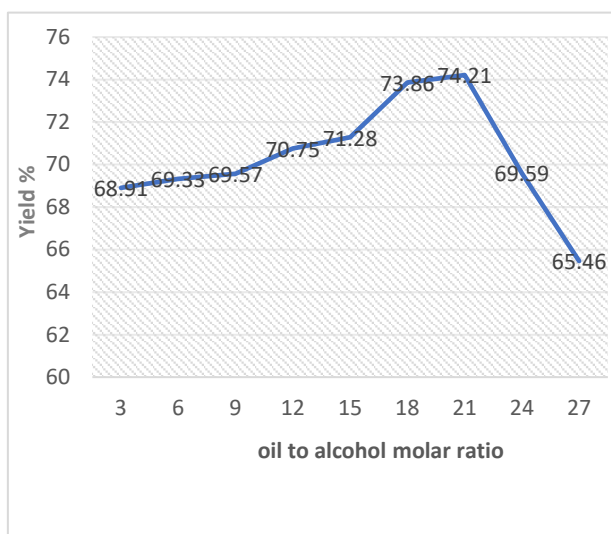


Fig 5.3 Oil to alcohol molar ratio

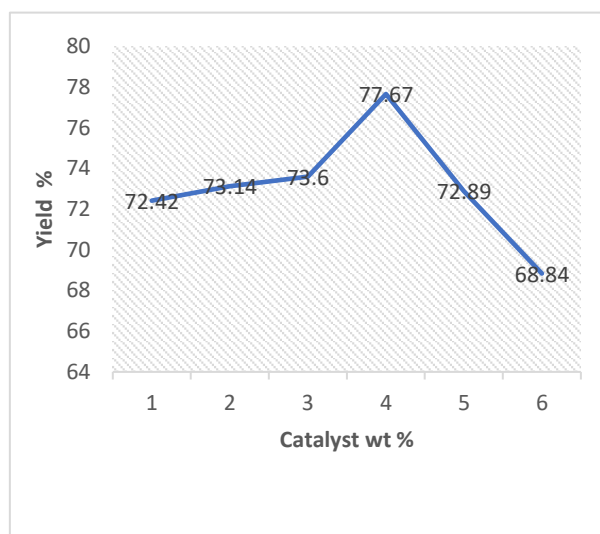


Fig 5.4 Catalyst wt%

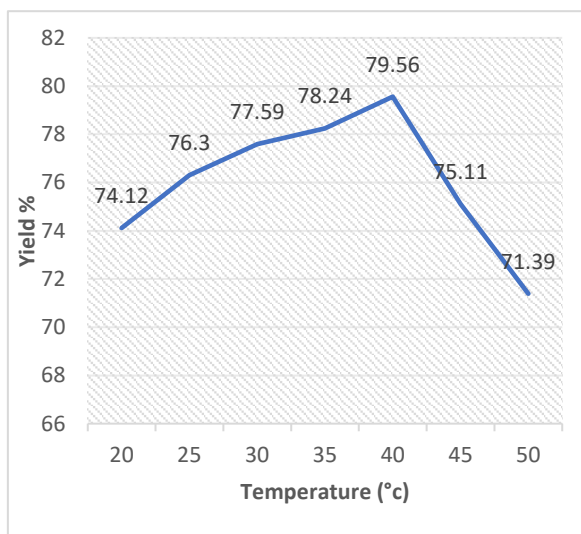


Fig 5.5 Temperature °C

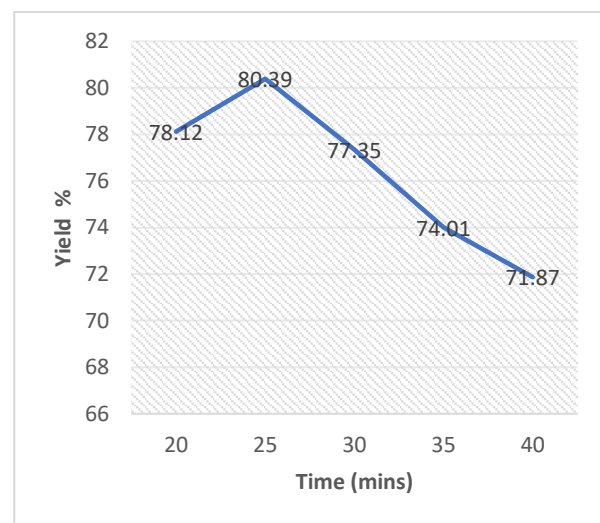


Fig 5.6 Time (mins)

Fig 5.3 oil to alcohol molar ratio vs. biodiesel yield at of 74.21 was obtain with oil to alcohol molar ratio 21:4. 4 wt% catalyst weight, 30°C Temperature, 25min Time.

Fig 5.4 catalyst wt% vs bio diesel yield of 77.67 was obtain with 4% catalyst weight .oil to molar ratio 24:1,30°C Temperature, 25min time.

Fig 5.5 temperature °C vs biodiesel of 79.56 were obtain with 40°C temperature.oil to molar ratio 24:1, 4 wt% catalyst weight, 25min time.

Fig 5.6 Time (min) vs biodiesel of 80.39 were obtained with 25 min time .oil to molar ratio 24:1,30°Ctemperature, 4 wt% catalyst weight.

5.4 ULTRASONICATOR TRANSESTERIFICATION PROCESS OF ESTERIFIED *Ceiba pentandra* SEED OIL USING MgSO_4 /BHT CATALYST

Using MATP and an MgSO_4 /BHT catalyst, the esterified CPSO was turned onto biodiesel. The OVAT has been employed to determine constants which involves reaction its duration, which stem MgSO_4 /BHT catalyst loading, MECO molar ratio, and ultrasonicator. studies and utilised to tweak the levels through additional refining procedures. The supplementary file describes how several factors affected the amount of biodiesel made during the OVAT experiment.

5.4.1 Process Optimization with Response Surface Methodology

Procedures and the design of the experiments can be optimized with Response Surface Methodology (RSM), a method of statistical analysis. It is used to look into the associations between multiple variables and responses in order to figure out the perfect set of input factors that will produce the intended output response. The objective of RSM is to create a mathematical model that predicts a process' action based on the input variable values.

Table 5.2: Level selected for RSM–CCD design for optimization process in MATLAB

Variables	Symbol	-1	0	1
oil: alcohol ratio	X_1	18:1	21:1	24:1
catalyst wt %	X_2	0.3	0.4	0.5
Time (min)	X_3	20	25	30
Temperature °C	X_4	30	35	40

Table 5.3: Actual values vs predicted values by optimization studies

Std order	X ₁	X ₂	X ₃	X ₄	Biodiesel yield%	
					Actual	Predicted
1	18	3	40	25	80.62	80.67
2	24	3	40	25	77.62	77.70
3	18	5	40	25	79.62	79.80
4	24	5	40	25	80.52	80.73
5	21	4	35	20	85.7	85.97
6	21	4	45	20	80.34	80.29
7	21	4	35	30	81.52	81.83
8	21	4	45	30	83.7	83.69
9	18	4	40	20	81.7	81.86
10	24	4	40	20	82.52	82.79
11	18	4	40	30	83.7	83.44
12	24	4	40	30	80.62	80.47
13	21	3	35	25	80.5	80.37
14	21	5	35	25	82.7	82.60
15	21	3	45	25	79.5	79.61
16	21	5	45	25	79.4	79.54
17	18	4	35	25	80.5	80.39
18	24	4	35	25	80.5	80.26
19	18	4	45	25	79.4	79.37
20	24	4	45	25	77.62	77.46
21	21	3	40	20	79.64	79.40
22	21	5	40	20	87.97	87.56
23	21	3	40	30	85.97	86.11
24	21	5	40	30	80.15	80.12
25	21	4	40	25	88.62	88.62
26	21	4	40	25	88.61	88.62
27	21	4	40	25	88.60	88.62
28	21	4	40	25	88.62	88.62
29	21	4	40	25	88.63	88.62

5.4.2 Stastical Analysis with Response Surface Methodology

A crew of mathematical and statistical techniques that are called Response Surface Methodology (RSM) are used to maximize efficiency and enhance a system's performance. RSM encompasses creating and analyzing mathematical models that illustrate the connection between input variables also alluded to as independent or predictor variables and the response also called to as the dependent variable of an interest process or system. RSM focuses extensively on statistical analysis given that it involves organizing experiments, collecting information and using statistical techniques to investigate the data and derive judgments about the underlying process or system. Establishing an amount of examinations in order to gather information on the reaction you want from the variable several variables is the first step in RSM. To effectively and efficiently analyze the response surface, which is the multidimensional space defined by the input variables and the response, experiment design should be adequately planned. The experiments are conducted once the experimental design has been determined settled with, and details surrounding the response variable(s) constitutes acquired. For the sake of The accuracy and consistency in subsequent statistical analyses, it is crucial to meticulously capture the data. Data Analysis: During data collection, the data is examined employing statistical techniques to identify the relationship between the input factors and the response. Analysis of variance (ANOVA), regression analysis, and graphical tackles as response surface plots and contour plots are common statistical methods used in RSM. To better understand the association between the input variables and the response, mathematical models have been developed based on the data analysis. Often polynomial regression models, these models can be utilized to predict what will happen for any combination of input variable values that are within the bounds of the experimental design. While establishing a model, an appropriate model form (linear, quadratic, etc.) needs to be picked, and the model parameters need to be estimated using techniques such least squares estimation. The models have to be assessed following creation in order to ensure their reliability and precision. To be able for this, new experimental data that hadn't been used in the creation of models will need to be contrasted with the displayed responses from the models. The models can be implemented for optimising once they go through verification, which involves finding the input variable values which

generate an optimal response. Depending on the purposes of the study, optimum approaches which includes numerical optimization, desirability operates, and algorithms based on the response surface methodology can be utilized to find the best input variable values that optimise or minimize the response. Finally, conclusions should be implemented from the statistical analysis conducted with RSM.

ANOVA for Quadratic model

ANOVA (Analysis of Variance) is a form of statistics for investigating the differences in groups of data. ANOVA can be used in the processing of biodiesel to determine the key factors, such as the particular feedstock chosen, the reaction temperature, and the reaction time frame, which have a major effect on the yield or quality of biodiesel. A quadratic model is a mathematical model that additionally includes linear terms plus a quadratic part (i.e., a squared term). A quadratic model can be employed to represent the nonlinear relationship between the input variables (such as temperature and reaction time) and the output variable (such as biodiesel yield) in the context of biodiesel synthesizing. When the relationship between the input and output isn't obvious, this can be informative.

Table 5.4: Response 1 Biodiesel Yield

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	368.41	14	26.32	437.68	< 0.0001*
X ₁ -Alcohol to oil molar ratio	3.14	1	3.14	52.25	< 0.0001*
X ₂ -Catalyst weight %	3.53	1	3.53	58.74	< 0.0001*
X ₃ -Temperature	10.94	1	10.94	182.03	< 0.0001*
X ₄ -Reaction time	0.4070	1	0.4070	6.77	0.0209*
X ₁ X ₂	3.80	1	3.80	63.24	< 0.0001*
X ₁ X ₃	0.7921	1	0.7921	13.17	0.0027*
X ₁ X ₄	3.80	1	3.80	63.24	< 0.0001*
X ₂ X ₃	1.32	1	1.32	22.00	0.0003*
X ₂ X ₄	50.06	1	50.06	832.53	< 0.0001*
X ₃ X ₄	14.21	1	14.21	236.39	< 0.0001*
X ₁ ²	163.92	1	163.92	2726.41	< 0.0001*
X ₂ ²	97.06	1	97.06	1614.38	< 0.0001*
X ₃ ²	115.63	1	115.63	1923.15	< 0.0001*
X ₄ ²	13.70	1	13.70	227.87	< 0.0001*
Residual	0.8417	14	0.0601		
Lack of Fit	0.8417	10	0.0842		
Pure Error	0.0000	4	0.0000		
Cor Total	369.26	28			

*Significant

Final Equation in Terms of Actual Factors

$$Y = (-561.66958 + 24.80083 X_1 + 46.95167 X_2 + 12.51767 X_3 + 4.04883 X_4 + 0.325000 X_1 * X_2 - 0.029667 X_1 * X_3 - 0.065000 X_1 * X_4 - 0.115000 X_2 * X_3 - 0.707500 X_2 * X_4 + 0.075400 X_3 * X_4 - 0.558565 X_1^2 - 3.86833 X_2^2 - 0.168883 X_3^2 - 0.058133 X_4^2).$$

5.4.3 3-D Surface Plots

When there are more than two input variables, three-dimensional (3-D) graphs are an invaluable resource for depicting results of RSM experiments. These graphs typically plot the third input variable on the vertical axis plus show the response variable (i.e., yield of biodiesel) as a function of two input variables.

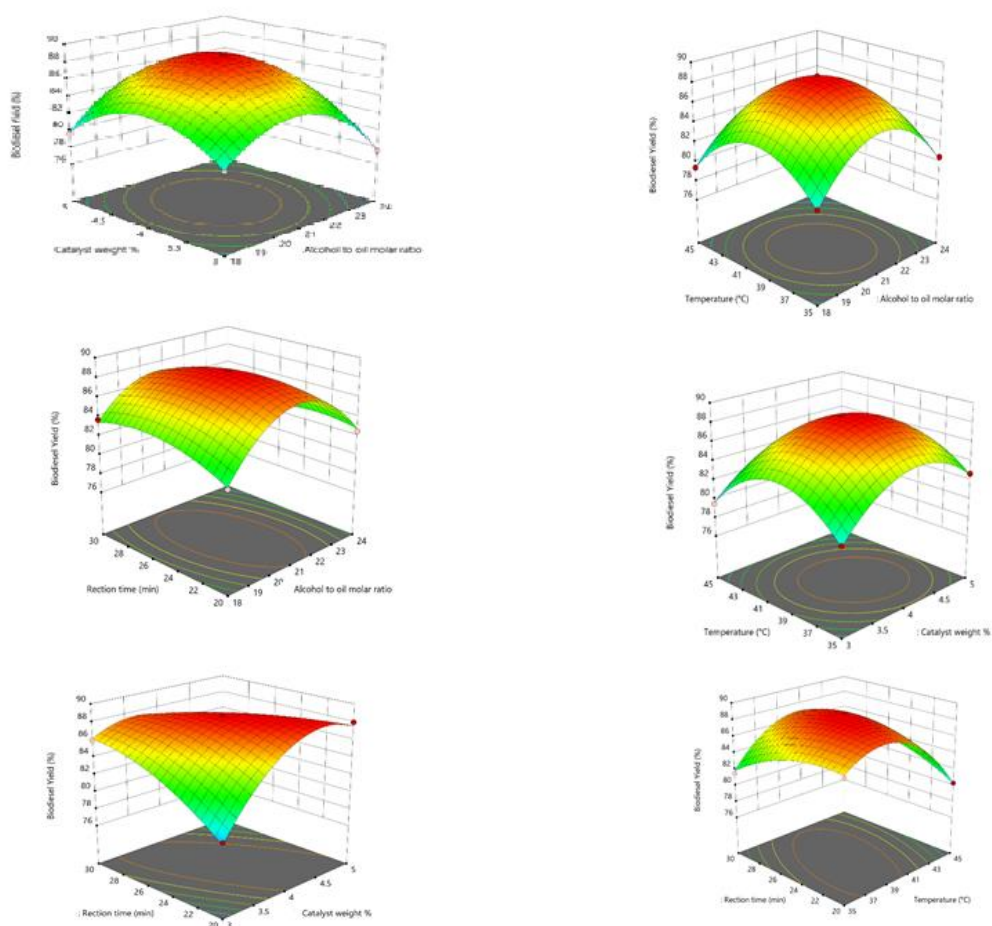


Fig 5.7 3-D surface plot which get from the optimization done in Response Surface Methodology

5.4.4 Predicted vs Actual

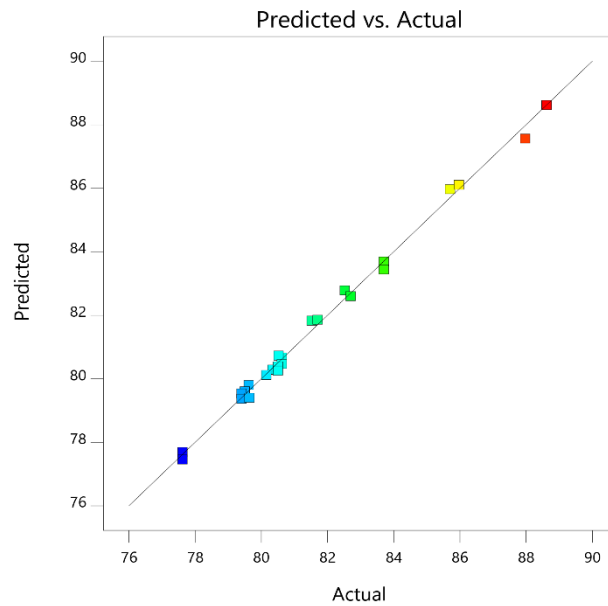


Fig 5.8 Predicted Vs Actual

The biodiesel yield estimated through the quadratic model is quite comparable to the actual output. The projected quadratic model's coefficient the data variation could possibly be attributed to the model. The adjusted of and the planned of exhibited an acceptable degree of agreement.

5.4.5 Normal plot of Residual

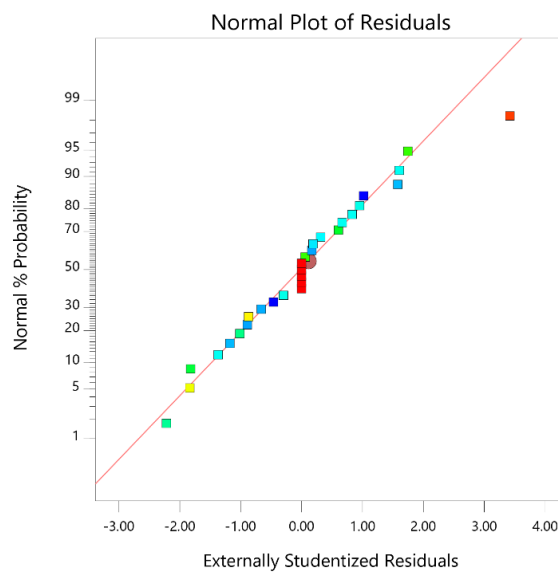


Fig 5.9 Normal plot of Residuals

The 45° angle, revealing that the field experiments succeeded in being carried out as the variation between the actual and presented rates is relatively minimal. , and this exhibits

5.5 BIODIESEL CHARACTERISATION

5.5.1 FT-IR-Fourier Transform Infrared Spectroscopy

For the purpose to figure out the sort and amount of functional groups present in the specimen, as well as the degree of unsaturation and other structural properties, FT-IR spectroscopy is extremely useful for biodiesel analysis.

