FYP FBKT

Characterization of Alumina Supported Banana Peel and Chicken Egg Shell for Biodiesel Catalyst

MUHAMMAD FAIZ BIN ZAINUDDIN
J20B0506

A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Bioindustrial Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY
UMK

2024

DECLARATION

I declare that this thesis entitled "Characterization of Alumina Supporterd Banana Peel and Chicken Egg Shell for Biodiesel Catalyst" is the results of my own research except as cited in the references.

Signature :
Student's Name : MUHAMMAD FAIZ BIN ZAINUDDIN
Date : 8 FEBRUARY 2024

Verified by:

Signature : ____________________________
Supervisor's Name : DR NIK NURUL ANIS BT YUSOFF

Stamp : ____________________________
Date : ____________________________

ACKNOWLEDGEMENT

Alhamdulillah as a conclusion of one hectic year, this day is the final part of my Degree Final Year Project. It has been a time of deepen learning for me not only in the scientific sphere but also on a personal scale. I would like to write about those people who have supported me and helped me so much during this time of writing this thesis.

Above all, I acknowledge Almighty Allah for granting me the necessary skills, direction, and blessings to finish this thesis. In the presence of Allah, hope never dies and this theory would not have been in existence even today.

Lastly, I would like to thank my outstanding supervisor Dr Nik Nurul Anis Binti Nik Yusoff for her unwavering guidance and support throughout my degree experience. Her patience and high moral standards have been priceless and I appreciate the opportunities she gave me to conduct my research.

First of all, I would like to thank my father Zainuddin bin Hussain and my mother Fatimah Zawiyah binti Hamzah, for their love, prayers, all sacrifices that they made to get me here today.

Beyond what I put into the project, the success of the project will largely be contingent on the help and leadership it receives from thousands of other people. This is the time that I would want to use to thank all the people who contributed to the success of this project in any manner.

PENCIRIAN ALUMINA YANG DISOKONG KULIT TELUR AYAM DAN KULIT UBI KENTANG UNTUK PEMANGKIN BIODIESEL

ABSTRAK

Kini, terdapat keperluan yang sangat besar untuk bahan api fosil yang boleh digantikan dengan biodiesel, yang merupakan pilihan yang selamat dan bijak dari segi alam untuk kenderaan. Minyak sayuran boleh ditransesterifikasi untuk menghasilkan biodiesel dengan kehadiran sebatian pemangkin. Sejumlah besar pemangkin yang digunakan dalam pengeluaran biodiesel berasal dari bahan kimia, mereka tidak mesra alam. Oleh itu, dalam kerja penyelidikan ini, kami bercadang untuk membangunkan sebatian pemangkin daripada bahan buangan yang melimpah, iaitu kulit telur dan kulit pisang. Kulit telur dan kulit pisang diketahui mengandungi tahap tinggi kalsium oksida (CaO) dan sifat kalium (K) masing-masing. Kalsium oksida dan Hidroksida Kalium adalah pemangkin pepejal yang biasa digunakan dalam MCT-transesterifikasi untuk pengeluaran biodiesel. Kulit telur dan kulit pisang buangan dikumpul dari restoran dan rumah-rumah dan dicuci sepenuhnya dengan air paip untuk menghilangkan kotoran untuk penyelidikan semasa ini. Selepas itu, mereka diletakkan di dalam ketuhar selama 12 jam pada suhu 120 °C untuk mengeluarkan kelebihan kelembapan dari permukaan dan dipindahkan ke dalam proses pemecahan dan penapisan yang dilakukan dengan menggunakan penumbuk atau penggiling. Serbuk itu dikeringkan di dalam ketuhar pada suhu 100°C selama 24 jam untuk menghilangkan kelembapan sepenuhnya. Kemudian serbuk itu dikalsinasi di dalam tanur selama suhu tinggi. Abu kalsinasi yang diaktifkan dikarakterisasikan dan dianalisis secara kualitatif dengan FTIR dan XRD. Kehadiran CaO dan K disahkan dari FTIR dan analisis menunjukkan bahawa pemangkin terbaik yang mengandungi kandungan CaO dan K yang tinggi adalah kulit pisang kemudian kulit telur. Struktur kristal dan komposisi fasa bahan telah dikenal pasti.

Kata kunci: Biodiesel, alumina oksida, kalsium oksida, kalium oksida, kulit pisang, kulit telur

CHARACTERIZATION OF ALUMINA SUPPORTED CHICKEN EGG SHELLS AND PLAINTAIN PEELS FOR BIODIESEL CATALYST

ABSTRACT

Currently, there is a tremendous need for fossil fuel which can be replaced by biodiesel, that is an environmentally safe and wise option for vehicles. Vegetable oil can be transesterified to produce biodiesel in the presence of a catalyst. A large number of catalyst used in biodiesel production come from chemical based, they are not friendly to the environment. Hence in this research intend to develop an environmentally friendly catalyst for biodiesel production using waste materials, specifically eggshells and banana peels. The chicken eggshell and banana peels are known to contain high level of Calcium oxide (CaO) and Potassium (K) properties respectively. Calcium oxide and Potassium Hydroxide are common solid catalysts employed in Medium-Chain Triglyceride (MCT) transesterification for biodiesel production. The waste eggshells and banana peels were collected from restaurants and houses and washed thoroughly by tap water to remove impurities for the current research. After that put under the oven for 12 hours on 120 ºC temperature to remove the excessive moisture from the surface and moved to the crushing into small size and sieving processes which were done by using heavy duty blender and 0.3 mm sieve . The powder was dried in the oven at 100°C for 24 hours to totally remove the moisture. Then the powder was calcined in a muffle furnace at high temperatures. The activated calcine ash was characterized and qualitatively analysed by FTIR , XRD and TGA. The presence of CaO and K was confirmed from FTIR and analysis showed that the best catalyst that contains high content of CaO and K is banana peel then eggshell. The crystalline structure and phase composition of materials were identify.

Keywords: Biodiesel, alumina oxide, calcium oxide, potassium oxide, banana peel, eggshell

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

CES	Chicken Egg Shells
PP	Plaintain Peels
FT-IR	Fourier Transform Infrared
XRD	X-ray Diffraction
Al_2O_3	Aluminium Oxide
K	Potassium
CaO	Calcium Oxide
$CaCO_3$	Calcium Carbonate
EPA	Egg – Plaintain - Alumina
$Al_2Ca_3H_{12}O_{12}$	Dialuminium tricalcium hydroxide
CaH_2O_2	Calcium Hydroxide
CO	Carbon Monoxide

LIST OF SYMBOLS

mL	Millilitre
º	Celsius
Oθ	Diffraction angle
cm	Centimeter
%	Percent

CHAPTER 1

INTRODUCTION

1.0 Background of Study

A vital and ever-changing necessity for a nation's social and economic growth is energy. Around 87 percent of the energy required for all social and economic activities worldwide is supplied by coal, petroleum, and natural gas. Around the planet, fossil fuels are only present in trace amounts and are mostly concentrated in a few specific regions. These fuels are still widely utilised, though, and because they emit a lot of exhaust gas emissions into the atmosphere, they have a negative impact on the environment and contribute to global warming. For this reason, theworld community has regarded renewable energy sources (such as wind, solar, and biofuels) as itsmain policy. There are now known varieties of biofuels, including biogas, bioethanol and biodiesel (Fekadu Ashine et al., 2023).