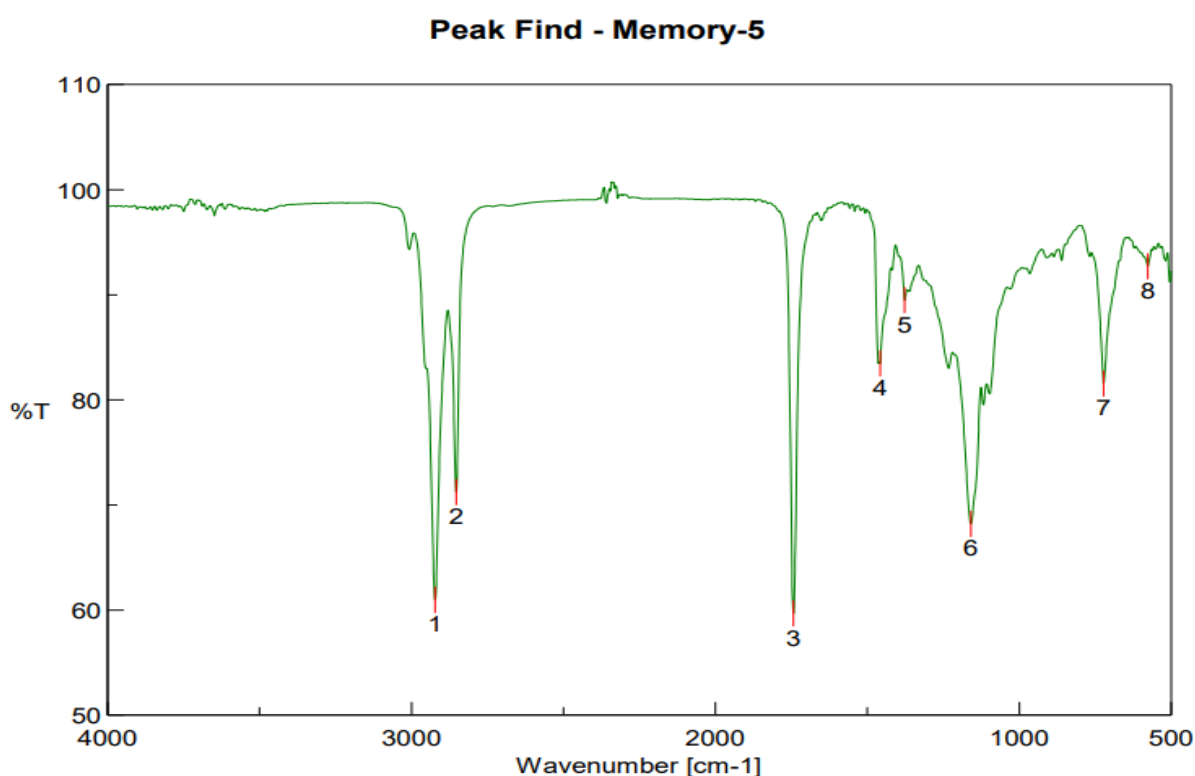


Fig 5.10 FT-IR for Biodiesel

The (C-H) stretching vibrations are picked up on due to the organic linker (BDC) used in the synthesis. Peaks at 2924.9 cm⁻¹ and 1711.2 cm⁻¹ were attributed, respectively, to the C-H-alkane and C=O's vibrational stretching. The clear peaks at 1114.9 cm⁻¹, 1185.2 cm⁻¹, and 1248.8 cm⁻¹ have been attributed to C-O stretching vibrations, while the peaks at 543 cm⁻¹ and 578 cm⁻¹.

5.5.2 Gas Chromatography Mass Spectrometry (GC-MS)

Using GC/MS, it can be done to determine the type and quantity of fatty acid methyl esters (FAMES) present in the sample as well as any extra chemicals that could be present to it, such as contaminants or additives.

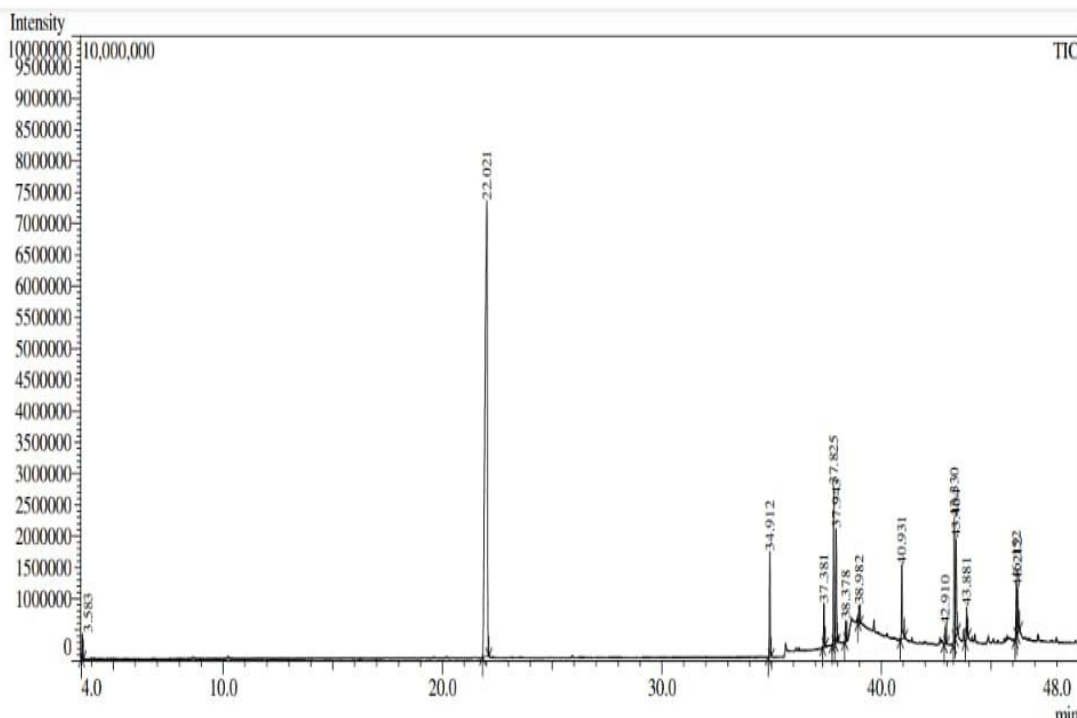


Fig 5.11 GC/MS

The volume of saturated fatty acid methyl ester (SFAME) of synthesized FAME was 66.38%. Also Phenol, 4,6-di(1,1-dimethylethyl)-2-methyl ester 59.72%. 15-Hydroxypentadecanoic acid 3.49% of SFAME is composed up primarily of hexadecenoic acid methyl ester. The two primary constituents of mono- and poly-unsaturated fatty acid methyl ester include octadecenoic acid methyl ester (3.94%).

CHAPTER-6

SUMMARY AND CONCLUSIONS

The installation of a heterogeneous catalyst for creating biodiesel from silk cotton seed oil has led to promising outcomes. Due to its high oil content and affordability as a by product of the silk cotton company operations, silk cotton seed oil, a non-edible oil, has the potential to be an important feedstock for the manufacturing of biodiesel. The effectiveness of heterogeneous catalysts, such as metal oxides, in encouraging the process of conversion of silk cotton seed oil to biodiesel has been investigated. In accordance with studies, heterogeneous catalysts can rapidly as well as with good yields change silk cotton seed oil into biodiesel. As a consequence of the catalysts' straightforward recovery from the reaction mixture, downstream processing has been simplified and the cost for making biodiesel reduces overall. The use of heterogeneous catalysts provides additional advantages. Subsequently has been examined at what it takes one can generate biodiesel from silk cotton seed oil using MgSO_4 /BHT as a heterogeneous catalyst. Non-edible silk cotton seed oil has the potential to be used as a feedstock for the production of biodiesel. The transesterification reaction, which transforms the triglycerides in silk cotton seed oil into biodiesel, was rendered faster in this study through the use of MgSO_4 / BHT as a catalyst. Under ideal circumstances, the step of transesterification was carried out employing a methanol-to-oil molar ratio of, a MgSO_4 / BHT catalyst loading, a reaction temperature of, and a reaction time of hours. MgSO_4 /BHT exhibited promising results while applied as a heterogeneous catalyst in the creation of biodiesel from silk cotton seed oil. A high biodiesel yield of almost 90% was attained with the perfect conditions of a methanol-to-oil molar ratio of, an MgSO_4 /BHT catalyst loading of, a reaction temperature of, and a reaction length of hours. The produced biodiesel has been shown to exhibit features falling within the acceptable range for biodiesel fuel demands. MgSO_4 /BHT can therefore be envisioned as an efficient catalyst for the transesterification of silk cotton seed oil into biodiesel, suggesting a potential solution for using non-edible oil feedstocks for biodiesel production. Further study may be completed for enhancing the process parameters and delve into.

REFERENCES

- 1) M. R. Avhad and J. M. Marchetti, "A review on recent advancement in catalytic materials for biodiesel production," *Renewable and Sustainable Energy Reviews*, vol. 50, pp. 696–718, 2015, doi: 10.1016/j.rser.2015.05.038.
- 2) Z. W. M. M. Phoo et al., "Evaluation of Indian milkweed (*Calotropis gigantea*) seed oil as alternative feedstock for biodiesel," *Industrial Crops and Products*, vol. 54, pp. 226–232, 2014, doi: 10.1016/j.indcrop.2014.01.029.
- 3) Exergy-based optimization of direct conversion of microalgae biomass to biodiesel doi.org/10.1016/j.iclepro.2016.09.032.
- 4) S. Rajagopalachar, S. S. Joshi, and R. P. Reddy, "Biodiesel synthesis from *Garcinia gummi-gutta* (L . Robson) seed oil : fuel feasibility evaluation of a novel feedstock by homogeneous and heterogeneous transesterification," *Biofuels*, vol. 0, no. 0, pp. 1–8, 2017, doi: 10.1080/17597269.2017.1306681.
- 5) A. Elfasakhany, "Exhaust emissions and performance of ternary iso-butanol e bio- methanol e gasoline and n-butanol e bio-ethanol e gasoline fuel blends in spark-ignition engines : Assessment and comparison," *Energy*, vol. 158, pp. 830–844, 2018, doi: 10.1016/j.energy.2018.05.120.
- 6) H. Venu, V. D. Raju, and L. Subramani, "Combined effect of influence of nano additives, combustion chamber geometry and injection timing in a DI diesel engine fuelled with ternary (diesel-biodiesel-ethanol) blends," *Energy*, vol. 174, pp. 386–406, 2019, doi: 10.1016/j.energy.2019.02.163.
- 7) L. Subramani and H. Venu, "Evaluation of methyl ester derived from novel *Chlorella emersonii* as an alternative feedstock for DI diesel engine & its combustion , performance and tailpipe emissions," 2018 <https://link.springer.com/article/10.1007/s00231-018-2530-0>
- 8) N. Yilmaz, A. Atmanli, and F. M. Vigil, "Quaternary blends of diesel, biodiesel, higher alcohols and vegetable oil in a compression ignition engine," *Fuel*, vol. 212, no. August 2017, pp. 462–469, 2018, doi: 10.1016/j.fuel.2017.10.050.
- 9) A. Atmanlı, B. Yüksel, E. Ileri, and A. D. Karaoglan, "Response surface methodology based optimization of diesel – n-butanol – cotton oil ternary blend ratios to improve engine performance and exhaust emission

- characteristics,” vol. 90, pp. 383–394, 2015, doi: 10.1016/j.enconman.2014.11.029.
- 10) P. Appavu, V. Ramanan M, and H. Venu, “Quaternary blends of diesel/biodiesel/vegetable oil/pentanol as a potential alternative feedstock for existing unmodified diesel engine: Performance, combustion and emission characteristics,” Energy, vol. 186, p. 115856, 2019, doi: 10.1016/j.energy.2019.115856.
 - 11). A. Atmanli, E. Ileri, and N. Yilmaz, “Optimization of diesel-butanol-vegetable oil blend ratios based on engine operating parameters,” Energy, vol. 96, no. 2016, pp. 569–580, 2016, doi: 10.1016/j.energy.2015.12.091.
 - 12) Perkins, G.; Techno-economic comparison of the levelised cost of electricity generation from solar PV and battery storage with solar PV and combustion of bio-crude using fast pyrolysis of biomass, Energy Conversion and Management. 2018, 171, 1573-1588. <https://doi.org/10.1016/j.enconman.2018.06.090>.
 - 13) Rehfeldt, M.; Worrell, E.; Eichhammer, W.; Fleiter, T.; A review of the emission reduction potential of fuel switch towards biomass and electricity in European basic materials industry until 2030, Renewable and Sustainable Energy Reviews. 2020, 120, 109672. 10.1016/j.rser.2019.109672.
 - 14). Mahmudul, H.M.; Hagos, F.Y.; Mamat, R.; Adam, A.A.; Ishak, W.F.W.; Alenezi, R.; Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review, Renewable and Sustainable Energy Reviews. 2017, 72, 497-509. <https://doi.org/10.1016/j.rser.2017.01.001>.
 - 15) Datta, A.; Mandal, B.K.; A comprehensive review of biodiesel as an alternative fuel for compression ignition engine, Renewable and Sustainable Energy Reviews. 2016, 57, 799- 821. <https://doi.org/10.1016/j.rser.2015.12.170>
 - 16) Rezanian, S.; Oryani, B.; Park, J.; Hashemi, B.; Yadav, K.K.; Kwon, E.E.; Hur, J.; Cho, J.; Review on transesterification of non-edible sources for biodiesel production with a focus on economic aspects, fuel properties and by-product applications, Energy Conversion and Management. 2019, 201, 112155. <https://doi.org/10.1016/j.enconman.2019.112155>

- 17) Mardhiah, H.H.; Ong, H.C.; Masjuki, H.H.; Lim, S.; Lee, H.V.; A review on latest developments and future prospects of heterogeneous catalyst in biodiesel production from non-edible oils, *Renewable and Sustainable Energy Reviews*. 2017, 67, 1225-1236. <https://doi.org/10.1016/j.rser.2016.09.036>
- 18) Banković-Ilić, I.B.; Stamenković, O.S.; Veljković, V.B.; Biodiesel production from nonedible plant oils, *Renewable and Sustainable Energy Reviews*. 2012, 16, 3621-3647. <https://doi.org/10.1016/j.rser.2012.03.002>.
- 19). Bhuiya, M.M.K.; Rasul, M.G.; Khan, M.M.K.; Ashwath, N.; Azad, A.K.; Hazrat, M.A.; Prospects of 2nd generation biodiesel as a sustainable fuel – Part 2: Properties, performance and emission characteristics, *Renewable and Sustainable Energy Reviews*. 2016, 55, 1129- 1146. <https://doi.org/10.1016/j.indcrop.2020.112493>.
- 20) Recent scenario and technologies to utilize non-edible oils for biodiesel production Author links open overlay panel T.M. Yunus khan ^a, A.E. Atabani ^{b c}, Irfan Anjum Badruddin ^a, Ahmad Badarudin ^a, M.S. Khayoon ^d, S. Triwahyono ^d <https://doi.org/10.1016/j.rser.2014.05.064>
- 21) O'Connor, P. (2013). *A General Introduction to Biomass Utilization Possibilities. The Role of Catalysis for the Sustainable Production of Bio-Fuels and Bio-Chemicals*, 1–25. doi:10.1016/b978-0-444-56330-9.00001-2.
- 22) Konwar, L.J.; Das, R.; Thakur, A.J.; Salminen, E.; Mäki-Arvela, P.; Kumar, N.; Mikkola, J.-P.; Deka, D.; Biodiesel production from acid oils using sulfonated carbon catalyst derived from oil-cake waste, *Journal of Molecular Catalysis A: Chemical*. 2014, 388–389, 167-176. <https://doi.org/10.1016/j.molcata.2013.09.031>.
- 23) Farooq, M.; Ramli, A.; Subbarao, D.; Biodiesel production from waste cooking oil using bifunctional heterogeneous solid catalysts, *Journal of Cleaner Production*. 2013, 59, 131- 140. <https://doi.org/10.1016/j.jclepro.2013.06.015>.
- 24) Jamil, F.; Al-Muhtaseb, A.a.; Myint, M.T.Z.; Al-Hinai, M.; Al-Haj, L.; Baawain, M.; Alabri, M.; Kumar, G.; Atabani, A.E.; Biodiesel production by valorizing waste *Phoenix dactylifera* L. Kernel oil in the presence of synthesized

- heterogeneous metallic oxide catalyst (Mn@MgO-ZrO₂), *Energy Conversion and Management*. 2018, 155, 128-137. (<https://doi.org/10.1016/j.enconman.2017.10.064>).
- 25) Noam Lior (2008) Energy resources and use: The present situation and possible paths to the future. ,33(6), 842-857. <https://doi.org/10.1016/j.energy.2007.09.009>.
 - 26) Nick A. Owen; Oliver R. Inderwildi; David A. King (2010). *The status of conventional world oil reserves—Hype or cause for concern?*. , 38(8), 4743–4749. doi:10.1016/j.enpol.2010.02.026.
 - 27) T. M. M. Marso, C. S. Kalpage, and M. Y. Udugala-Ganehenegge, “Metal modified graphene oxide composite catalyst for the production of biodiesel via pre-esterification of Calophyllum inophyllum oil,” *Fuel*, vol. 199, pp. 47–64, Jul. 2017, doi: 10.1016/j.fuel.2017.01.004.
 - 28) Hamelinck, C. N., Hooijdonk, G. van, & Faaij, A. P. (2005). *Ethanol from lignocellulosic biomass: techno-economic performance in short-, middle- and long-term. Biomass and Bioenergy*, 28(4), 384–410. doi:10.1016/j.biombioe.2004.09.002.
 - 29) B. Basumatary, S. Basumatary, B. Das, B. Nath, and P. Kalita, “Waste Musa paradisiaca plant: An efficient heterogeneous base catalyst for fast production of biodiesel,” *J Clean Prod*, vol. 305, p. 127089, Jul. 2021, doi: 10.1016/j.jclepro.2021.127089.
 - 30) Martins, Maria F.O.; Dias, Sara S. (2010). *Developmental Impact of Very Low Birth Weight on Childhood Disability: A Parametric and Semiparametric Binary Choice Model Approach. American Journal of Mathematical and Management Sciences*, 30(3-4), 217–242. doi:10.1080/01966324.2010.10737786.
 - 31) Dennis Y.C. Leung; Xuan Wu; M.K.H. Leung (2010). *A review on biodiesel production using catalyzed transesterification.* , 87(4), 1083–1095. doi:10.1016/j.apenergy.2009.10.006.
 - 32) Borhanipour, Morteza; Karin, Preechar; Tongroon, Manida; Chollacoop, Nuwong; Hanamura, Katsunori (2014). *SAE Technical Paper Series [SAE International The 10th International Conference on Automotive Engineering - (MAR. 31, 2014)] SAE Technical Paper Series -*

- Comparison Study on Fuel Properties of Biodiesel from Jatropha, Palm and Petroleum Based Diesel Fuel.* , 1(), –. doi:10.4271/2014-01-2017.
- 33) Atabani, A.E.; César, Aldara da Silva (2014). *Calophyllum inophyllum* L. – A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. *Renewable and Sustainable Energy Reviews*, 37(), 644–655. doi:10.1016/j.rser.2014.05.037.
- 34) Y Zhang; M.A Dube; D.D McLean; M kates (2003). Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. , 90(3), 229-240. [https://doi.org/10.1016/S0960-8524\(03\)00150-0](https://doi.org/10.1016/S0960-8524(03)00150-0)
- 35) Y Zhang; M.A Dubé; D.D McLean; M Kates (2003). *Biodiesel production from waste cooking oil: 1. Process design and technological assessment.* , 89(1), 1–16. doi:10.1016/s0960-8524(03)00040-3.
- 36) Sani, Yahaya Muhammad; Daud, Wan Mohd Ashri Wan; Abdul Aziz, A.R. (2014). *Activity of solid acid catalysts for biodiesel production: A critical review.* *Applied Catalysis A: General*, 470(), 140–161. doi:10.1016/j.apcata.2013.10.052.
- 37) Garg, Bhaskar; Bisht, Tanuja; Ling, Yong-Chien (2014). *Graphene-Based Nanomaterials as Heterogeneous Acid Catalysts: A Comprehensive Perspective.* *Molecules*, 19(9), 14582–14614. doi:10.3390/molecules190914582.
- 38) Navalon, Sergio; Dhakshinamoorthy, Amarajothi; Alvaro, Mercedes; Garcia, Hermenegildo (2014). *Carbocatalysis by Graphene-Based Materials.* *Chemical Reviews*, 114(12), 6179–6212. doi:10.1021/cr4007347.
- 39) Park, Sungjin; Lee, Kyoung-Seok; Bozoklu, Gulay; Cai, Weiwei; Nguyen, SonBinh T.; Ruoff, Rodney S. (2008). *Graphene Oxide Papers Modified by Divalent Ions—Enhancing Mechanical Properties <i>via</i> Chemical Cross-Linking.* *ACS Nano*, 2(3), 572–578. <https://doi.org/10.1021/nn700349a>.
- 40) Hawkins, C., Fuls, J., and Hugo, F., "Sunflower Oil Esters: An Alternative Fuel for Direct Injection Diesel Engines," SAE Technical Paper 831356, 1983, <https://doi.org/10.4271/831356>.