Heterogeneous catalysts are used in the transesterification process to chemically create biodiesel. However, the catalyst's type, alcohol level, and loading all affect the yield and fuel characteristics. Homogeneous alkaline catalysts, such as CH_3ONa, CH_3OK, NaOH, and KOH, arefrequently used for the manufacture of biodiesel due to their high catalytic activity (Amesho et al., 2022). In addition, they demonstrate a rapid pace of reaction and less corrosivity when compared to homogenous acid catalyst (H_2SO_4) (Colombo et al., 2017)

Homogeneous base-catalyzed transesterification is a fast reaction with a high yield, but because the catalysts cannot be recovered and used again after the transesterification reaction steps,they are not economically viable. Likewise, a variety of feedstocks makes base-catalyzed homogeneous transesterification difficult. According to studies, oils made from inedible seeds andwaste cooking sources that have a high fatty acid content induce saponification, which leads to oilloss and problems with product separation. In order to overcome this challenge and prevent saponification with biodiesel with reduced production costs, it is essential to design more effectiveand reuseable heterogeneous catalysts (Ashine et al.., 2023)

Different concentrations of biodiesel can be applied. B5 (up to 5%) and B20 (6% to 20%)biodiesel blends are the most common. Blendstock, or pure biodiesel, is frequently utilised. Bothedible and non-edible oils have the potential to be crucial biodiesel feedstocks (Madhuri Pydimallaet al., 2023). The most common biodiesel mixes, which typically contain B5 (up to 5%) and B20 (6% to 20%), are biodiesel and diesel fuel. Blends of B20 biodiesel provide performance that is comparable to that of diesel engines. Mono-alkyl esters of long-chain fatty acids, usually referredto as FAME, are the main component of biodiesel, which is made from vegetable oils or animal fats. Biodiesel can cut GHG emissions by at least 50% compared to petrol, which releases greenhouse gases (GHGs) that are equal to or higher than baseline GHG emissions. Triacylglycerides (TAGs) from plants or animals can be used to make biodiesel.reusable heterogeneous catalysts (Fekadu Ashine et al., 2023)

B5 is a 5% biodiesel 95% petroleum fuel mix. It decreases the use of fossil fuels and the reliance on petroleum diesel while remaining compatible with existing diesel engines. In terms ofengine power and efficiency, B5 is comparable to petroleum diesel. It also offers environmental advantages, such as fewer greenhouse gas emissions, lower particulate matter, and lower sulphurand aromatic chemical concentration in diesel fuel. B20 is a 20% biodiesel 80% petroleum fuel mix. It promotes the use of renewable resources and represents an important step towards more sustainable and cleaner fuel solutions. B20 operates similarly to petroleum diesel and offers comparable advantages for emissions reduction as B5, but with a possibly bigger impact owing tothe increased biodiesel percentage. It considerably reduces greenhouse gas emissions, particulatematter emissions, and the sulphur and aromatic component content of diesel fuel.

Biodiesel is an alternative fuel which came from renewable natural resources in terms of vegetative oils, animal fats and cooking waste materials. The composition and properties of biodiesel are influenced mainly by the components present in fuel, examples; methanol or ethanol. These fats being reacted with reagent alcohol (methyl-or ethlyl) under catalyst presence causes chemical transformation called transesterification as illustrated above. The catalyst helps in conducting the reaction that changes fats and oil into fatty acid methyl esters or fatty acid ethyl ester with them biodiesel formed of chemical compounds.

Catalyst plays an important role in esterification as it increases the speed of reaction and thereby its efficiency. Some typical catalysts used in the production process of biodiesel are sodium hydroxide (NaOH) and potassium hydroxide (KOH), two caustic bases that aid in their breakdown into esters – fatty acid methyl or ethyl ester, FAME; glycerol.

Regarding waste from chicken eggshells and plantain peels, these materials can be utilized in various ways to reduce waste and promote sustainability. Furthermore, the government accepted all of them downright. The egg compose primarily of calcium carbonate which can be utilized in other areas. In gardening or farming harvested oyster shells can shattered and applied as calcium additives for plants. Further, eggshells may be treated for a calcium carbonate powder that can serve in industries like food and medication manufacture cosmetic product industry production. The peels of plantains are full in valuable nutrients and Organic. They also may serve as food for livestock or a raw material in the biofuels production via, anaerobic digestion and fermentation. The CES as well plants PP are some of the available raw materials that could be reused or recycled in order to reduce wastage and environmental sustainability.