- 41) Silitonga, A.S., Masjuki, H.H., Mahlia, T.M.I., Ong, H.C., Chong, W.T., 2013. Experimental study on performance and exhaust emissions of a diesel engine fuelled with *Ceiba pentandra* biodiesel blends. *Energy Convers. Manag.* 76, 828–836. <https://doi.org/10.1016/j.enconman.2013.08.032>.
- 42) Vedharaj, S., Vallinayagam, R., Yang, W.M., Chou, S.K., Chua, K.J.E., Lee, P.S., 2013. Experimental investigation of kapok (*Ceiba pentandra*) oil biodiesel as an alternate fuel for diesel engine. *Energy Convers. Manag.* 75, 773–779. <https://doi.org/10.1016/j.enconman.2013.08.042>.
- 43) Dave, D.V., Ramakrishnan, V., Sheila, T., Heather, M., Julia, P., Wade, M., 2014. Marine oils as potential feedstock for biodiesel production: physicochemical characterization. *J. Bioprocess. Biotech.* 1. <https://doi.org/10.4172/2155-9821.1000168>, 04(05).
- 44) Muhammad, C., 2018. Biodiesel production from *Ceiba pentandra* seed oil using CaO derived from snail shell as catalyst. *Petroleum Sci. Eng.* 2 (1), 7–16. <https://doi.org/10.11648/j.pse.20180201.12>.
- 45) Pasawan, M., Chen, S.S., Das, B., Chang, H.-M., Chang, C.T., Nguyen, T.X.Q., Ku, H.M., Chen, Y.-F., 2022. Ultrasonication assisted catalytic transesterification of *Ceiba Pentandra* (Kapok) oil derived biodiesel using immobilized iron nanoparticles. *Fuels* 3 (1), 113–131. <https://doi.org/10.3390/fuels3010008>.
- 46) Bokhari, A., Chuah, L.F., Yusup, S., Ahmad, J., Shamsuddin, M.R., Teng, M.K., 2015. Microwave-assisted methyl esters synthesis of Kapok (*Ceiba pentandra*) seed oil: parametric and optimization study. *Biofuel Res. J.* 2 (3), 281–287. <https://doi.org/10.18331/brj2015.2.3.6>.
- 47) <https://doi.org/10.5897/JPTAF2018.0141?sid=semanticscholar> Fatty acid profile and quality parameters of *Ceiba pentandra* (L.) seed oil: A potential source of biodiesel Papin Sourou MONTCHO1 , Léopold TCHIAKPE2 , Guevara NONVIHO1 , Fifa Théomaine Diane BOTHON1 , Assou SIDOHOUNDE 1 , Cokou Pascal AGBANGNAN DOSSA1 , David BESSIERES3 , Anna CHROSTOWSKA4 and Dominique Codjo Koko SOHOUNHLOUE1*.
- 48) Integrated global optimization and process modelling for biodiesel production from non-edible silk-cotton seed oil by microwaveassiste

transesterification with heterogeneous calcium oxide catalyst

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- 49)Nayak, S.N., Nayak, M.G., Bhasin, D.C.P., 2021. Parametric, kinetic, and thermodynamic studies of microwave-assisted esterification of Kusum oil. Fuel Commun 8, 100018. <https://doi.org/10.1016/j.jfueco.2021.100018>.
- 50)Moorthy, I.M., Baskar, R., 2013. Statistical modeling and optimization of alkaline protease production from a newly isolated alkalophilic Bacillus species BGS using response surface methodology and genetic algorithm. Prep.Biochem.Biotechnol.43(3),293–314. <https://doi.org/10.1080/10826068.2012.719850>.

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PRODUCTION OF BIO DIESEL FROM SILK COTTON SEED OIL USING HETEROGENOUS CATALYST

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CHAPTER-1 INTRODUCTION

The efforts to investigate certain alternate sources of petroleum-based fuels have been prompted by the depletion of the world's petroleum reserves as a result of the rapidly increasing energy demands and environmental concerns. Because they can be burned to create a considerable amount of energy, fuels are very important. Fossil fuels make up a large portion of the energy that is now used in the world. 80 percent of the world's energy challenge are met by fossil fuels. Vegetable oils, for example, can be used as renewable fuels. Vegetable oils provide a number of advantages over other energy sources, such as alcohols, including a larger energy content. Vegetable oils have recently gained popularity due to their favourable effects on the environment and their production from renewable resources. Vegetable oils contain 90% of the energy in diesel. Vegetable oils are currently more affordable than petroleum fuel, but they still require additional R&D to be developed and are not yet economically feasible. Vegetable oils can be used in CI engines by modifying the fuel and engine. Engine alter include heated fuel lines, a bifold fuel booster modification process, and the blending of diesel and vegetable oil. The transesterification procedure conclusion in the mono-alkyl esters of fatty acids that make up biodiesel. Heterogeneous catalysts may be reused, produce very little water, and use very little energy. The brake power and torque of biodiesel combine tested in a 6-cylinder DI diesel engine were slightly reduced. Higher compression ratios, earlier injection timing, and higher injector opening pressure can all boost the conducting of a deflate ignition engine running on biodiesel fuel. The emissions of fragment matter, hydrocarbons, carbon dioxide, carbon monoxide, and nitrogen oxide are all significantly decreased when biodiesel blends are used. Diesel engines are utilised frequently because of their superior efficiency and low fuel usage. Consumption of fuel is always rising. However, the quick depletion of petroleum fuels and their steadily rising prices have sparked a vigorous quest for other fuels. According to one analysis, the current reserves of petroleum fuel, including diesel, will run out in 40 years at a higher consumption rate that is roughly 3% per year. It is understood that the current level of energy use is insufficient for a developing economy. There are a number of potential fuel alternatives, including vegetable oils, alcohols like methanol and ethanol, gases like compressed natural gas (CNG), liquefied petroleum gas (LPG), producer gas, and others. Since they are sustainable and simple to manufacture in rural regions, where there is a pressing

demand for contemporary forms of energy, vegetable oils stand out among them as a particularly potential substitute for diesel. The idea of make use of vegetable oils as fuel for diesel engines was developed along with vegetable oil-powered diesel engines. Vegetable oils have the capacity to be an alternative fuel for diesel engines, according to numerous researchers. However, make use of raw vegetable oils in diesel engines can lead to a variety of issues with the engines. Vegetable oils have a higher viscosity and less volatility, which causes severe engine deposits, booster clogging, and piston ring sticking. However, by transesterifying vegetable oil to create methyl ester, these effects can be mitigated or even reversed. Fuel viscosity produced by transesterification is comparable to that of No. 2 diesel fuel. Transesterification has demonstrated strong capacity for lowering engine issues brought on by vegetable oils. A triglyceride and an alcohol are combined during the transesterification process to create glycerol and fatty acid esters. This reaction takes place in the presence of a catalyst. The ester has a viscosity that is almost twofold that of diesel fuel and has a molecular weight that is around one-third that of a clean vegetable oil molecule. In comparison, the viscosity of raw vegetable oil is 10 to 20 times greater than that of diesel fuel. Due to the fuel's spray pattern and deposit deposition, viscosity is a major concern. Vegetable oil esters are familiar to have substantially greater cloud points and pour points than diesel fuel, making them far more problematic to utilise in hazy conditions. Methyl esters from spent frying oil have been created, and their fuel qualities have been compared to those that are acceptable for methyl esters from rapeseed oil. The oil's free fatty acid concentration ranged from 0.26% to 2.12%. Biodiesel's heat of combustion was found to be 12% lower than that of conventional diesel fuel. When the engine was run on biodiesel instead of No. 2 diesel fuel, it was organize that the smoke opacity and engine power were reduced by 71% and 4.8%, exactly. However, at 1700 and 1300 rpm, the peak engine torsion fell by 6.2% and 3.2%, respectively. Thermal efficiencies, however, do not significantly differ from one another. When biodiesel was utilised, emissions tests revealed a 54% reduction in HC, a 46% reduction in CO, a 14.7% reduction in NOx, and a 0.5% enlarge in CO2. Researchers have shown that using biodiesel has an impact on exhaust emissions. It is well familiar that when contrast to diesel fuel, biodiesel often results in an increase in NOx emissions and a decrease in HC, CO, and PM emissions. There are, however, a few papers on the examination of the impact of biodiesel sterility on engine output and emissions. The biodiesel was 99% pure. According to Suryawanshi, 100%

biodiesel results in slightly higher NO_x emissions but reduced CO, THC, smoke, and PM emissions. The creation of efficient alternative sources of energy that are based on seeds, algae, and casings is required due to the severe energy shortage the world is currently experiencing [1]. likewise some non-edible fuel sources, like Gama gummi-gutta seed (GGGS), mango seed, or jatropha seed, have greater benefits than a meal fuel sources.

The reality that inedible fuel sources don't impact the food chain, consisting of soy, peanut, sunflower, and mustard, is a good thing [2] The following paper seeks to provide helpful data on the use of ¹² in-situ transesterification of microalgae sludge assisted ¹² the ultrasound for the manufacture of biodiesel, which is a cleaner process than typical ¹² production. In the ¹² recommend research it has been concentrated on constructing the following authority on biodiesel yield and energy regulation of the in-situ transesterification: ultrasonic power (energy necessary for the reaction agitation and cavitation), reaction time, methanol:oil molar ratio and chloroform:oil molar ratio. Another innovation of the current work is ² the simultaneous optimizing of energy regulation and biodiesel output using ² Response Surface Methodology (RSM) and ² Artificial Neural Networks (ANNs), this might improve the sustainability of microalgae biodiesel by minimising energy dropping. [3]. Along with these perks, there are some pitfalls as well. These shortcomings embrace the fuel's a lack of energy substance, poor cold start, harmful effects, and more corrosive quality . Thus, these issues often cause an urge for blending ethanol from biomass with diesel engine fuel, a sort of fuel blend commonly referred to as "ternary encourage blends" [4] and [3]. Due to the multi-injection planning, the dual-injection mode was made feasible, and without any adverse side effects, diesel-ethanol and biodiesel were injected directly into the tank [5], [6]. The major methods emerged as a outcome of the bio-ethanol merge with the evaluation fuel mix (diesel and biodiesel) [7], which will alter the fuel's properties like fleshliness. Sugar canes and other plants were previously used to create immigrants bio-ethanol, and just a little of lignin-based biomass (agricultural waste and leafy flora) was then used to make second-generation bio-ethanol [9], [10]. owing to its enhanced chemical structure, and that ²⁶ can be combined with gasoline and tested using a alter diesel engine .Fuels like ethanol and petroleum are less good at cooling vehicles than these types of fuel due to their decreased latent values of vaporisation[11]. Rising rates of biodiesel, gasoline, and ethanol are employed in an emission test by

academics Yilmaz et al. [8]. ethanol levels of 3, 5, 15, and 25%. After the engine test, researchers arrived at the increasing ethanol Leaks were calculated as a percentage based on greater oxygen supply, a reduction in cooling impact, and little heating value. Researchers have taken particular note to biodiesel increasingly due to its status as renewable, non-toxic, sustainable, and biodegradable biofuel. Without any revisions, it is completely compatible with typical diesel fuel engines, which will decrease the quantity of emerging contaminants and wastes. Moreover, biodiesel has very high cetane levels, a high flash point, no aromatics, no sulphur, and endogenous lubricity. The enlightenment witnessed an upward trend in the production of energy from renewable sources owing to the upswing and vagaries in the price of fossil fuels as well as their adverse ecological effects. In contrast to solar and wind energy alternatives, biofuels proceed from plant matter are the complimentary useful orgin for energy fabrication and distribution, as stated in a study carried out by the International Energy Agency (IEA) [12, 13]. Liquid biofuels convert from biomass have always had the perks of being easy to transport, environmentally friendly, biodegradable, and renewable. The most suitable and viable liquid fuel that may be exploited for energy production and conveyance is deemed to be biodiesel [14, 15]. The cost of biodiesel, which hinges on its feedstock and can generate up to 75% of its contract sum, is a hurdle for its commercialization. So, when determining a raw-material, non-edible waste and agricultural waste may be the ideal route to reducing the cost generating biodiesel [16]. There have been allegations including both edible and non-edible oil orgin in the search for appropriate feedstock for conversion of biomass. However, to avoid the current debate over food versus fuel, non-edible oil feedstock is selected, and the complimentary widely known plant-predicated oils are soybean oil, palm oil, Jatropha curcas oil, rubber seed oil, and waste cooking oil. Animal fats are also abundantly orgin for the manufacturing of biodiesel [17, 18]. In pursuit of the highest profit of methyl and inhibit soap formation, a non-edible feedstock can frequently contain a high FFA content, prompting the use of a two-step biodiesel production method that calls for first esterifying FFA and then transesterifying triglycerides [19, 20]. Due to its high activity and reusability, amphiphilic metallic oxide catalyst has grown to be a phenomenon in previous decades and has attracted the focus of specialists. As these catalysts feature operational acidic and basic sites, they can support oxidation reactions involving call for both acidic and basic catalysts [21]. So according previous findings, the vast majority of non-edible oils have excessive FFA

content and demand a two method to convert to biodiesel [22]. In order to make the process more practical, this concerns can be addressed through the application of a bifunctional catalyst. Bi-functional catalysts (Mo-Mn/-Al₂O₃-MgO) were devised by Farooq et al and processed to obtain biodiesel from leftover cooking oil with something like a yield of 91.4% [23] . In the presence of the dual-use catalyst Mn-MgO/ZrO₂, Jamil et al. managed to convert date seed oil with similar FFA to biodiesel [24]. It seems under explanation because organic catalysis, such as enzymatic catalysis, can be used to convert biomass, such as the process of processing sugars into ethanol, and has been employed in the same reason in previous generations. The author makes the comment that inorganic catalysis can be more acceptable for the economically systematic tranformation of unrefined natural biomass, including agricultural biomass and forestry waste, in this introduction because of one's own particular opinions and different points of view. It is crucial to take into account the abundant supply of these unwanted biomass flow and the underlying immorality of refraining the conversion of wholesome biomass'"nonwaste" ingredients into fuels and chemicals[21]. Which is also why, a double catalyst for biodiesel formation from high-FFA oil might serve as an viable. To identify the ideal combination for the biodiesel synthesis process, a heterogeneous catalyst constructed from carbon extracted from unwanted biomass and alter by the several alkaline earth metal oxides has been built in the present investigation. The performance of the catalyst was then assessed for the creation of biodiesel. Multiple oils (waste cooking oil, date seed oil, palm oil, and coconut oil) all tested to confirm that catalyst generated the best biodiesel. The product biodiesel was assessed often using conventional techniques prescribed by ASTM D-6751 and EN-14214 to determine its quality. Per the our knowledge, again no studies of this kind have been publicly released. The use of renewable energy sources expands as a consequence of globally population explosion and economic expansion. In regard to the present circumstance, the But since petroleum fuel is a non-renewable commodity, it has become a degrading source of energy [25-26]. With an average yearly fuel consumption of 86%, the coveyance sector, which turn to 96% on fossil fuels, may encounter significant problems as a outcome of the surging price of petroleum fuels [27]. In furthermore presenting the innovations that are available for by employing biomass raw-material for manufacturing of biofuels and/or chemicals, this chapter deals with the essential chemical components of biomass raw-material. As many as 1GB raw-material are brought up, the target is on 2GB biomass since this

size is predicted to have the most possible for the establishment of the biomass industry in the future. A raw-materials chemical constitution is an essential consideration when evaluating whether or not it is adequate for conversion, nevertheless it is not the only one. Other important variables are price, sustainability, and supply seasonality. Along with describing each of the principal biomass categories lonely with looking at some of the most relevant lignocellulosic feedstocks, those elements additionally get taken into account[28]. It has not yet been made available on the implementation of heterogeneous base catalysts generated from the computational chemistry-trunk and underground stem of *M. paradisiaca* for the fabrication of biodiesel or for any other base-catalyzed steps. A particular *M. paradisiaca* (Malbhog) plant provides larger post-harvest trunk as remainders over fruit the flesh, followed by rhizome. Considering waste generated, the *M. paradisiaca* trunk and rhizome areas have more potential to be investigated for a number of application reasons, such as the creation of a catalyst for the extraction of biodiesel. This dissertation is the first to offer comparative catalytic activity assessments of catalysts generated from the *M. paradisiaca* peel, trunk, and rhizome for the synthesis of biodiesel from jatropha oil [29]. Biodiesel appeared to be a viable solution to tackle these issues because it is a clean, sustainable, and renewable energy source [30–31]. Further more, because biodiesel has a sufficient proportion of oxygen atoms, it can promote in an optimal combustion [32]. The second generation of biodiesel feedstock is characterised as non-edible earthly oil crops. Some examples are *Ricinus communis* (Castor), *Jatropha curcas*, *Moringa oleifera*, and the others. one of numerous non-edible oil-bearing crops, has a multitude of noticeable criteria, besides a skilled labour viability possible in nature (up to 50 years), a high oil content (40–73%) in its waterless seed kernel, a raised oil yield (4680 kg ha⁻¹ year⁻¹), a raised heating value of the arising FAME, and adaptability with ASTM D6751 and EN 14214 biodiesel standard [33]. Hence, utilising low-cost feedstock with both a high level of FFA, such *Calophyllum inophyllum*, can be the better means of reducing expenses. And besides all of the aforesaid perks, there are specific severe physical symptoms inherent with the direct transesterification of cheaper, non-edible oils into biodiesel via classical alkali facilitated techniques since the content of FFA in here oils is greater than is needed. Addressing this, Zhang et al. [34,35] carried a comparison investigation into varied biodiesel production strategies and establish that straight base aided transesterification is the quickest and the atmost viable strategy for putting dehydrated

and well-refined oil with a below FFA level into biodiesel. As a consequence of the significant moisture and FFA component of those feedstocks, one pace alkaline accelerated transformation of high FFA-containing oil is prone to saponification. These soaps may congeal into unwanted gel and semi-solid bulk at ambient temperature. In parallel to all of the aforementioned benefits, straight transesterification of less expensive, non-edible oils into biodiesel using conventional alkali accelerated procedures is associated with specific, severe effects because the FFA level of these oils is bigger than is warranted. At room temperature, these soaps may clump toward unwelcome gel and semi-solid bulk. In this aspect, Sani et seq.'s of the characteristics and superiority of solid acid catalysts greater than heterogeneous base and homogeneous acid catalysts exploited in the biodiesel manufacturing process [36] is critical. Even if the homogeneous catalysis issues associated with catalyst rebirth and reprocess in nonstop processes are minimized by the heterogeneous base catalyzed-biodiesel production method, saponification complications are indeed present. The utilize of refillable heterogeneous acid catalysts for the preesterification, which prevents the migration of catalytic and toxic residues to the next step, is therefore the focus of current research. Heterogeneous acid catalysts too are selective, easily files are placed, washable, and able to generate a clear biodiesel solution, which makes them more profitable and less affordable. The use of heterogeneous acid catalysts has added features, including that of the elimination of various problems and including biodiesel washing process, saponification, product contamination, chemical corrosion, etc. These potential advantages decrease the general expenses associated with blended fuels. Ordinarily, a catalytic assist is required to buffer the catalyst's energitic sites versus undesirable deterioration besides molecules in the reaction medium, spilling into the reaction medium, etc. A thorough assessment utilizing graphene-based materials as heterogeneous acids was already presented by Garg et al. [37]. According to the information they reported, these high temperature superconductors' exceptional physical, chemical, and mechanical characteristics enable them to retain high activity in chemical reactions that are facilitated by acids while also having provided extremely stable Brnsted acidic sites, high mass transfer, approximately large surface areas, water open mindedness, and aggrement fixable and reclaimable. The carbocatlysis with graphene-found materials, particularly graphene oxide , has really been described by Navalon et al. [38]. According to their investigation, does indeed have a wide range of distinctive features that are favorable for its catalytic

activity. Several of these would be mentioned under. Along with carbonyl and carboxyl groups at the sheet edges, always has hydroxyl with epoxy functional groups on the basal planes. The oxygen-hold functional groups maintain a network within the sheets by allowing unoccupied voids between nonoxidized regions and a sizable inter sheet distance. This is because substances are exceptionally hydrophilic, which makes them unstable in water. The low fracture toughness of the membranes is caused by the weak contact between sheets. These issues can be solved by organically inter-connect sheets utilize divalent metal ions, according to Park et al. [39] Strong Brnsted and Lewis acid kinetics of metal oxide supported catalysts are favorable. They behave as solid acid catalysts by restricting the dispersion of protons in water, optimizing toughness, and permitting simple associations with the nucleophilic units of FFA. The predominant main concentration when it pertains to graphene modified catalysts is on graphite oxide, graphene oxide, with sulfonated/sulfated graphene and as acid catalysts [37]. Investigators have identified potential possibilities for graphene-based catalysts in the organic compound synthesis procedure. To our knowledge, currently there aren't any reported prove deployments of metal-alter formation for pre-esterification of feedstock for biodiesel that include an abundance of FFA. A novel catalyst was established in the proposed investigation by adding metal centres with Lewis acidic tendencies to a robust and steady supporting framework formation. The pre-esterification of Calophyllum inophyllum oil, cast-off in the process of make biodiesel, adopting metal modified composite is talked about in the article along with its synthesis, portrayal, and use. A crucial phase in the heterogeneous catalysis process is adsorption. The approach by which the reactant molecule, which tends to exist in the gaseous stage, links to the atoms at the surface of the adsorbent, is recognized as adsorption. the heterogeneous catalyst, usually present in the solid stage). Desorption is an acronym coined to signify the opposite of adsorption. The adsorbents and the adsorbate are separated into smaller pieces in the following sentence. The adsorbate is utilized as the reactant in heterogeneous enzymes that catalyze-induced reactions, though the heterogeneous catalyst normally acts as the adsorbent. There are actually two independent adsorption processes, physisorption and chemisorption, that could trigger the reactant molecules to stick to the surface of the heterogeneous catalyst. It is essential not to forget that when physisorption hits, no chemical attach are established to connecting the adsorbent and adsorbate. The incentive molecules oxidoreductase onto the surface of the heterogeneous catalyst

during heterogeneous catalysis primarily a result of the Van der Waals forces which arise connecting the reactant molecules and the atoms/molecules on the outside of the heterogeneous catalyst. The incentive molecules can now undergo either desorption and move away from the surface of the heterogeneous catalyst, or they are able to continue to be more effectively adsorbed onto the catalyst regions via a process known as chemisorption. Furthermore, it ought to have noted that the reactant molecules may migrate across the catalyst's surface after physisorption to the surface. The electron clouds of the adsorbent and the adsorbate can overlap if the molecules of the adsorbate are close enough to the atoms or molecules on the outside of the adsorbent. Chemisorption is an adjective adopted widely for describing the phenomenon in question. It is standard for the adsorbate with the adsorbent to share electrons during chemisorption. This indirect new chemical bonds get formed throughout the chemisorption process. The incentive molecules normally become adsorbed onto the outside of the heterogeneous catalyst in heterogeneous catalysis by chemisorption to the degree that their electron clouds overlap. For consequence, it is characteristic for chemical bonds to grow in the processes with the reactants and the heterogeneous catalysts. It should be famous that there are two approaches whereby the reactant molecules could possibly oxidoreductase onto the catalyst surface. The adsorbate (the reactant)'s molecular structure remains the same in the procedure of molecular adsorption. Without splitting any of the chemical bonds with the atoms which form up the incentive molecule, it generates connect with the heterogeneous catalyst. The adherence of alkenes to the surface of activated platinum catalysts provides a representation of molecular adsorption. The brake adsorption walkway: in the context of chemisorption, the adsorbate's (or the reactant's) molecular structure is influenced. After permit for the synthesis of new connect with the heterogeneous catalyst, the chemical bonds with the atoms that compose up the molecule have to be modified or rearranged. As therefore, the rapidity during which the bonds in the adsorbent breakdown influence the rate at which this sort of adsorption occurs. Dihydrogen molecule adsorption to a platinum catalyst is a widely recognized occurrence of dissociative adsorption. The hydrogen-hydrogen correspond of the H_2 molecule is broken upon adhesion onto the platinum surface. For the manufacture of biodiesel, cottonseed oil (CSO) was utilised. Considering cottonseed is not edible, so will likely be no conflict both nourishment and petroleum if it is used in the production of biodiesel. The transesterification results revealed the

fact that various catalysts, for instance methanol or ethanol, might generate various volumes of biodiesel. Cottonseed, a by product of the cotton processing the business world, had been considered as having been virtually worthless before the late 19th century. Throughout the 17th, 18th, and latter of the 19th centuries, cotton production climbed, but a largely useless stock of cottonseed also accumulated. The majority of the seed was left to diminish or was illegally dumped into rivers, nonetheless some was used for planting, fertilizer, and animal feed. In 1979, South Africa began manage studies on the utilisation of transesterified sunflower oil and its clarification to diesel fuel statement. The policy for generate fuel-quality, engine-tested biodiesel was completed and build public on a global scale by 1983.[40] The South African Agricultural Engineers sold the technology to an Austrian firm called Gaskoks, which built the first biodiesel pilot plant in November 1987 with the first industrial-scale unit in April 1989. (with a volume of 30,000 tons of rapeseed per annum). Multiple European nations, especially the Czech Republic, Germany, and Sweden, extend plants throughout the 1990s. The extraction and manufacturing of biodiesel fuel (also familiar as diester) against rapeseed oil has begun domestically in France. This fuel has been combined with regular gasoline at a quantity of 5% and with diesel worn by some pressioneer fleets (like those used for public transportation) at a quantity of 30%. Truck engines including Renault, Peugeot, with other manufacturers are capable of being worn with up to that group of partial biodiesel; series with 50% biodiesel are presently ongoing. Domestic manufacturing of biodiesel emerged in other countries at the matching era period; by 1998, the Austrian Biofuels Institute own honored 21 nations with trade biodiesel forecast. Due to its low amounts of fats that are saturated and high levels of polyunsaturated and monounsaturated fats, cottonseed oil grows widely recognized as a nutritious replacement for other cooking oils, such as palm and coconut oil. However, it should be mentioned that some consumers are worried that cottonseed oil might include traces of pesticides. Epsom salt, often shortened to as magnesium sulfate, is a chemical compound made up of magnesium, sulfur, and oxygen. It is frequently used in a broad spectrum of professions and circumstances, such as agriculture, cosmetics, and medicine. Magnesium sulfate, also referred to as is a laxative used in medicine to treat magnesium deficiency and ease constipation. Furthermore, it is used to treat eclampsia, an extremely hazardous pregnancy circumstance that might end in seizures and high blood pressure. Similarly used in agriculture as a kind of fertilizer and soil conditioner is magnesium sulphate. For crops

like tomatoes, peppers, and potatoes that require a lot of magnesium, it proves particularly favorable. The mineral magnesium sulfate is found in bath salts and other personal care products in the field of cosmetics due to how it can ease being uncomfortable and relax muscles. Since it helps provide hair greater thickness and construction, it is additionally utilized in hair care products. By diluting magnesium carbonate or magnesium oxide with sulfuric acid, a compound called magnesium sulfate can be made. It can easily dissolve in water and generally is sold as crystals or powder. To stop the oxidation of fats and oils, butylated hydroxytoluene is a synthetic antioxidant that is often employed in the food, cosmetics, and other industries. Products might turn rancid, degrade, and lose their color, flavor and nutritional value as a consequence of oxidation. BHT serves by preventing the synthesis of free radicals, chemical compounds that are highly reactive that can damage cells and hasten up withering. BHT aids in mitigating oxidative damage to items and lengthening their shelf life by scavenging these free radicals. BHT is used as a fuel additive for preventing the oxidation of both gasoline and diesel fuels in addition to its use as an antioxidant and in certain medicinal products. Notwithstanding having been shown that BHT is normally thought of as safe for applications in small quantities, some studies have revealed that it may have health hazards, including having the potential to promote cancer and disrupt with hormone function. In response to this, a number of countries have set guidelines on the extent that BHT can be used in food and other stuff. a type of which are fats and oils, undergo transformation into fatty acid esters during the chemical process of trans-esterification, sometimes with the aid of a catalyst. This approach has been frequently utilized in the extraction of biodiesel, a sustainable replacement for diesel fuel manufactured from petroleum.

A triglyceride plus ⁴an alcohol, such as methanol or ethanol, react while undergoing the trans-esterification process ⁸¹in the residence of a catalyst, frequently sodium either ⁵⁵potassium hydroxide. Depending on what kind of alcohol used, the reaction provides alternatively ⁹³fatty acid methyl esters (FAME) either fatty acid ethyl esters (FAEE). The triglyceride turns into each of its ⁶⁷fatty acids and glycerol across the entire process, and both of these substances are afterward esterified with the alcohol. By lower the activation energy needed for the reaction occurring, the catalyst aids in its facilitating. In the chemical process of esterification, an alcohol and a carboxylic acid react

resulting in an ester and water. This approach is commonly used in the fabrication of polymers that are used in perfumes, and aromas. Alcohol and carboxylic acid are blended through the esterification process and heated in the presence of a catalyst, such as sulfuric acid or hydrochloric acid. By protonating the carboxylic acid's carbonyl group and increasing its reactivity with the alcohol, the acid catalyst aids in accelerating the reaction. A condensation reaction occurs as the manufacturing procedure progresses, producing an ester and water as a byproduct. Frequently, water is removed from the reaction mixture employing a molecular sieve or distillation. After removal, the resultant ester can be taken to use in a variety of fashions. Because of their low toxicity and appealing perfume, esters, for instance, are frequently utilized as solvents, plasticizers, and fragrances. The process of esterification, which transforms free fatty acids into fatty acid esters that might be used as a fuel in diesel engines, is also crucial in the creation of biodiesel. In this instance, the alcohol is often methanol or ethanol, and the carboxylic acid is typically a fatty acid obtained from vegetable oil or animal fat. During the purification process, the resulting FAME or FAEE could be applied as a fuel for diesel engines. As a green renewal for typical fossil fuels, the transesterification process has increased in popularity as a relatively quick and cheap way to produce biodiesel. In order to guarantee that the reaction unfolds without an issue and that the resulting biodiesel fulfills the quality standards that are needed criteria, the procedure must be carefully managed. High-frequency sound waves are put on to a liquid or mixture via the ultrasonic mixing process in order to encourage mixing, emulsification, or dispersion. Ultrasonic homogenization or ultrasonic dispersion are two distinct terms often employed when talking about the process at hand. By releasing high-intensity sound waves that go into the liquid or mixture, cavitation—the production and implosion of minuscule cavities—is induced. This is essentially what happens. This cavitation delivers a mechanical force that improves mixing, emulsification, or dispersion by releasing particles. Food, medical practice, cosmetics, and chemical processing include a few industries that frequently use ultrasonic mixing. In particular, it can be used to destroy cell walls in biological samples for DNA extraction, to disperse particles in a liquid to make a smooth suspension, or to emulsify oil and water to create stable oil-in-water emulsions. The rate of mass transfer between reactants can be improved during ultrasonic mixing, which may also be utilized to speed up certain processes like extraction or oxidation. Overall, ultrasonic mixing is a flexible and effective

technology that has various advantages over conventional mixing techniques, including higher productivity, shortened processing times, and superior product quality.

CHAPTER-2 LITERATURE REVIEW

In their 2015 review, **Avhad and Marchetti** surveyed recent advancements in catalytic materials for biodiesel production. They highlighted the importance of efficient and selective catalysts in the production of high-quality biodiesel, and discussed the various types of catalysts that have been investigated, including homogeneous catalysts, heterogeneous catalysts, and enzyme catalysts. The authors discussed several promising catalytic materials for biodiesel production, such as solid acid catalysts, supported metal catalysts, and hybrid catalysts, and provided an overview of the synthesis and characterization methods used to develop these catalysts. They also highlighted the importance of optimizing reaction conditions, such as temperature, pressure, and reaction time, to maximize biodiesel yield and quality.

In their 2014 study, **Phoo et al.** evaluated Indian milkweed (*Calotropis gigantea*) seed oil as a potential feedstock for biodiesel production. They noted that the demand for alternative feedstocks for biodiesel production is increasing due to concerns of energy security and environmental sustainability. The authors conducted a series of experiments to assess the feasibility of using milkweed seed oil for biodiesel production. They analyzed the oil's physicochemical properties, including its fatty acid composition, iodine value, saponification value, and acid value, and found that it was a suitable feedstock for biodiesel production.

In their 2016 study, the authors focused on the exergy-based optimization of direct conversion of microalgae biomass to biodiesel. They noted that microalgae are a promising feedstock for biodiesel production due to their high lipid content and fast growth rates. The authors proposed an optimization framework based on exergy analysis, which considers both the energy and entropy of a system. They used this framework to evaluate the efficiency of different processing pathways for microalgae biodiesel production, including lipid extraction, transesterification, and glycerol purification.

In their 2017 study, **Rajagopalachar et al.** explored the feasibility of using **Garcinia gummi-gutta** (L. Robson) seed oil as a novel feedstock for biodiesel production. They noted that there is a growing interest in using non-conventional feedstocks for biodiesel production, and that **G. gummi-gutta** seed oil is potentially promising source due to its high oil content. The authors used both homogeneous and heterogeneous transesterification methods to synthesize biodiesel from **G. gummi-gutta** seed oil, and evaluated the fuel properties of the resulting biodiesel. They analyzed the physicochemical properties of the oil and the biodiesel, including their fatty acid composition, viscosity, density, flash point, and cetane number.

In their 2018 study, **Elfasakhany** investigated the exhaust emissions and performance of ternary fuel blends containing iso-butanol, bio-methanol, gasoline, n-butanol, and bio-ethanol in spark-ignition engines. The authors noted that blending biofuels with gasoline can reduce the environmental impact of transportation and increase energy security. The authors tested the fuel blends using a single-cylinder spark-ignition engine, and evaluated their performance and emissions characteristics. They analyzed parameters such as brake power, brake specific fuel consumption, and emissions of carbon monoxide, carbon dioxide, nitrogen oxides, and hydrocarbons.

In their 2019 study, **Venu et al.** investigated the combined effect of nano-additives, combustion chamber geometry, and injection timing on the performance of a direct injection diesel engine fuelled with ternary blends of diesel, biodiesel, and ethanol. The authors noted that the use of biofuels such as biodiesel and ethanol can help to reduce the environmental impact of transportation, and that the addition of nano-additives can improve engine performance and reduce emissions. The authors conducted experiments using a single-cylinder direct injection diesel engine and tested the ternary blends with varying ratios of diesel, biodiesel, and ethanol. They also added nano-additives such as aluminum oxide and copper oxide to the blends, and varied the injection timing and combustion chamber geometry.

In their 2018 study, **Subramani** and Venu evaluated the potential of methyl ester derived from **Chlorella emersonii**, a type of microalgae, as an alternative feedstock for a direct injection diesel engine. The authors noted that microalgae-based biodiesel has the potential to be a sustainable and environmentally-friendly alternative to fossil fuels. The authors conducted experiments using a single-cylinder direct injection diesel engine and tested the **Chlorella emersonii**-derived methyl ester as a fuel. They analyzed parameters such as brake power, brake specific fuel consumption, and emissions of pollutants such as carbon monoxide, nitrogen oxides, and particulate matter.

In their 2018 study, **Yilmaz et al.** investigated the potential of using ternary blends of diesel, biodiesel, higher alcohols, and vegetable oil as fuel for a compression ignition engine. The authors noted that such blends have the potential to reduce the dependence on fossil fuels and mitigate the environmental impact of transportation. The authors conducted experiments using a single-cylinder compression ignition engine and tested various quaternary blends of the four aforementioned components. They analyzed parameters such as brake power,

brake specific fuel consumption, and emissions of pollutants such as carbon monoxide, nitrogen oxides, and particulate matter.

Atmanli et al. (2015) conducted a study to optimize the blend ratios of diesel, n-butanol, and cotton oil for improved engine performance and reduced exhaust emissions. The authors used response surface methodology to determine the optimal blend ratios and conducted experiments on a four-stroke diesel engine to evaluate the performance and emissions of the optimized blends. The results of the study showed that the optimal blend ratios improved engine performance in terms of brake power and brake specific fuel consumption, while also reducing exhaust emissions of carbon monoxide, nitrogen oxides, and particulate matter. The authors also found that the optimal blend ratios varied based on the operating conditions of the engine.

CHAPATER-3

AIM AND SCOPE

3.1 AIM

- Oil extraction from silk cotton seed.
- reparation of heterogenous catalyst Magnesium sulphate and Butylatedhydroxytoluene.
- Bio diesel production from extracted silk cotton seed oil.
- Analysing the produced Bio-diesel.

3.2 SCOPE

- Source of biodiesel is important factor for biodiesel .Silk cotton seed oil can be an easy source of biodiesel making the process more effortless and cost effective.
- Due to increasing effects of fossil fuel the demand for alternative fuel is high . biodiesel can a viable option as an alternative fuels.
- In biodiesel production , heterogenous catalyst as many perks such as, high reusability, effective conversion

CHAPTER-4

¹ MATERIALS AND METHODS

4.1 raw material and chemical

Ceiba pentandra seeds originated from a field located near Marthandam in the Kanyakumari district about Tamil Nadu, India (8.3022 N, 77.22 E). All A variety of analytical-grade chemicals, including magnesium sulphate (MgSO₄), methanol (CH₃OH), butylated hydroxytoluene (BHT), ethyl alcohol (C₂H₅OH), Stirrer with a magnet fireplace mantel cylinder flask distinct funnel crystal pipette Funnel filtration paper were pursued from Chennai chemicals.

4.2 Oil extraction

¹
To get rid of moisture, the C. pentandra seed (37 kg) was sun dried. A minor mechanical screw press was utilized to dry the sun-dried seeds. The barrel bore of the miniature screw press is 60 mm in diameter, and the drainage length is 155 mm. The threads have five and exhibit a helical shape. Using eq, the yield of CPSO¹ was oxidoreductase. (1). To allow the pathogens to settle, the CPSO was retained in a stainless-steel barrel for six days. The CPSO's highest layer has been placed to use for monitoring.

$$\text{Oil Yield (\%)} = \text{Weight of Oil Extracted (g)} / \text{Weight of Seeds (g)} \times 100$$

4.3 Physiochemical properties and characterization study of Ceiba pentandra seed oil

⁸⁸
Oleic acid, linoleic acid, and palmitic acid, from one another because order, account for nearly every one of the fatty acids in Ceiba pentandra seed oil. These fatty acids help the oil's nutritional and commercial aspects. Physical traits such as The seed oil derived from Ceiba pentandra seed is yellowish in shade and has a mild fragrance and perfume. It has a melting point of -5 to -10°C, a specific gravity of 0.922-0.925, and a refractive index of 1.470-1.471. Chemical features: ¹ Ceiba pentandra seed oil exhibits a high degree of unsaturation¹, evidenced by the iodine value of 117–132 g I₂/100 g oil. A significant quantity of high molecular weight fatty acids is detected by the saponification value, which ranges from 186 to 195 mg KOH/g oil. In order to be sure the MgSO₄ catalyst runs efficiently and to fully understands its catalytic abilities, it has to be evaluated. The following are some of the techniques used for the characterization of MgSO₄ catalyst: FTIR (Fourier Transform Infrared Spectroscopy): FTIR is used to look into the catalyst's chemical bonding. It delivers insights ⁶ the catalyst's functional groups and their interactions with the other components. X-Ray Diffraction (XRD): XRD is used for looking at the catalyst's crystal structure. It offers ¹⁶ details on the catalyst particles' aspects, arrangement, as well as and shape. SEM (Scanning Electron Microscopy): SEM is used to look into the catalyst's surface

morphology. It contains information about the catalyst particles' size, shape, and surface area.

4.4 Pre-treatment of Ceiba pentandra seed oil using esterification

The esterification approach was implemented in order to reduce the CPSO's FFA focused to less than 1 percent. H₂SO₄ was volumetrically imposed from 1% to 5% as an esterification catalyst, and methanol substituted to CPSO. The ratio was changed between 1:1 and 3:1. In a 60°C water bath for 60 minutes, the experiment occurred out in a three-necked round bottom flask reactor. After that, the reaction mixture was heated to eradicate any alcohol that weren't abused yet reacted. For the extraction of pathogens from the esterified CPCO, the leftover solution was placed in a conical flask and left there for four hours. (upper layer). To pinpoint the most appropriate circumstances for reaction, the FFA value of esterified CPSO was checked after each experiment (41).

4.5 Catalyst preparation

In a magnetic stirrer, incorporate 15g of an antioxidant plus 100 ml of distilled water. After a twenty-minute period, delicately add MgSO₄. Transfer the solution to the ultrasonicator for 20 minutes after a period of two hours. Set the solution inside a magnetic stirrer to stir for two hours at a time. Employing filter paper, filter the solution after two hours has passed. Try the newly developed catalyst at 90°C for two hours in a hot air oven.





Fig 4.1 Catalyst preparations

4.6 Characterization of MgSO_4 catalyst

In order to be sure the MgSO_4 catalyst runs efficiently and to fully understand its catalytic abilities, it has to be evaluated. The following are some of the techniques used for the characterization of MgSO_4 catalyst

⁶
X-Ray Diffraction (XRD): XRD is used to examine the catalyst's crystal structure. It includes insights on the catalyst particles' dimensions that setting up, and shape A vital approach to recognize mgso_4 catalysts is X-ray diffraction. (XRD). XRD may disclose data concerning a substance's crystal structure through examination of the lattice parameters, crystal symmetry, and Miller indices of the diffraction peaks. a formulation of Bragg's Law ($n = 2d \sin \theta$), the sampling is scanned using 2, and the range is from 10° to 60° , the interplanar spacing (d) of the crystal lattice planes that scattered X-rays at this angle may be underestimated. Cu radiation's wavelength exceeds 1.54 Å.