1.1 Problem Statement

Banana peel waste includes carbon-rich organic components that can take up to two yearsto disintegrate and biodegrade. During this time, a lot of greenhouse gases (GHGs), which contribute to climate change, are released, which causes an unpleasant odour. Unfortunately, banana peels cannot be recycled and are considered food waste. Peels from bananas may be utilised for a variety of purposes besides composting; they should never be placed in the recycling. Bananapeel, which is typically thrown away, makes up around one-third of the weight of this meal. Globally, over 39.9 million tonnes of banana peel waste are produced each year. When banana peels decompose in landfills, they create methane, a powerful greenhouse gas that contributes to climate change. Furthermore, banana peels take up precious space in landfills, increasing the problem of limited capacity and potentially leading to landfill development, which can impact local ecosystem.

Eggshell is a type of agricultural waste that is often disregarded as worthless and dumped because it causes pollution. This waste has the capacity to generate hydroxyapatite, a key component of bone and teeth. The vast amounts of eggshell garbage that are generated worldwideeach year are often exclusively disposed of in landfills, where smell formation and microbiologicaldevelopment take place, making it challenging to manage. Eggshell waste may be used in the production of biodiesel as a solid base catalyst for the reduction of biodiesel pollutants. This decreases the cost of creating biodiesel and ensures that the process is completely ecologically andenvironmentally sound.

1.2 Objectives

The objective for this research is :

i. To synthesize catalyst from chicken egg shell and banana peel
ii. To characterize of chicken egg shell and banana peel by using XRD and FT-IR for identify the composition , phase of sample and functional group.

1.3 Scope Of Study

This study's objective is two non-renewable alternatives to the catalysts used in this study will be derived from agricultural waste materials. One of these is chicken eggshell while banana peel adopts the other alternative for use as a source during production of required arylactic acid and styrenes. This will involve the production and purification of these raw materials to get catalysts acceptable towards a possible deployment in biodiesel synthesis or other analogous technologies.

In addition, the characterization stage of research will require sample analysis for chicken eggshell and banana peel by XRD and FT-IR technique. 70% of CES , 17% of PP and 13% of Alumina Oxide were used in this study. The studies of crystalline structure and phase composition will be carried out through the XRD to detect nature physical properties, possible reactivity behavior. With the use of FT-IR spectroscopy, these functional groups can be identified in samples; hence suitability for catalyst synthesis can also determine through chemical composition assessment.

1.4 Significance Of Study

This research on the characterization of alumina supported banana peel and chicken eggshell for biodiesel catalyst provides several worthwhile features. It encourages ecological responsibility through the upcycling of agricultural waste materials created into catalysts thus reducing wastes and proferring an environmentally friendly alternative for biodiesel production. Secondly, the study helps to increase resource efficiency since it utilizing waste materials and reducing demand for traditional catalysts that could have adverse impacts during their production. Furthermore, the research gives an increase in cost-effectiveness as it might be able to reduce their costs of producing biodiesel which will make such a process popular with many people who find this form economical owing to its low prices. Further, advancing biodiesel technology using novel catalysts helps raise awareness and acceptance of renewable energy technologies. Finally, the research extends scientific information in advancing that which concerns biotechnology industry through discovery of new catalyst materials used and the way it is implemented into biodiesel production playing part in knowledge development on sustainable energy solutions. On the whole, studies on alumina assisted banana peel and chicken egg shell for biodiesel catalyst proposes a viable route towards sustainable as well as efficient production of biodiesel offering benefits to environment, economy and renewable energy sector.