FESEM with EDX

³¹
SEM (Scanning Electron Microscopy): SEM is used for looking at the catalyst's surface morphology. It reveals an overview of the catalyst particles' size, shape, and surface area. EDS (energy dispersive X-ray spectroscopy): EDS is used for

assessing the catalyst's elemental breakdown. It delivers facts on the relative quantities of different components identified in the catalyst

56

BET (Brunauer-Emmett-Teller)

BET (Brunauer-Emmett-Teller) Surface Area Analysis: BET is used to figure out the catalyst's surface area. It supplies info on the total quantity of catalyst-responsive surface area. Thermogravimetric Analysis (TGA) happens for assessing the catalyst's thermal stability. It illustrates the catalyst's weight loss and chemical degradation at different temperatures. Overall, the examination of the MgSO₄ catalyst employing the techniques previously mentioned will help in preserving the conditions and catalyst preparation for optimal catalysis. Magnesium sulphate ranks among the inorganic substances whose might be classified utilizing Fourier-transform infrared (FT-IR) spectroscopy. (MgSO₄). Here include a few specifics on MgSO₄'s FT-IR characterization: Investigation of the FT-IR spectrum The crystal structure and bonding of MgSO₄ are made clear by the FT-IR electromagnetic spectrum of the analyte.

4.7 BIODIESEL PRODUCTION

75

The next step is the conversion of the triglycerides in the feedstock produce biodiesel. The process of reacting the feedstock with an alcohol (particularly in methanol) while using a catalyst (MgSO₄) has been referred to as transesterification. The procedure causes a generation of glycerol and biodiesel as leftovers.

4.7.1 FREE FATTY ACID TEST FOR CPSO

STEPS

1. Weigh a sample of the oil into a dry, clean beaker (typically 1-4 grammes).
2. Include 25 cc of isopropyl alcohol and heat to 60 °C.
3. Add phenolphthalein indicator after freezing at room temperature during heating.
4. carry on to use the appearance of pale pink as the end point when calibrating against NaOH.

24

Calculate the free fatty acid content of the sample using the following equation:

95

49

$$\text{FFA}\% = (\text{volume of base solution used} \times \text{normality of base solution} \times 28.2) / \text{weight of sample}$$

$$\text{FFA}\% = 1.3 \times 0.1 \times 28.2 / 5\text{g}$$

=

4.7.2 Ultrasonicator transesterification process

Ultrasonic transesterification is an approach that entails turning triglycerides through biodiesel by catalyzing the transesterification reaction between two or more molecules utilising high-frequency ultrasound. Cavitation bubbles are induced in the reaction mixture employing ultrasonic trembling. As these bubbles collapsed, high temperatures and pressures emerge in particular areas, which could quicken forward the transesterification reaction. Compared to standard transesterification methodologies, this may outcome with faster reaction times, more yields, and a lower consumption of electricity. Regarding the ultrasonic irradiation action to the conventional method, the reaction time has been lowered by roughly 30 minutes. The ultrasonicator absorbs 25ml of oil. The reactor has a methanol to oil ratio of 18:1, 21:1, 24:1,... with a reaction time of 20, 25, or 30 minutes. a catalyst loading of 3–5% at a desired temperature of 35–45 °C. The catalyst that created confined and unconverted glycerol is subsequently extracted by sliding these into a separating funnel. the yield of the biodiesel was calculated.

$$\text{Yield of Biodiesel (\%)} = \frac{\text{Weight of Biodiesel (g)}}{\text{Weight of CPSO (g)}} \times 100$$

4.7.3 Process optimization

RSM was implemented for generating a four-factor, three-level statistical experiment which employed Box-Behnken designs (BBD) for MATP. The one-variable-at-a-time (OVAT) technique was implemented in the RSM-BBD testing (Refer auxiliary file) for establishing boundaries. RSM-BBD was used to analyse the impact of catalyst loading, methanol to esterified CPSO (MECO) molar ratio, reaction time, and ultrasonicator power on biodiesel yield. 29 tests have been performed with 5 central areas adopting RSM-BBD. To prepare for and perform RSM experiments, Stat Ease, Inc.'s Design-Expert initiatives (version 11.1.2.0 64 bit, USA) was implemented. The relationship between the process variable and the biodiesel yield is given by the polynomial equation

where Y is the response (biodiesel yield%) and α , β_i , β_{ii} , β_{ij} are the model's intercept, square, linear, and interaction effects, correspondingly; The independent variable levels are X_i and X_j , and the random error vector is. To linearize the RSM model, a

multilayer feed-forward Artificial Neural Network (ANN) was constructed in MATLAB Neural Network enzymes that catalyze. An input layer, two hidden layers, and an output layer make up the three layers of the ANN model. With 70% training, 20% validation, and 10% testing, a multi-layered ANN had been developed using findings of the RSM experiment. The Levenberg-Marquardt algorithm and the purelin activation function were implemented in the input layer for transmitting signals from the process variables to the hidden layer. (10 neurons). We hired two discrete layers with configurable weights. In typical circumstances, a neural network construction, which covers the first hidden layer whereas provides the second layer

p_1 is the input matrix composed of the four input variables, $IW_{1,1}$ is the matrix made up of the four input matrices and each of the ten hidden neuron layers, and b_1 is the bias matrix constructed up of the ten hidden neuron layers.

The end result of the top tucked layer is a_1 , where a_2 is caused by of the ANN investigations, b_2 is the bias matrix, and $LW_{2,1}$ is the matrix built from a_1 and 10 hidden neuron layers. The supplementary file illustrates the ANN design for MATP. (Fig. S1). For assessing the accuracy of the ANN over RSM, correlation coefficient (R^2) and standard error of prediction have been used to represent the parameters. The GA optimization. action utilized the tools of the MATLAB GA toolbox. A uniform distribution random getting started population can be built through the application of a uniform creation function that is dependent on requirements was established. A rank scaling function was employed to define a particular individual using only raw scores. Implementing a Gaussian mutation function, each vector belonging to a person had a random number assigned to it. The scattered crossover function was used to generate a random binary vector. The strategy that was use was forward migration, in which migration is centered on its most historic subgroups. Those that follow are the GA-based optimisation parameters: Population size is 50, crossover chance is 0.8, and the number of generations over which GA has evolved is 100. Population type is a double vector. Using eq., the response GA problem was resolved.

4.7.4 EXPERIMENTEL SETUP

The main mechanism used to generate ultrasonic waves comprises an ultrasonicator. A generator frequently produces high-frequency impulses of energy, which a transducer then interprets into mechanical vibrations. The ultrasonic waves get delivered to the sample through the transducer across a coupling medium, which is commonly a liquid medium submerged in waters.

Sample: The sample is an object that needs to be treated with ultrasonic treatment for certain reasons, such as destroying cell walls or dispersing particles. The material being examined can be a liquid, solid, or a single system. Container: The sample frequently rests within an ultrasonic oxidoreductase-compatible container, whether a glass beaker or a plastic tube. The container must be sufficiently resilient to resist the ultrasonicator's mechanical vibrations.



Fig 4.2 ultrasonicator

Cooling system (optional): For the purpose of keeping the temperature of the sample within an appealing range, a cooling system, such as a water bath or a heat exchanger, may be essential if the ultrasonicator outputs significant amounts of heat whereas it is operational. Place the ultrasonicator on an even and well-ventilated surface. Connect the ultrasonicator to a power source that is compatible with the device's voltage,

current, and frequency. Fill the container completely with the ultrasonic wave-treated sample. Place the sample in a container that can withstand the mechanical vibrations induced by the ultrasonicator. The study electrical power the supply needs to be present for the function properly. Check that the power source exceeds the voltage, current, and frequency requirements. Safety apparel: Since ultrasonic waves can present risks, it is essential to have the necessary safety gear, such as gloves, goggles, and ear protection, to safeguard one's own abilities from possible hazards. Place the container enclosing the sample on the ultrasonicator's platform or, if implementing a cooling system, in a water bath. Set the ultrasonicator's desired circumstances, such as the frequency, power, and duration of the ultrasonic waves, based on what is required of your experiment. Turn on the ultrasonicator and permit it operating for the desired period of time. After performing the ultrasonic treatment, turn off the ultrasonicator and carefully remove the container housing the sample from the instrument. Apply your experimental protocol while examining the treated sample. For getting rid of any residue or contamination, thoroughly disinfect the ultrasonicator and the container after use.

4.7.5 WASHING AND DRYING

On average, a washing phase is implemented for cleansing the biodiesel excess glycerol and other residues. Water is utilized in the above procedure to help elements sink to the bottom of the biodiesel composition. Pure biodiesel is left behind after the water and glycerol have been thoroughly removed. This washing technique deserves to be undertaken on multiple occasions to ensure that the biodiesel is properly washed. To get rid of any remaining water, biodiesel can be dried in a hot water bath. In this technique, the biodiesel is cooked in a container to a temperature of approximately 80–90 °C (158–176 °F). The container afterwards goes ⁸⁴in a hot water bath that stays at a constant temperature approximately 90°C (194°F). Due to the heat from the water bath, all of the water that remains in the biodiesel evaporates, and its vapor eventually escapes from the container through a vent. Although it is a simple and cheap technique, drying biodiesel in a hot water bath cannot be absent disadvantages. The biodiesel can't always be adequate for drying big quantities of the fuel since it costs a lot of time and energy to heat it to the necessary temperature. Furthermore, it might not be acceptable to use biodiesel containing a substantial water

content since the heating process could result in emulsions that make it harder to separate the water from the biodiesel.



Fig 4.3 WASHING AND DRYING BIODIESEL

4.8 BIODIESEL CHARACTERIZATION

HSQC, HMBC, and ^1H & ^{13}C NMR techniques were employed to determine the molecular structure of biodiesel. (BRUKER AVIII 500 MHz NMR spectrometer). The NMR examine was carried out utilising a trial version of the MNova software. The composition and functional group analysis of the caused biodiesel has been performed employing GC-MS and FT-IR. Some of the features associated with the biodiesel have been determined using the composition of the FAME obtained during the GC-MS research.

4.9 Catalyst reusability study

After countless repeating runs, the catalyst's likelihood of regeneration was investigated. The experiments were carried out in the best possible conditions. For the

removal of the MgSO_4 catalyst, the reaction mixture was cooled and centrifuged at 800 rpm for 15 min. The catalyst was subsequently removed out of the centrifuge tube, wiped with methanol, and let to dry for 24 hours at 50°C . In addition, the research studies utilized dried catalyst for assessing the catalyst's functionality. Three times a single study happened and the average conclusions were recorded.

CHAPTER-5

RESULTS AND DISCUSSION

5.1 Extraction of *Ceiba pentandra* seed oil

40 kg of sun-dried *C. pentandra* saplings produced 7.44 kg of CPSO (18.6%) upon their passage through a small screw press. As opposed to solvent extraction, mechanical oil extraction supplies numerous advantages. Mechanical digestion of large batches of seed can be achieved fast. Oil can potentially be retrieved mechanically for less funds and using fewer solvents, which is less toxic to the ecosystem. As opposed to solvent-assisted oil extraction, mechanical oil extraction produces less oil yield. The 21% CPSO yield generated from steaming and crushing *C. pentandra* seeds was almost identical to the CPSO extraction yield measured in this study (42).

5.1.1 Physicochemical properties study of *Ceiba pentandra* seed oil

To gain insight into CPSO quality, various physicochemical analyses have been carried out. The oil's purity and quality are established by its acid value. Feedstocks with a high acid value might reconsider part in a side reaction. (saponification) that reduces the output of biodiesel during transesterification. Whenever biodiesel is produced from acidic feedstock, injectors frequently get plugged and machines degrade. FFA is molded by acidification. The acid value of CPSO as 13.67 mg KOH/g oil, and the FFA equaled 6.87%. CPSO requires to be pre-treated (acid-catalyzed esterification) to reduce FFA to less than 1% with the goal to increase biodiesel productivity. 125 g I₂/100 g oil (in accordance to generate soap, among them coconut oil), semi-drying oils (110–125 g I₂/100 g oil), and non-drying oils (below 110 g I₂/100 g oil). In juxtaposition to *Moringa stenopetala* oil, having has an iodine value of 91.6

¹g I₂/100 g oil, the CPSO has an iodine value of 98.9 g I₂/100 g oil.¹ The CPSO is a non-drying oil it can potentially be retained in preservation for an extended amount of time without needing for antioxidants due to the fact that it possesses a significant number of carbon double bonds. The hydroperoxide proportion of the feedstock is displayed via its peroxide value. During transesterification, hydroperoxide accelerates the polymerization process, triggering the emergence of ¹sediments and gums. During combustion, ¹the sediments preserves the engine's filter. The CPSO's low peroxide value, corresponding to 3.29 meq O₂/kg oil, demonstrates that the feedstock is fairly robust without its level of oxidation. The appearance, taste, smell, and viscosity of ¹Ceiba pentandra seed oil comprise a few of its physical attributes. Ceiba pentandra seed oil typically displays an even odour and is a pale yellow colour. A crucial physiochemical feature of Ceiba pentandra seed oil that influences its nutritious and useful characteristics is its fatty acid substance.² Unsaturated fatty acids, particularly oleic acid and linoleic acid, are known for providing beneficial health benefits like bolstering heart health and reducing inflammation, and studies indicate that Ceiba pentandra seed oil is exceptionally rich in these essential fatty acids. It was apparently discovered to have a low viscosity, which makes it appropriate for use in an assortment of food, cosmetic, and medicinal products. This value correlates to the ¹2.16 meq O₂/kg oil estimate for CPSO reported by. Conjugation, unsaturation, and molecular weight, and fatty acid chain length substantially determine the substance's refractive index (RI). The refining index of non-edible oil fluctuates between 1.447 to 1.482. The CPSO's RI (1.464) was within the range that is appropriate. The quantity of unsaturation in the feedstock determines ¹the oxidative stability of biodiesel. The saponification value (SV), determined by mg of KOH, is the amount of chemicals necessary for transforming ¹1 g of oil into soap. The SV reflects the molecular weight and fatty acid chain length that constitute the feedstock. A high molecular weight feedstock can be identified by the SV becoming less than 195 mg KOH/g oil, and a low molecular weight feedstock and is able to be exploited to generate soap is signified as the SV containing deeper than 300 ¹mg KOH/g oil. The CPSO suggests that the feedstock contains high molecular weight fatty acids because it has an SV of 189.14 mg KOH/g oil. The CPSO is excellent for the transesterification process given that it has a smaller probability to generate soap. The SV was implemented for estimating the molecular weight of CPSO, and came down at ¹959.13 g/mol. During transesterification, moisture in the feedstock might communicate with the catalyst and

make soap. Due to the reaction mixture's increased viscosity combined the soap it forms, gel is created. Esters and glycerine become interconnected in this process, making it hard to discern between compounds. Oil's high water content endorses a proliferation of microorganisms, resulting in turbidity. The CPSO has 260 ppm of moisture. The feedstock's low moisture content was accomplished via 96 hours of holding in a barrel upon extraction. During this time, harmful substances and water molecules would have plummeted to the barrel's bottom. Only the outermost layer within the CPSO was utilized in the course of the experiment. Without any prior therapy, the low-moisture CPSO might be utilized to perform transesterification. CPSO has a 0.911 specific gravity, it has been determined by the purity and subject matter of fatty acids(43).

Table 5.1

Physio-chemical properties of CPSO

S.no	Acid Value (mg KOH/g oil)	FFA (%) (oleic acid)	Iodine Value(gI ₂ /100g)	Peroxide value (meq O ₂ /kg oil)	Refractive index(40 °C)	SV (mg KOH/g oil)	Specific Gravity (30° C)	reference
1	15.99	7.99	94.54	-	-	129.03	0.892	44
2	18.54	9.32	-	-	-	186.81	0.850	45
3	11.80	5.90	102.4	-	-	194.00	0.910	46
4	4.42	2.26	129.8	2.16	1.47	152.79	0.920	47
5	13.67	6.87	98.90	3.29	1.46	189.14	0.911	Current study

5.1.2 Pre-treatment of Ceiba pentandra seed oil using esterification

The pH value of CPSO equaled 13.67 mg KOH/g oil, yet its fatty acids value equaled 6.87%. The levels of FFA were reduced down to less than 1% by heating CPSO. During the esterification reaction that used the H₂SO₄ catalyst, the carbonyl group in the FFA was protonized. This makes an excellent electrophile for strengthening the carbon-oxygen double bond. The resulting carbon II offers with methanol to decrease the free fatty acid ester and produce an unstable tetrahedral intermediate III, free hydrogen ions, and water molecules. At 5% H₂SO₄, the FFA value of CPSO declined

to 0.83% for a 3:1 methanol to oil ratio. The esterification of CPSO had been carried efficiently beneath those circumstances as the FFA dropped to less than 1%(48).

5.2 PHYSICOCHEMICAL ANALYSIS OF MgSO_4

Due to its enormous surface area, varies porosity, and distinct metal-ligand connection variations, magnesium sulphate (MgSO_4) comprises a particular kind of crystalline product that is growing popular as a catalyst. Theoretical and chemical knowledge are needed to appreciate the makeup, chemical houses, and functionality of MgSO_4 catalysts. Catalyst character development is an essential component in developing and research of catalyse. Understanding a catalyst's chemical and physical features may assist you forecast how it is going to react to and function in various reactional circumstances.

5.2.1 FESEM-FIELD EMISSION SCANNING ELECTRON MICROSCOPE

FESEM, occasionally referred to as field emission scanning electron microscopy, is a valuable imaging methodology to illustrate the surface morphology and microstructure of materials at a high magnification. The structure of MgSO_4 (magnesium sulphate) at the micro- and nanoscale is capable of being evaluated with FESEM.

MgSO_4 , FESEM are instruments that can utilized to investigate the size, shape, and distribution of the crystals that make up the substance. Furthermore, it might give insights concerning a material's porosity and surface area, which constitute crucial considerations when establishing its probable uses. The material's shortcomings or impurities that may impact its performance and the characteristics can be identified by employing FESEM. MgSO_4 catalysts are distinguished by their high porosity and surface area, outstanding thermal stability, chemical endurance, and computational chemistry which renders them potential catalysts for an assortment of industrial applications. Several processes, including the catalysis of fuel cells, organic reactions, and CO_2 conversion, have been researched and utilized with MgSO_4 catalysts. In addition to their tremendous porosity and surface area, MgSO_4 catalysts frequently make a desirable material for catalytic applications because they exceed customary catalysts in terms of catalytic activity, selectivity, and efficiency. MgSO_4 catalysts are able to be used in a number of industrial processes, but additional research is needed to fully exploit their capabilities.

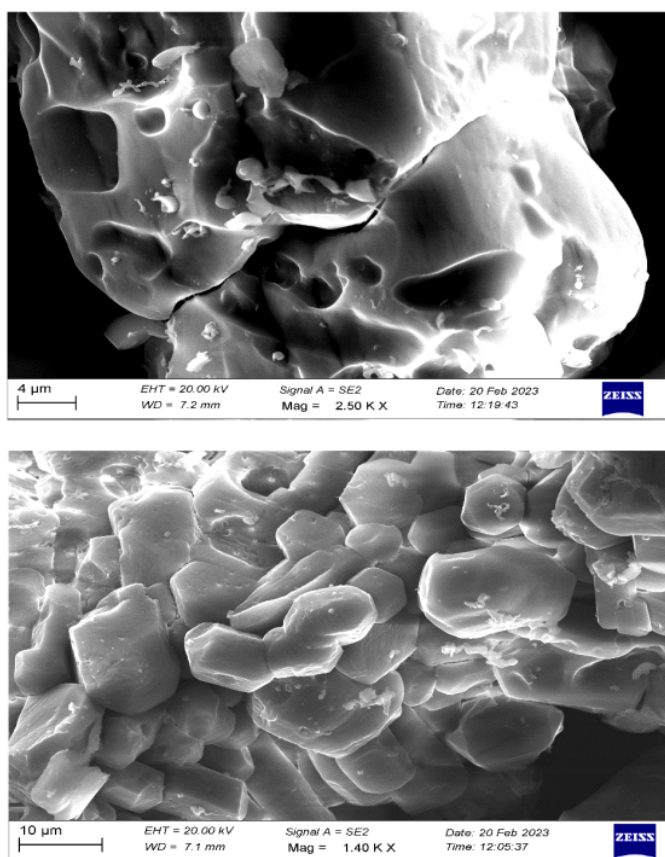


Fig 5.1 FESEM IMAGES

MgSO₄ surface characteristics, size, and morphology may all be seen in FESEM pictures. MgSO₄ may be found in a variety of forms, and their morphology can be examined using FESEM pictures of pellets and powder. For instance, a MgSO₄ pellet's morphology may be revealed by a pellet FESEM picture, which can be used to assess the material's packing density and particle size distribution. On the other hand, a powder FESEM picture may display the size distribution and morphology of each individual MgSO₄ particle in the powder. Both of them will gives better yield. But we used pellet in packed bed column for easy handling and removable that will help to stop leaching into the product

5.2.2 EDX-⁶ ENERGY DISPERSIVE X-RAY ANALYSIS

An approach termed **energy dispersive X-ray (EDX) analysis** leverages the X-rays that a sample announces after being bombarded by high-energy electrons or X-rays to detect and estimate the compounds that make up the sample. This approach is widely utilised in materials science, biology, and geology, and is frequently used together with scanning electron microscopy. (SEM).

The outcome of the EDX spectrum contains useful information concerning the chemical make-up of the sample and can be used to identify individual elements or compounds which are present in them. We are able to observe how Mg and other atoms are present in the graph up front. The peaks in the EDX spectrum, which

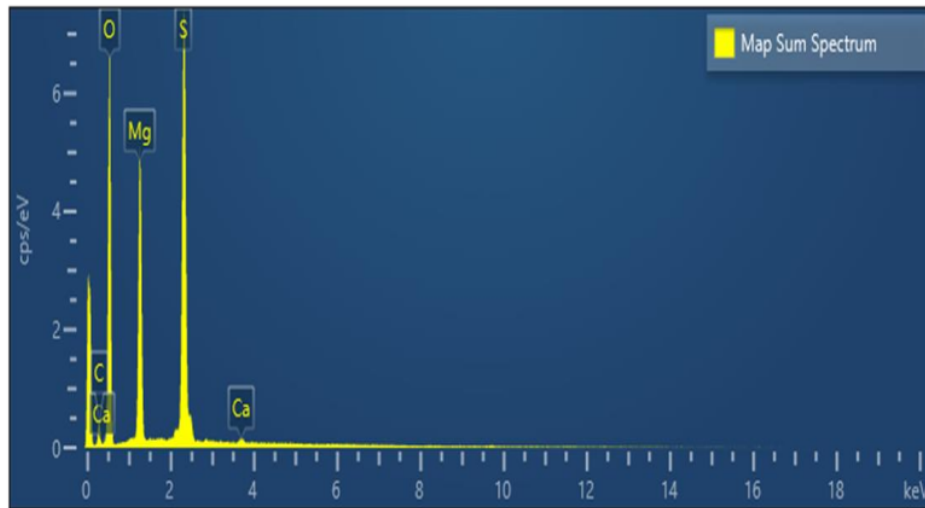


Fig 5.2 EDX image

correspond to the particular X-rays that each element manufactures, can be utilized to determine the relative abundance of each element in the sample.

5.3 OVAT EXPERIMENTS

(one variable at a time)

35

Alcohol to oil molar ratio

1% = catalyst wt %

30°C = Temperature

25 min = Time

X axis = Oil to alcohol molar ratio

Y axis = Yield %

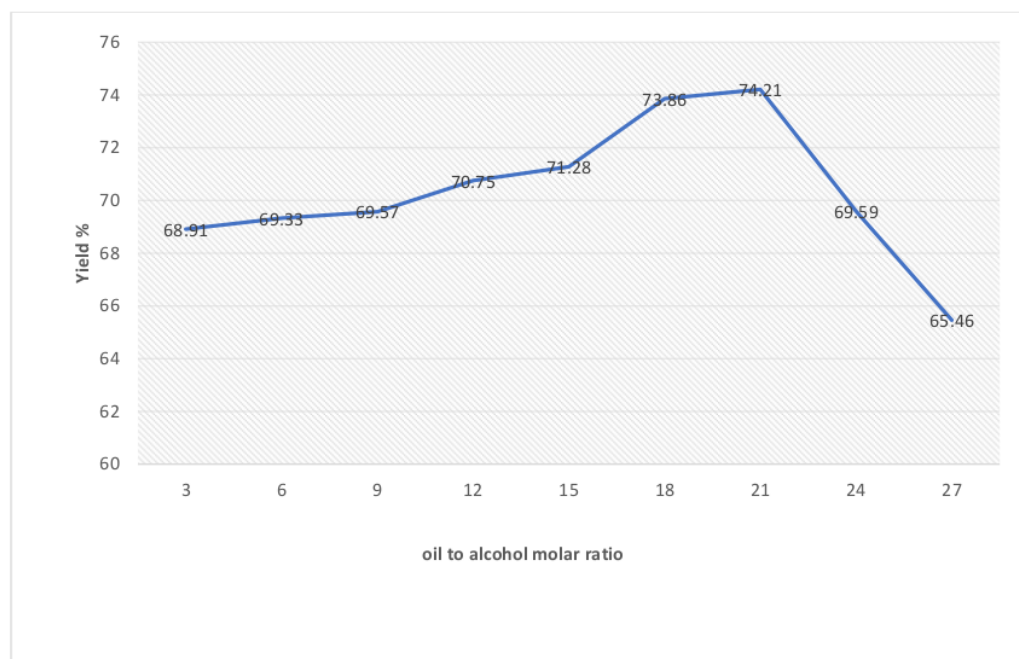


Fig 5.3 highest Yield % obtained is 74.21

24:1 = Alcohol to oil ratio

30°C = Temperature

25 min = Time

X axis = Catalyst wt %

Y axis = Yield %

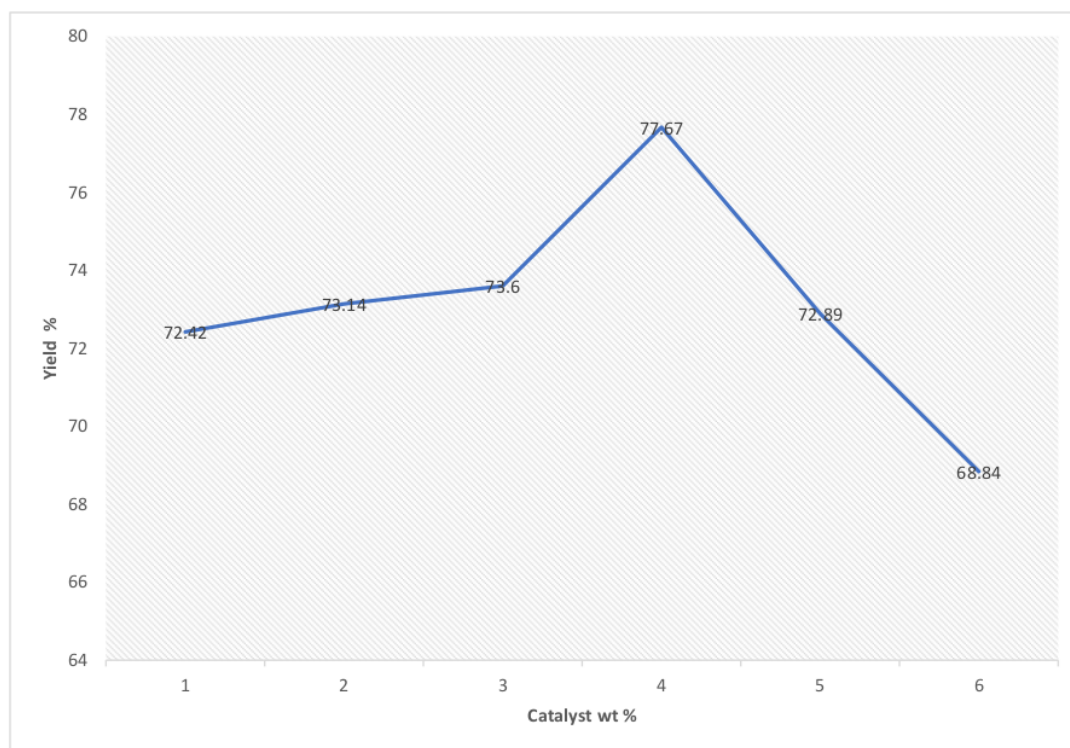


Fig 5.4 highest yield % obtained is 77.67%

24:1 = ⁷⁹ Alcohol to oil molar ratio

4% = Catalyst wt %

25 min = Time

X axis = temperature °C

Y axis = Yield %

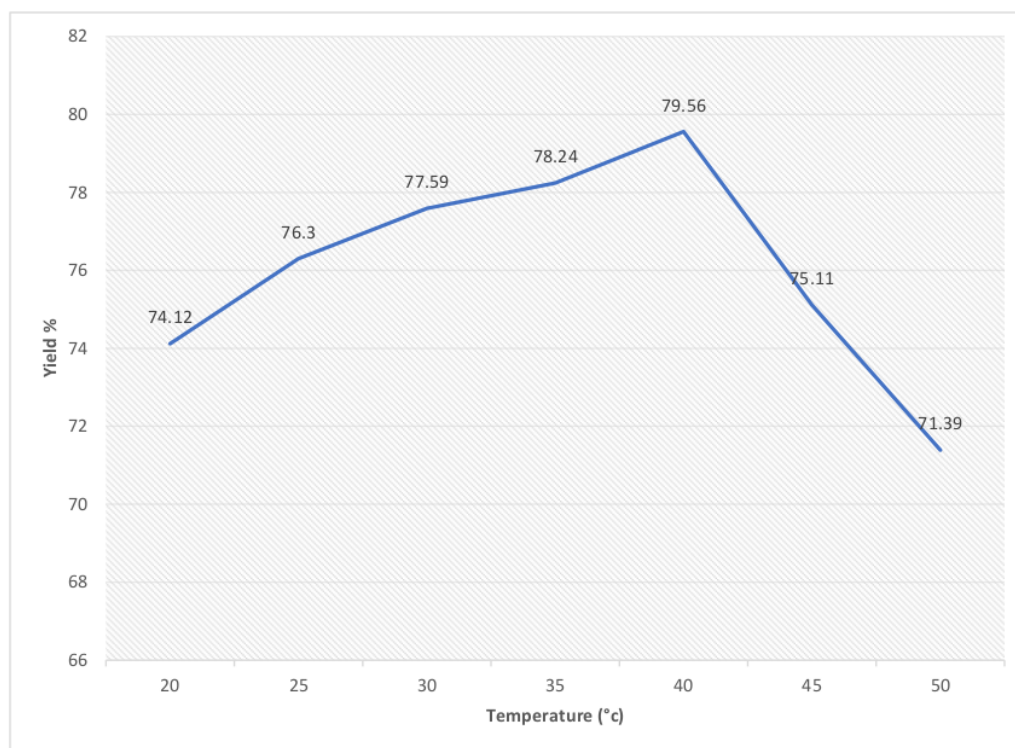


Fig 5.5 highest yield % obtained is 79.56

24:1 = ³⁵Alcohol to oil ratio

4% = Catalyst wt %

40°C = Temperature

X axis = Time(mins)

Y axis = yield %

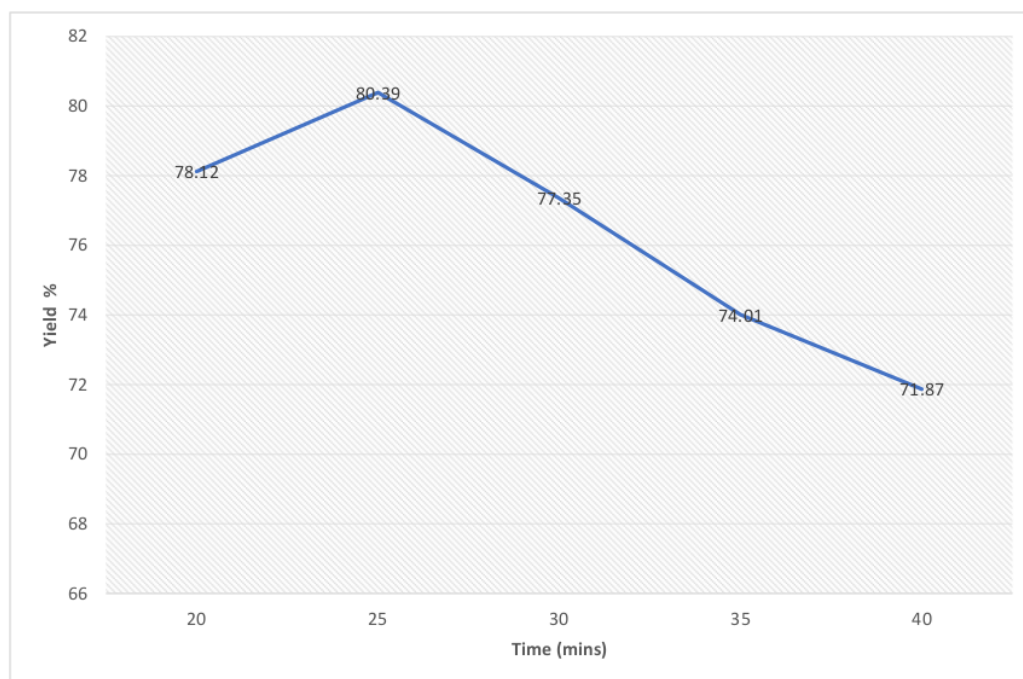


Fig 5.6 highest yield % obtained is 80.39

5.4 Ultrasonicator¹ transesterification process of esterified Ceiba pentandra seed oil using MgSO₄ catalyst¹

Using MATP and a MgSO₄ catalyst¹, the esterified CPSO was turned onto biodiesel. The OVAT has been employed to determine constants which involves reaction its duration, which stem MgSO₄ catalyst loading¹, MECO molar ratio, and ultrasonicator. studies and utilised to tweak the levels through additional refining procedures. The supplementary file describes how several factors affected the amount of biodiesel made during the OVAT experiment.

5.4.1² PROCESS OPTIMIZATION WITH RESPONSE SURFACE METHODOLOGY

Procedures and the design of the experiments can be optimized with Response Surface Methodology (RSM), a method of statistical analysis⁶³. It is used to look into the associations between multiple variables and responses in order to figure out the perfect set of input factors that will produce the intended output response. The objective of RSM is to create a mathematical model that predicts a process' action based on the input variable values.

Table 5.2¹

Level selected for RSM–CCD design for optimization process in MATP

Variables	Symbol	-1 ⁵²	0	1	Coding
oil: alcohol ratio	X ₁	18:1	21:1	24:1	Actual
catalyst wt %	X ₂	0.3	0.4	0.5	Actual
Time(mins)	X ₃	20	25	30	Actual
Temperature °C	X ₄	30	35	40	Actual

Run No	X ₁	X ₂	X ₃	X ₄	Biodiesel yield%	
					Actual	Predicted
1	18	3	40	25	80.62	80.67
2	24	3	40	25	77.62	77.70
3	18	5	40	25	79.62	79.80
4	24	5	40	25	80.52	80.73
5	21	4	35	20	85.7	85.97
6	21	4	45	20	80.34	80.29
7	21	4	35	30	81.52	81.83
8	21	4	45	30	83.7	83.69
9	18	4	40	20	81.7	81.86
10	24	4	40	20	82.52	82.79
11	18	4	40	30	83.7	83.44
12	24	4	40	30	80.62	80.47
13	21	3	35	25	80.5	80.37
14	21	5	35	25	82.7	82.60
15	21	3	45	25	79.5	79.61
16	21	5	45	25	79.4	79.54
17	18	4	35	25	80.5	80.39
18	24	4	35	25	80.5	80.26
19	18	4	45	25	79.4	79.37
20	24	4	45	25	77.62	77.46
21	21	3	40	20	79.64	79.40
22	21	5	40	20	87.97	87.56
23	21	3	40	30	85.97	86.11
24	21	5	40	30	80.15	80.12
25	21	4	40	25	88.62	88.62
26	21	4	40	25	88.61	88.62
27	21	4	40	25	88.60	88.62
28	21	4	40	25	88.62	88.62
29	21	4	40	25	88.63	88.62

5.4 STATICAL ANALYSIS WITH RESPONSE SURFACE METHODOLOG

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A crew of mathematical and statistical techniques that are called Response Surface Methodology (RSM) are used to maximize efficiency and enhance a system's performance. RSM encompasses creating and analyzing mathematical models that illustrate the connection between input variables—also alluded to as independent or predictor variables—and the response—also called to as the dependent variable—of an interest process or system. RSM focuses extensively on statistical analysis given that it involves organizing experiments, collecting information and using statistical techniques to investigate the data and derive judgments about the underlying process or system. Establishing an amount of examinations in order to gather information on the reaction you want from the variable several variables is the first step in RSM. To effectively and efficiently analyze the response surface, which is the multidimensional space defined by the input variables and the response, experiment design should be adequately planned. Central composite design (CCD), Box-Behnken design, and factorial design are all commonly employed experimental designs in RSM. The experiments are conducted once the experimental design has been determined settled with, and details surrounding the response variable(s) constitutes acquired. For the sake of The accuracy and consistency in subsequent statistical analyses, it is crucial to meticulously capture the data. Data Analysis: During data collection, the data is examined employing statistical techniques to identify the relationship between the input factors and the response. Analysis of variance (ANOVA), regression analysis, and graphical tackles as response surface plots and contour plots are common statistical methods used in RSM. To better understand the association between the input variables and the response, mathematical models have been developed based on the data analysis. Often polynomial regression models, these models can be utilized to predict what will happen for any combination of input variable values that are within the bounds of the experimental design. While establishing a model, an appropriate model form (linear, quadratic, etc.) needs to be picked, and the model parameters need to be estimated using techniques such least squares estimation. The models have to be assessed following creation in order to ensure their reliability and precision. To be able for this, new experimental data that hadn't been used in the creation of models will need to be contrasted with the displayed responses from the models. The models can be implemented for optimising once they go through verification, which involves finding the input variable values which generate an optimal response. Depending on the purposes of the study, optimum approaches which includes numerical optimization, desirability operates, and algorithms based on the response surface methodology can be utilized to find the best input variable values that optimise or minimize the response. Finally, conclusions should be implemented from the statistical analysis conducted with RSM.

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ANOVA for Quadratic model

ANOVA (Analysis of Variance) is a form of statistics for investigating the differences in groups of data. ANOVA can be used in the processing of biodiesel to determine the key factors, such as the particular feedstock chosen, the reaction temperature, and the reaction time frame, which have a major effect on the yield or quality of biodiesel. A quadratic model is a mathematical model that additionally includes linear terms plus a quadratic part (i.e., a squared term). A quadratic model can be employed to represent the nonlinear relationship between the input variables (such as temperature and reaction time) and the output variable (such as biodiesel yield) in the context of biodiesel synthesizing. When the relationship between the input and output isn't obvious, this can be informative.

Table 5.3 Response Value

5

Response 1: Biodiesel Yield

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	368.41	14	26.32	437.68	< 0.0001	significant
X ₁ -Alcohol to oil molar ratio	3.14	1	3.14	52.25	< 0.0001	
X ₂ -Catalyst weight %	3.53	1	3.53	58.74	< 0.0001	
X ₃ -Temperature	10.94	1	10.94	182.03	< 0.0001	
X ₄ -Reaction time	0.4070	1	0.4070	6.77	0.0209	
X ₁ X ₂	3.80	1	3.80	63.24	< 0.0001	
X ₁ X ₃	0.7921	1	0.7921	13.17	0.0027	
X ₁ X ₄	3.80	1	3.80	63.24	< 0.0001	
X ₂ X ₃	1.32	1	1.32	22.00	0.0003	
X ₂ X ₄	50.06	1	50.06	832.53	< 0.0001	
X ₃ X ₄	14.21	1	14.21	236.39	< 0.0001	
X ₁ ²	163.92	1	163.92	2726.41	< 0.0001	
X ₂ ²	97.06	1	97.06	1614.38	< 0.0001	
X ₃ ²	115.63	1	115.63	1923.15	< 0.0001	
X ₄ ²	13.70	1	13.70	227.87	< 0.0001	
Residual	0.8417	14	0.0601			
Lack of Fit	0.8417	10	0.0842			
Pure Error	0.0000	4	0.0000			
Cor Total	369.26	28				

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Factor coding is Coded.