CHAPTER 2

LITERATURE REVIEW

2.1 Chicken Egg Shell

Many Asian nations, including Malaysia, Thailand, the Philippines, and Singapore, regularly eat chicken eggs. Eggs include a variety of nutrients, but the primary one is protein, which is present in greater quantities than in the majority of other meals. Eggs are therefore a necessary component of everyone's diet, which accounts for the increased production of chicken eggshell (CES) waste. Eggshells, which make up around 10% of a chicken's egg, are trash. Eggshells are a good heterogeneous catalyst for the generation of biodiesel since they contain 49.98% CaO (Gaide et al., 2022).

A growing chick's incubator is one of the CES's main jobs, but it also acts as an inventive container for necessary nourishment. About 2.2 g of calcium, in the form of calcium carbonate, is present in the majority of commercial layers of high-quality CES. CES is chicken faeces with a high calcium content and a chemical composition similar to that of limestone. It may be suggested that eggshells could serve as an inexpensive heterogeneous catalyst for the manufacture of biodiesel given their chemical makeup. CaO is a crucial ingredient in eggshells. Over the last ten years, the volume of eggs produced globally rose by more than 14%, reaching 76.7 million tonnes in 2018.A chicken's egg weighs around 10% eggshell (Gaide et al., 2022).

According to the chemical analysis of CES, calcium oxide (Ca) was still the most prevalent component in the sample of avian CES waste. The presence of calcium carbonate, which makes up the majority of avian CES, is connected to the high concentration of calcium oxide.Calcium carbonate makes up 94% of egg shells, with the remaining 1% of magnesium carbonate, 1% of calcium phosphate, and 4% of organic matter making up the remainder. One of the most often eaten meals in the world, eggs have a strong calcium content in their shells. Utilising a calcium oxide (CaO) catalyst made by calcining egg shells, discarded shells are assessed to improve reaction quality. Due to its porous structure and high $CaCO_3$ concentration, eggshell is an ideal material for creating active heterogeneous catalysts (Merve elik Tolu & Oguz, 2018).

The use of chicken eggshells as a catalyst in biodiesel synthesis has several advantages. For starters with, since eggshells are a byproduct of the egg business, they are readily available and inexpensive. Their extensive availability aids to the economic feasibility of biodiesel manufacturing. Second, eggshells have a high concentration of calcium carbonate ($CaCO_3$), making them excellent for use as a heterogeneous catalyst or support material. The alkaline nature of calcium carbonate enhances the transesterification processes involved in biodiesel generation. Furthermore, eggshells have a porous structure and a large surface area, allowing for better interaction between the reactants and the catalyst. This increases the efficiency of chemical processes and the total catalytic activity (Fekadu Ashine et al., 2023).

Nevertheless, there are certain drawbacks to employing chicken eggshells as a catalyst. Eggshell composition varies based on factors such as source, age, and processing methods. This diversity may have an effect on catalytic performance and result in uneven results. Furthermore, the number of active sites on the surface of eggshells, which determines catalytic activity, may be low in comparison to other catalysts. This has the potential to reduce the overall efficiency of the transesterification process. Furthermore, the process of transforming eggshells into a useable catalyst sometimes entails chemical treatment or calcination, which increases the complexity and cost of the manufacturing process (Merve elik Tolu & Oguz, 2018).

2.2 Banana Peel

In Malaysia, banana peels are a common agricultural waste. With 16% of the world's total fruit production, the banana ranks second in terms of fruit production overall. Bananas were notably the most popular tropical fruit in terms of consumption, and because of how widely used its byproduct, banana peel, is receiving more attention (Fan et al., 2019). Due to the simple nature of the materials, easy availability, cheap cost, reusability, and eco-friendliness of the process, a few number of waste banana plant parts derived catalysts have been reported for biodiesel synthesis with promising efficacies (Zurena Mohd Salleh et al., 2021).