Sum of squares is Type III - Partial

The **Model F-value** of 437.68 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

P-values less than 0.0500 indicate model terms are significant. In this case $X_1, X_2, X_3, X_4, X_1X_2, X_1X_3, X_1X_4, X_2X_3, X_2X_4, X_3X_4, X_1^2, X_2^2, X_3^2, X_4^2$ are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model

Final Equation in Terms of Actual Factors

$$Y = (-561.66958 + 24.80083 X_1 + 46.95167 X_2 + 12.51767 X_3 + 4.04883 X_4 + 0.325000 X_1 X_2 - 0.029667 X_1 X_3 - 0.065000 X_1 X_4 - 0.115000 X_2 X_3 - 0.707500 X_2 X_4 + 0.075400 X_3 X_4 - 0.558565 X_1^2 - 3.86833 X_2^2 - 0.168883 X_3^2 - 0.058133 X_4^2).$$

It is easy to predict what will happen for certain amounts of each factor employing the equation written in terms of the actual factors. Here, the levels for each factor should be expressed in their initial units. Because the coefficients are scaled so that they account for the units of every component and the intercept is not at the geographic center of the design space, this equation should not be utilized for calculating the corresponding significance of each factor.

3-D SURFACE PLOTS

When there are more than two input variables, three-dimensional (3-D) graphs are an invaluable resource for depicting results of RSM experiments. These graphs typically plot the third input variable on the vertical axis plus show the response variable (i.e., yield of biodiesel) as a function of two input variables.

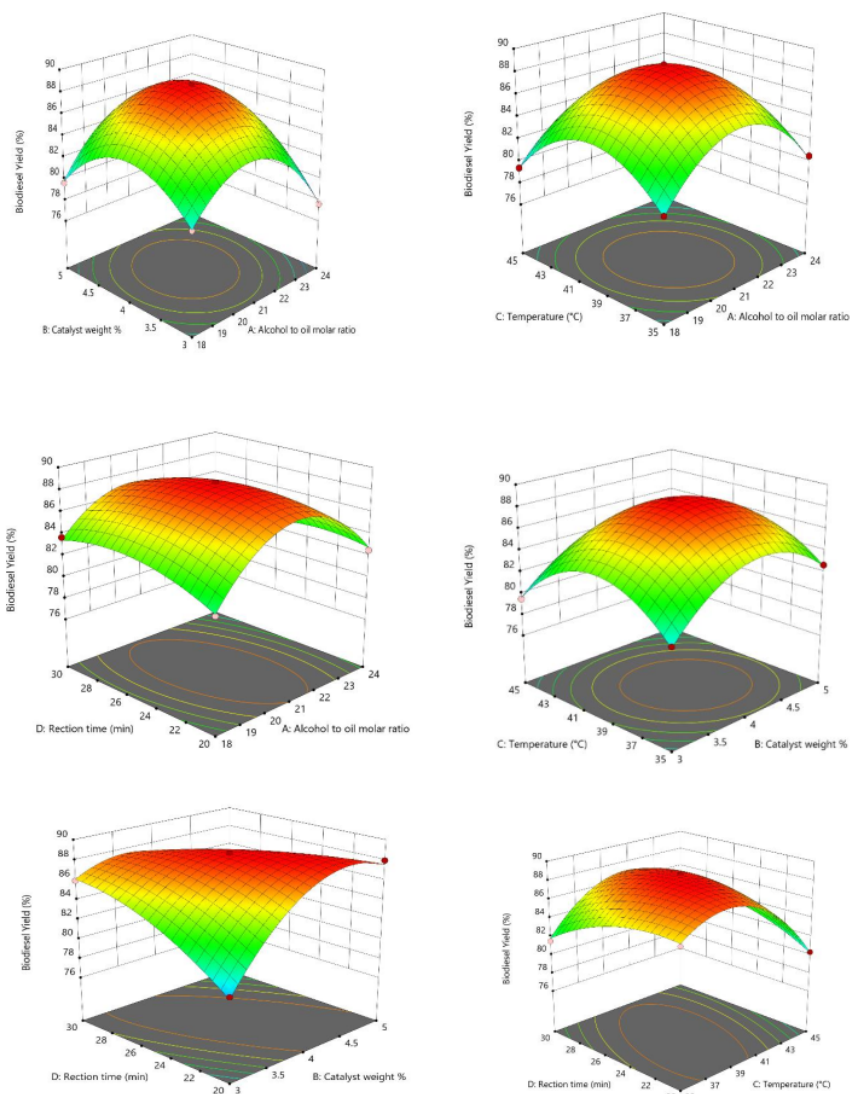


Fig 5.7 3-D surface plot which get from the optimization done in Response Surface Methodology

PREDICATED VS ACTUAL

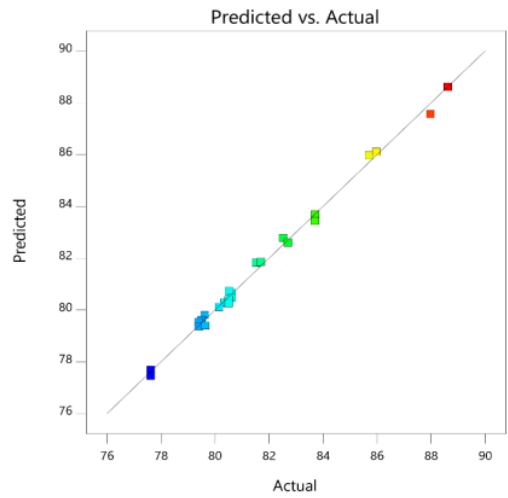


Fig 5.8 PREDICATED VS ACTUAL

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Normal plot of Residuals

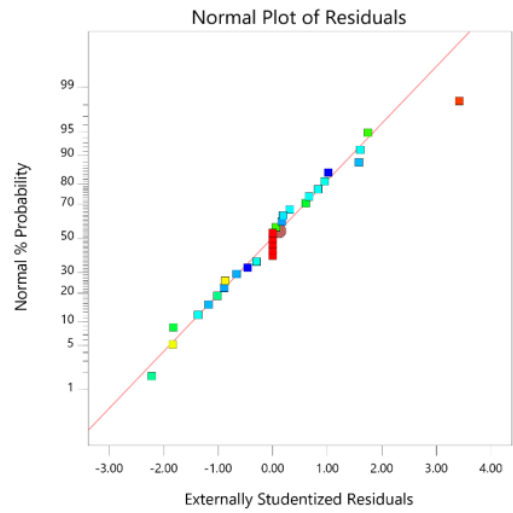


Fig 5.9 Normal plot of Residuals

Table 5.4**SOLUTIONS FOUNDED**

Number	Alcohol to oil molar ratio	Catalyst weight %	Temperature	Rection time	Biodiesel Yield	Desirability
1	19.169	3.631	35.900	28.747	83.411	1.000
2	24.000	3.000	40.000	25.000	77.695	1.000
3	21.000	4.000	40.000	25.000	88.620	1.000
4	21.000	5.000	45.000	25.000	79.542	1.000
5	24.000	4.000	40.000	20.000	82.787	1.000
6	21.000	4.000	35.000	20.000	85.969	1.000
7	21.000	3.000	40.000	30.000	86.109	1.000
8	18.000	4.000	35.000	25.000	80.392	1.000
9	24.000	4.000	35.000	25.000	80.259	1.000
10	21.000	4.000	35.000	30.000	81.830	1.000
11	18.000	4.000	40.000	20.000	81.860	1.000
12	24.000	4.000	45.000	25.000	77.459	1.000
13	21.000	3.000	35.000	25.000	80.367	1.000
14	24.000	4.000	40.000	30.000	80.469	1.000
15	18.000	5.000	40.000	25.000	79.804	1.000
16	21.000	5.000	40.000	30.000	80.119	1.000
17	21.000	5.000	35.000	25.000	82.602	1.000
18	21.000	4.000	45.000	20.000	80.289	1.000
19	21.000	3.000	45.000	25.000	79.607	1.000
20	21.000	4.000	45.000	30.000	83.690	1.000
21	18.000	4.000	40.000	30.000	83.442	1.000
22	18.000	4.000	45.000	25.000	79.373	1.000
23	21.000	3.000	40.000	20.000	79.403	1.000
24	18.000	3.000	40.000	25.000	80.669	1.000
25	21.000	5.000	40.000	20.000	87.563	1.000
26	18.312	3.689	43.389	26.738	83.466	1.000
27	22.841	3.164	36.556	24.374	81.137	1.000
28	23.197	4.596	42.003	27.222	82.310	1.000
29	21.684	4.561	40.259	27.577	85.804	1.000
30	23.724	3.086	38.571	28.777	79.763	1.000

31	20.450	4.549	40.050	27.336	86.350	1.000
32	22.920	3.666	39.638	22.411	84.955	1.000
33	21.842	3.043	36.756	26.912	82.766	1.000
34	23.059	3.355	44.787	23.338	77.552	1.000
35	18.628	4.504	42.360	21.606	82.959	1.000
36	20.517	4.658	40.201	29.521	83.843	1.000
37	18.491	4.618	39.856	27.681	82.627	1.000
38	22.322	3.701	42.459	20.544	82.903	1.000
39	23.822	3.323	39.748	26.265	81.182	1.000
40	21.930	4.948	35.815	25.915	82.676	1.000
41	19.793	3.227	42.515	26.320	85.278	1.000
42	18.885	3.859	42.940	22.260	83.045	1.000
43	23.350	3.812	44.650	20.718	77.663	1.000
44	18.615	4.916	40.225	24.790	82.437	1.000
45	18.568	4.263	40.326	25.550	85.292	1.000
46	23.304	4.157	35.730	23.657	84.202	1.000
47	22.510	3.798	37.076	26.436	85.477	1.000
48	19.042	4.309	37.318	25.391	85.511	1.000
49	22.010	3.774	42.563	23.227	85.247	1.000
50	23.459	4.613	39.270	28.158	81.602	1.000
51	20.796	3.801	38.553	29.616	87.063	1.000
52	23.014	3.903	41.191	23.093	85.139	1.000
53	21.302	3.120	42.928	23.526	81.937	1.000
54	20.034	3.517	37.052	29.500	85.575	1.000
55	22.781	4.323	36.297	26.233	84.325	1.000
56	18.060	3.585	44.338	22.064	77.604	1.000
57	19.006	4.333	40.653	28.435	85.086	1.000
58	22.946	4.203	38.329	21.193	87.041	1.000
59	18.255	3.317	42.903	22.040	78.796	1.000
60	23.199	3.466	43.688	21.950	78.759	1.000
61	21.089	3.566	35.910	20.188	84.250	1.000
62	23.103	4.955	43.941	22.247	80.457	1.000
63	21.506	4.681	43.206	23.137	84.807	1.000
64	18.600	3.421	41.625	28.291	85.634	1.000
65	19.397	4.747	44.804	22.170	80.130	1.000
66	19.162	3.196	40.261	28.007	86.060	1.000

67	20.681	4.760	38.921	20.175	88.522	1.000
68	20.770	3.182	39.591	23.802	84.956	1.000
69	20.895	4.338	39.858	22.675	88.727	1.000
70	21.423	4.759	37.517	28.245	83.246	1.000
71	18.471	3.735	37.097	27.967	83.880	1.000
72	19.562	3.037	35.695	23.326	80.231	1.000
73	23.821	3.609	43.104	27.234	80.551	1.000
74	19.584	4.354	35.984	26.127	84.688	1.000
75	21.847	4.056	35.656	27.855	84.104	1.000
76	18.367	3.905	41.909	22.560	83.191	1.000
77	21.853	3.985	36.917	27.919	85.699	1.000
78	23.445	3.359	38.121	21.935	81.277	1.000
79	20.426	4.363	36.542	23.229	87.613	1.000
80	22.228	3.809	35.475	29.747	81.878	1.000
81	19.831	4.369	36.954	25.181	86.545	1.000
82	18.481	4.685	36.399	29.662	77.821	1.000
83	21.537	3.438	35.971	27.996	84.117	1.000
84	20.850	4.460	42.329	24.017	86.686	1.000
85	19.299	3.406	43.996	23.679	81.797	1.000
86	19.713	3.981	39.322	23.548	87.799	1.000
87	21.086	4.942	39.080	27.890	83.109	1.000
88	18.553	4.833	41.732	23.389	82.313	1.000
89	18.233	4.428	41.338	24.087	83.445	1.000
90	19.783	3.796	44.045	21.961	82.484	1.000
91	18.039	3.788	43.636	25.716	82.008	1.000
92	18.418	3.808	37.716	27.527	84.449	1.000
93	18.994	3.694	44.533	24.479	82.124	1.000
94	23.650	4.434	35.276	29.893	76.208	1.000
95	21.823	4.005	44.236	21.727	82.799	1.000
96	21.799	3.736	41.925	25.168	86.703	1.000
97	20.619	4.072	37.687	21.769	88.306	1.000
98	20.304	4.427	42.171	22.663	86.611	1.000
99	22.507	4.059	39.616	27.065	86.538	1.000
100	23.884	3.728	41.754	24.674	81.805	1.000

5.5 BIODIESEL CHARACTERISATION

5.5.1 FTIR-FOURIER TRANSFORM INFRARED SPECTROSCOPY

For the purpose to figure out the sort and amount of functional groups present in the specimen, as well as the degree of unsaturation and other structural properties, FTIR spectroscopy is extremely useful for biodiesel analysis.

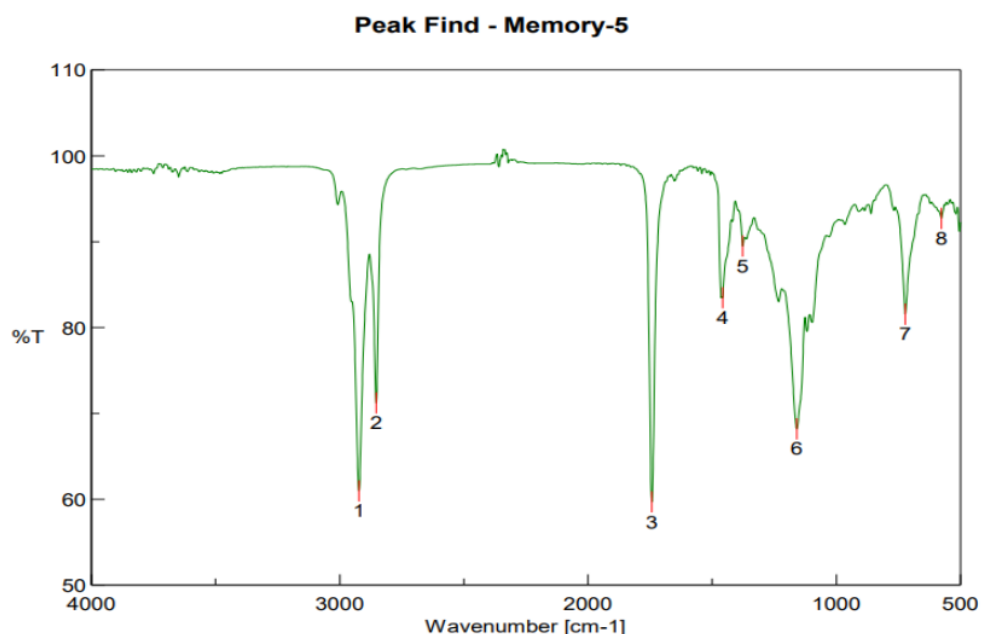


Fig 5.10 FTIR FOR BIODIESEL

The (C-H) stretching vibrations are picked up on due to the organic linker (BDC) used in the synthesis. Peaks at 2924.9 cm¹ and 1711.2 cm¹ were attributed, respectively, to the C-H-alkane and C=O's vibrational stretching. The clear peaks at 1114.9 cm¹, 1185.2 cm¹, and 1248.8 cm¹ have been attributed to C-O stretching vibrations, while the peaks at 543 cm¹ and 578 cm¹ illustrate the Mg-O vibrations, establishing the emergence of the Mg-SO₄

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5.5.2 GAS CHROMATOGRAPHY MASS SPECTROMETRY (GC/MS)

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Using GC/MS, it can be done to determine the type and quantity of fatty acid methyl esters (FAMES) present in the sample as well as any extra chemicals that could be present to it, such as contaminants or additives.

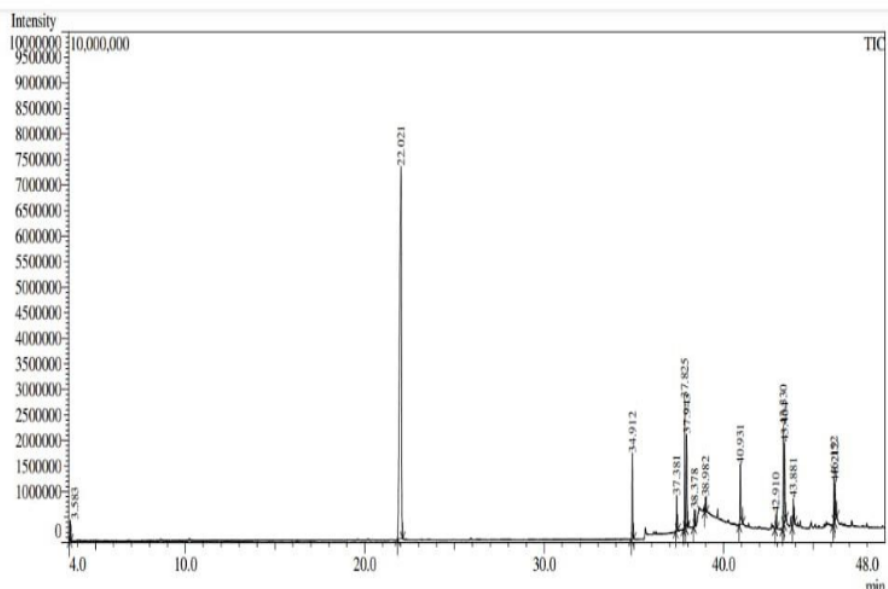


Fig 5.11 GC/MS

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Table 5.5 Peak Report

Peak #	R. Time	Area	Area%	Name
1	3.583	712405	0.75	1-UNDECYNE
2	22.021	56531526	59.72	PHENOL, 2,6-BIS(1,1-DIMETHYLETHYL)
3	34.912	4245042	4.48	Hexadecanoic acid, methyl ester
4	37.381	1629099	1.72	Methyl2-octylcyclopropene-1-heptanoate
5	37.825	5989613	6.33	9,12-Octadecadienoic acid (Z,Z)-,methyl est
6	37.943	4443985	4.69	9-Octadecenoic acid, methyl ester, (E)-
7	38.378	720257	0.76	Methyl stearate
8	38.982	704912	0.74	Methyl2-octylcyclopropene-1-octanoate
9	40.931	3306089	3.49	Glycidyl palmitate
10	42.910	702861	0.74	Methyl2-octylcyclopropene-1-heptanoate
11	43.330	5397794	5.70	Linoleyl acetate
12	43.404	3998959	4.22	9-Octadecenoicacid(Z)-oxiranylmethyl est
13	43.881	1339748	1.42	Hexadecanoicacid,2-hydroxy-1-(hydroxyme
14	46.152	2650490	2.80	n-Propyl 9,12-octadecadienoate
15	46.212	2293053	2.42	9-Octadecenoicacid(Z)-,2,3-dihydroxypropyl
		94665833	100.00	

CHAPTER-6

SUMMARY AND CONCLUSIONS

The installation of a heterogeneous catalyst for creating biodiesel from silk cotton seed oil has led to promising outcomes. Due to its high oil content and affordability as a by product of the silk cotton company operations, silk cotton seed oil, a non-edible oil, has the potential to be an important feedstock for the manufacturing of biodiesel. The effectiveness of heterogeneous catalysts, such as metal oxides, in encouraging the process of conversion of silk cotton seed oil to biodiesel has been investigated. In accordance with studies, heterogeneous catalysts can rapidly as well as with good yields change silk cotton seed oil into biodiesel. As a consequence of the catalysts' straightforward recovery from the reaction mixture, downstream processing has been simplified and the cost for making biodiesel reduces overall. The use of heterogeneous catalysts provides additional advantages. subsequently has been examined at what it takes one can generate biodiesel from silk cotton seed oil using MgSO_4 as a heterogeneous catalyst. Non-edible silk cotton seed oil has the potential to be used as a feedstock for the production of biodiesel. The transesterification reaction, which transforms the triglycerides in silk cotton seed oil into biodiesel, was rendered faster in this study through the use of MgSO_4 as a catalyst. Under ideal circumstances, the step of transesterification was carried out employing a methanol-to-oil molar ratio of, a MgSO_4 catalyst loading, a reaction temperature of, and a reaction time of hours. MgSO_4 exhibited promising results while applied as a heterogeneous catalyst in the creation of biodiesel from silk cotton seed oil. A high biodiesel yield of almost 90% was attained with the perfect conditions of a methanol-to-oil molar ratio of, a MgSO_4 catalyst loading of, a reaction temperature of, and a reaction length of hours. The produced biodiesel has been shown to exhibit features falling within the acceptable range for biodiesel fuel demands. MgSO_4 can therefore be envisioned as an efficient catalyst for the transesterification of silk cotton seed oil into biodiesel, suggesting a potential solution for using non-edible oil feedstocks for biodiesel production. Further study may be completed for enhancing the process parameters and delve into.

REFERENCES

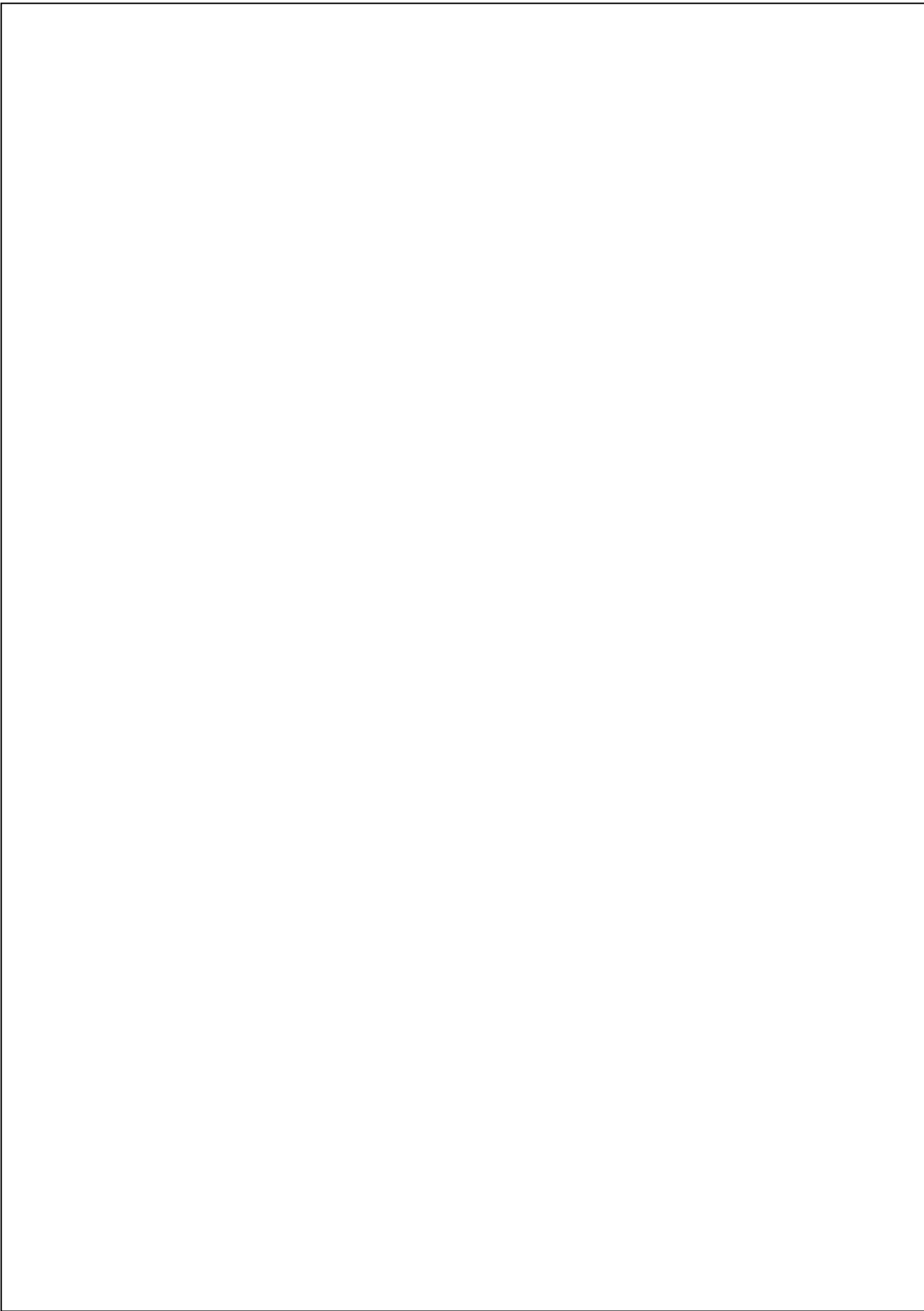
- 1) M. R. Avhad and J. M. Marchetti, "A review on recent advancement in catalytic materials for biodiesel production," *Renewable and Sustainable Energy Reviews*, vol. 50, pp. 696–718, 2015, doi: 10.1016/j.rser.2015.05.038.
- 2) Z. W. M. M. Phoo et al., "Evaluation of Indian milkweed (*Calotropis gigantea*) seed oil as alternative feedstock for biodiesel," *Industrial Crops and Products*, vol. 54, pp. 226–232, 2014, doi: 10.1016/j.indcrop.2014.01.029.
- 3) Exergy-based optimization of direct conversion of microalgae biomass to biodiesel <https://doi.org/10.1016/j.jclepro.2016.09.032>.
- 4) S. Rajagopalachar, S. S. Joshi, and R. P. Reddy, "Biodiesel synthesis from *Garcinia gummi-gutta* (L . Robson) seed oil : fuel feasibility evaluation of a novel feedstock by homogeneous and heterogeneous transesterification," *Biofuels*, vol. 0, no. 0, pp. 1–8, 2017, doi: 10.1080/17597269.2017.1306681.
- 5) A. Elfasakhany, "Exhaust emissions and performance of ternary iso-butanol e bio-methanol e gasoline and n-butanol e bio-ethanol e gasoline fuel blends in spark-ignition engines : Assessment and comparison," *Energy*, vol. 158, pp. 830–844, 2018, doi: 10.1016/j.energy.2018.05.120.
- 6) H. Venu, V. D. Raju, and L. Subramani, "Combined effect of influence of nano additives, combustion chamber geometry and injection timing in a DI diesel engine fuelled with ternary (diesel-biodiesel-ethanol) blends," *Energy*, vol. 174, pp. 386–406, 2019, doi: 10.1016/j.energy.2019.02.163.
- 7) L. Subramani and H. Venu, "Evaluation of methyl ester derived from novel *Chlorella emersonii* as an alternative feedstock for DI diesel engine & its combustion , performance and tailpipe emissions," 2018 <https://link.springer.com/article/10.1007/s00231-018-2530-0>
- 8) N. Yilmaz, A. Atmanli, and F. M. Vigil, "Quaternary blends of diesel, biodiesel, higher alcohols and vegetable oil in a compression ignition engine," *Fuel*, vol. 212, no. August 2017, pp. 462–469, 2018, doi: 10.1016/j.fuel.2017.10.050.
- 9) A. Atmanlı, B. Yüksel, E. Ileri, and A. D. Karaoglan, "Response surface methodology based optimization of diesel – n-butanol – cotton oil ternary blend ratios to improve engine performance and exhaust emission characteristics," vol. 90, pp. 383–394, 2015, doi: 10.1016/j.enconman.2014.11.029.
- 10) P. Appavu, V. Ramanan M, and H. Venu, "Quaternary blends of diesel/biodiesel/vegetable oil/pentanol as a potential alternative feedstock for existing unmodified diesel engine: Performance, combustion and emission characteristics," *Energy*, vol. 186, p. 115856, 2019, doi: 10.1016/j.energy.2019.115856.

- 11). A. Atmanli, E. Ileri, and N. Yilmaz, "Optimization of diesel-butanol-vegetable oil blend ratios based on engine operating parameters," *Energy*, vol. 96, no. 2016, pp. 569–580, 2016, doi: 10.1016/j.energy.2015.12.091.
- 12) Perkins, G.; Techno-economic comparison of the levelised cost of electricity generation from solar PV and battery storage with solar PV and combustion of bio-crude using fast pyrolysis of biomass, *Energy Conversion and Management*. 2018, 171, 1573-1588. <https://doi.org/10.1016/j.enconman.2018.06.090>.
- 13) Rehfeldt, M.; Worrell, E.; Eichhammer, W.; Fleiter, T.; A review of the emission reduction potential of fuel switch towards biomass and electricity in European basic materials industry until 2030, *Renewable and Sustainable Energy Reviews*. 2020, 120, 109672. 10.1016/j.rser.2019.109672.
- 14). Mahmudul, H.M.; Hagos, F.Y.; Mamat, R.; Adam, A.A.; Ishak, W.F.W.; Alenezi, R.; Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review, *Renewable and Sustainable Energy Reviews*. 2017, 72, 497-509. <https://doi.org/10.1016/j.rser.2017.01.001>.
- 15) Datta, A.; Mandal, B.K.; A comprehensive review of biodiesel as an alternative fuel for compression ignition engine, *Renewable and Sustainable Energy Reviews*. 2016, 57, 799- 821. <https://doi.org/10.1016/j.rser.2015.12.170>
- 16) Rezania, S.; Oryani, B.; Park, J.; Hashemi, B.; Yadav, K.K.; Kwon, E.E.; Hur, J.; Cho, J.; Review on transesterification of non-edible sources for biodiesel production with a focus on economic aspects, fuel properties and by-product applications, *Energy Conversion and Management*. 2019, 201, 112155. <https://doi.org/10.1016/j.enconman.2019.112155>
- 17) Mardhiah, H.H.; Ong, H.C.; Masjuki, H.H.; Lim, S.; Lee, H.V.; A review on latest developments and future prospects of heterogeneous catalyst in biodiesel production from non-edible oils, *Renewable and Sustainable Energy Reviews*. 2017, 67, 1225-1236. <https://doi.org/10.1016/j.rser.2016.09.036>
- 18) Banković-Ilić, I.B.; Stamenković, O.S.; Veljković, V.B.; Biodiesel production from nonedible plant oils, *Renewable and Sustainable Energy Reviews*. 2012, 16, 3621-3647. <https://doi.org/10.1016/j.rser.2012.03.002>.
- 19). Bhuiya, M.M.K.; Rasul, M.G.; Khan, M.M.K.; Ashwath, N.; Azad, A.K.; Hazrat, M.A.; Prospects of 2nd generation biodiesel as a sustainable fuel – Part 2: Properties, performance and emission characteristics, *Renewable and Sustainable Energy Reviews*. 2016, 55, 1129- 1146. <https://doi.org/10.1016/j.indcrop.2020.112493>.
- 20) Recent scenario and technologies to utilize non-edible oils for biodiesel production Author links open overlay panelT.M. Yunus khan ^a, A.E. Atabani ^{b c}, Irfan Anjum Badruddin ^a, Ahmad Badarudin ^a, M.S. Khayoon ^d, S. Triwahyono ^d <https://doi.org/10.1016/j.rser.2014.05.064>.

- 21) O'Connor, P. (2013). *A General Introduction to Biomass Utilization Possibilities. The Role of Catalysis for the Sustainable Production of Bio-Fuels and Bio-Chemicals*, 1–25. doi:10.1016/b978-0-444-56330-9.00001-2.
- 22) Konwar, L.J.; Das, R.; Thakur, A.J.; Salminen, E.; Mäki-Arvela, P.; Kumar, N.; Mikkola, J.-P.; Deka, D.; Biodiesel production from acid oils using sulfonated carbon catalyst derived from oil-cake waste, *Journal of Molecular Catalysis A: Chemical*. 2014, 388–389, 167-176. <https://doi.org/10.1016/j.molcata.2013.09.031>.
- 23) Farooq, M.; Ramli, A.; Subbarao, D.; Biodiesel production from waste cooking oil using bifunctional heterogeneous solid catalysts, *Journal of Cleaner Production*. 2013, 59, 131- 140. <https://doi.org/10.1016/j.jclepro.2013.06.015>.
- 24) Jamil, F.; Al-Muhtaseb, A.a.; Myint, M.T.Z.; Al-Hinai, M.; Al-Haj, L.; Baawain, M.; AlAbri, M.; Kumar, G.; Atabani, A.E.; Biodiesel production by valorizing waste Phoenix dactylifera L. Kernel oil in the presence of synthesized heterogeneous metallic oxide catalyst (Mn@MgO-ZrO₂), *Energy Conversion and Management*. 2018, 155, 128-137. (<https://doi.org/10.1016/j.enconman.2017.10.064>).
- 25) Noam Lior (2008) Energy resources and use: The present situation and possible paths to the future. ,33(6), 842-857. <https://doi.org/10.1016/j.energy.2007.09.009>.
- 26) Nick A. Owen; Oliver R. Inderwildi; David A. King (2010). *The status of conventional world oil reserves—Hype or cause for concern?*. , 38(8), 4743–4749. doi:10.1016/j.enpol.2010.02.026.
- 27) T. M. M. Marso, C. S. Kalpage, and M. Y. Udugala-Ganehenegge, “Metal modified graphene oxide composite catalyst for the production of biodiesel via pre-esterification of Calophyllum inophyllum oil,” *Fuel*, vol. 199, pp. 47–64, Jul. 2017, doi: 10.1016/j.fuel.2017.01.004.
- 28) Hamelinck, C. N., Hooijdonk, G. van, & Faaij, A. P. (2005). *Ethanol from lignocellulosic biomass: techno-economic performance in short-, middle- and long-term. Biomass and Bioenergy*, 28(4), 384–410. doi:10.1016/j.biombioe.2004.09.002.
- 29) B. Basumatary, S. Basumatary, B. Das, B. Nath, and P. Kalita, “Waste Musa paradisiaca plant: An efficient heterogeneous base catalyst for fast production of biodiesel,” *J Clean Prod*, vol. 305, p. 127089, Jul. 2021, doi: 10.1016/j.jclepro.2021.127089.
- 30) Martins, Maria F.O.; Dias, Sara S. (2010). *Developmental Impact of Very Low Birth Weight on Childhood Disability: A Parametric and Semiparametric Binary Choice Model Approach. American Journal of Mathematical and Management Sciences*, 30(3-4), 217–242. doi:10.1080/01966324.2010.10737786.

- 31) Dennis Y.C. Leung; Xuan Wu; M.K.H. Leung (2010). *A review on biodiesel production using catalyzed transesterification*. , 87(4), 1083–1095. doi:10.1016/j.apenergy.2009.10.006.
- 32) Borhanipour, Morteza; Karin, Preechar; Tongroon, Manida; Chollacoop, Nuwong; Hanamura, Katsunori (2014). *SAE Technical Paper Series [SAE International The 10th International Conference on Automotive Engineering - (MAR. 31, 2014)] SAE Technical Paper Series - Comparison Study on Fuel Properties of Biodiesel from Jatropha, Palm and Petroleum Based Diesel Fuel*. , 1(), -. doi:10.4271/2014-01-2017.
- 33) Atabani, A.E.; César, Aldara da Silva (2014). *Calophyllum inophyllum L. – A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance. Renewable and Sustainable Energy Reviews*, 37(), 644–655. doi:10.1016/j.rser.2014.05.037.
- 34) Y Zhang; M.A Dube; D.D McLean; M kates (2003). Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. , 90(3), 229–240. [https://doi.org/10.1016/S0960-8524\(03\)00150-0](https://doi.org/10.1016/S0960-8524(03)00150-0)
- 35) Y Zhang; M.A Dubé; D.D McLean; M Kates (2003). *Biodiesel production from waste cooking oil: 1. Process design and technological assessment*. , 89(1), 1–16. doi:10.1016/s0960-8524(03)00040-3.
- 36) Sani, Yahaya Muhammad; Daud, Wan Mohd Ashri Wan; Abdul Aziz, A.R. (2014). *Activity of solid acid catalysts for biodiesel production: A critical review. Applied Catalysis A: General*, 470(), 140–161. doi:10.1016/j.apcata.2013.10.052.
- 37) Garg, Bhaskar; Bisht, Tanuja; Ling, Yong-Chien (2014). *Graphene-Based Nanomaterials as Heterogeneous Acid Catalysts: A Comprehensive Perspective. Molecules*, 19(9), 14582–14614. doi:10.3390/molecules190914582.
- 38) Navalon, Sergio; Dhakshinamoorthy, Amarajothi; Alvaro, Mercedes; Garcia, Hermenegildo (2014). *Carbocatalysis by Graphene-Based Materials. Chemical Reviews*, 114(12), 6179–6212. doi:10.1021/cr4007347.
- 39) Park, Sungjin; Lee, Kyoung-Seok; Bozoklu, Gulay; Cai, Weiwei; Nguyen, SonBinh T.; Ruoff, Rodney S. (2008). *Graphene Oxide Papers Modified by Divalent Ions—Enhancing Mechanical Properties via Chemical Cross-Linking. ACS Nano*, 2(3), 572–578. doi:10.1021/nn700349a.
- 40) Hawkins, C., Fuls, J., and Hugo, F., "Sunflower Oil Esters: An Alternative Fuel for Direct Injection Diesel Engines," SAE Technical Paper 831356, 1983, <https://doi.org/10.4271/831356>.

- 41) Silitonga, A.S., Masjuki, H.H., Mahlia, T.M.I., Ong, H.C., Chong, W.T., 2013. Experimental study on performance and exhaust emissions of a diesel engine fuelled with *Ceiba pentandra* biodiesel blends. *Energy Convers. Manag.* 76, 828–836. <https://doi.org/10.1016/j.enconman.2013.08.032>.
- 42) Vedharaj, S., Vallinayagam, R., Yang, W.M., Chou, S.K., Chua, K.J.E., Lee, P.S., 2013. Experimental investigation of kapok (*Ceiba pentandra*) oil biodiesel as an alternate fuel for diesel engine. *Energy Convers. Manag.* 75, 773–779. <https://doi.org/10.1016/j.enconman.2013.08.042>.
- 43) Dave, D.V., Ramakrishnan, V., Sheila, T., Heather, M., Julia, P., Wade, M., 2014. Marine oils as potential feedstock for biodiesel production: physicochemical characterization. *J. Bioprocess. Biotech.* 1. <https://doi.org/10.4172/2155-9821.1000168>, 04(05).
- 44) Muhammad, C., 2018. Biodiesel production from *Ceiba pentandra* seed oil using CaO derived from snail shell as catalyst. *Petroleum Sci. Eng.* 2 (1), 7–16. <https://doi.org/10.11648/j.pse.20180201.12>.
- 45) Pasawan, M., Chen, S.S., Das, B., Chang, H.-M., Chang, C.T., Nguyen, T.X.Q., Ku, H.M., Chen, Y.-F., 2022. Ultrasonication assisted catalytic transesterification of *Ceiba Pentandra* (Kapok) oil derived biodiesel using immobilized iron nanoparticles. *Fuels* 3 (1), 113–131. <https://doi.org/10.3390/fuels3010008>.
- 46) Bokhari, A., Chuah, L.F., Yusup, S., Ahmad, J., Shamsuddin, M.R., Teng, M.K., 2015. Microwave-assisted methyl esters synthesis of Kapok (*Ceiba pentandra*) seed oil: parametric and optimization study. *Biofuel Res. J.* 2 (3), 281–287. <https://doi.org/10.18331/brj2015.2.3.6>.
- 47) <https://doi.org/10.5897/JPTAF2018.0141>?sid=semanticscholar Fatty acid profile and quality parameters of *Ceiba pentandra* (L.) seed oil: A potential source of biodiesel Papin Sourou MONTCHO1 , Léopold TCHIAKPE2 , Guevara NONVIHO1 , Fifa Théomaine Diane BOTHON1 , Assou SIDOHOUNDE 1 , Cokou Pascal AGBANGNAN DOSSA1 , David BESSIERES3 , Anna CHROSTOWSKA4 and Dominique Codjo Koko SOHOUNHLOUE1*.
- 48) Nayak, S.N., Nayak, M.G., Bhasin, D.C.P., 2021. Parametric, kinetic, and thermodynamic studies of microwave-assisted esterification of Kusum oil. *Fuel Commun* 8, 100018. <https://doi.org/10.1016/j.fueco.2021.100018>.
- 49) Moorthy, I.M., Baskar, R., 2013. Statistical modeling and optimization of alkaline protease production from a newly isolated alkalophilic *Bacillus* species BGS using response surface methodology and genetic algorithm. *Prep. Biochem. Biotechnol.* 43 (3), 293–314. <https://doi.org/10.1080/10826068.2012.719850>.



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