Potassium and sodium oxides, which have been changed into their equivalent oxides, may be found in banana peels. The banana peel was dried at 80°C for 48 hours and then calcined at 700°C for 4 hours to create a catalyst (Minakshi Gohain et al., 2017). It was established by characterization using XRD, FT-IR, SEM, EDS, TGA, and CO2-TPD that the calcined banana peel catalyst exhibited strong alkalinity and good dispersity in microstructure, with K2O-KCl as the primary active components. Due to the excellent dispersibility of K2O-KCl generated during the decomposition of carbon fibre by calcination of banana peel, the calcined banana peel catalyst demonstrated superior catalytic performance than the catalysts made by physical mixing of K2O and KCl (Fan et al., 2019).

After harvest, the banana peel ash creates a large amount of peel and stem trash. Banana peel ash residue has the potential to be employed as a catalyst for the generation of biodiesel due to its high potassium content (78%). There are various advantages to using banana peels as a catalyst in biodiesel synthesis. For starters, banana peels are high in alkaline minerals such as potassium, magnesium, and calcium, which, because to their alkaline characteristics, can operate as catalysts or catalytic supports. These minerals help in the transesterification reaction that occurs during the biodiesel synthesis process. Second, banana peels are abundant as agricultural waste, making them a cost-effective and sustainable catalyst alternative. Using banana peels as a catalyst can help reduce waste while also providing economic benefits. Furthermore, the porous nature of banana peels provides for greater surface area and enhanced interaction between the reactants and the catalyst. This improves catalytic activity and allows for more efficient biodiesel generation (None Meriatna et al., 2023).

However, employing banana peels as a catalyst has significant drawbacks. Banana peel composition varies based on factors such as banana type, maturity, and processing processes. This variation in composition may result in inconsistency in catalytic performance. Furthermore, banana peels may have lesser thermal stability than other catalysts, limiting their utility in high- temperature reactions or long-term use. Stability concerns may have an impact on the catalyst's reusability and longevity. Furthermore, transforming banana peels into a catalyst often necessitates chemical treatments or extraction methods that necessitate additional resources and energy. As a result, to ensure efficient and cost-effective catalyst manufacturing, the preparation process should be optimized (Zurena Mohd Salleh et al., 2021).

.

2.3 Biodiesel

The demand for primary energy is anticipated to increase by 1.6% annually during the following ten years. While nuclear and renewable energy sources account for 7 and 5% of global energy consumption, respectively, a large portion of the main energy utilised today comes from fossil fuel resources including crude oil (35%), coal (29%) and natural gas (24%). Biodiesel is one of these alternative fuels that is marketed as an additional fuel for diesel engines. Mono-alkyl esters of long-chain fatty acids obtained from vegetable oil are used to make biodiesel. Due to its adaptable physical and chemical qualities, it may be utilised in compression-ignition (diesel) engines with little to no modification and is renewable, non-toxic, biodegradable, and ecologically benign. Additionally, compared to petroleum-based diesel fuel, it produces far less carbon monoxide, sulphur dioxide, and unburned hydrocarbons during combustion (Baskar Thangaraj et al., 2018).

The development of biodiesel as a liquid fuel derived from modified vegetable oil is now gaining interest. In addition to competing with cooking oil, biodiesel made from edible oils is now more costly than traditional petroleum-based fuels (Baskar Thangaraj et al., 2018). The most widely used technique of producing biodiesel, which is gaining prominence in the field of renewable, clean energy, is transesterification of fatty acid methyl ester (FAME). Consumption of energy is rising globally. The transesterification process produces biodiesel, also known as fatty acid methyl esters (FAME). Triglycerides in the feedstock are reacted with an alcohol, commonly methanol, in the presence of a catalyst, typically sodium or potassium hydroxide, in this process. The triglycerides are converted into fatty acid esters, which are the major component of biodiesel, during this process (Merve Çelik Tolu & Oguz, 2018).

Biodiesel has unique physical and chemical properties. Biodiesel has a higher viscosity than petroleum diesel in terms of physical properties. Blending biodiesel with petroleum diesel, on the other hand, can alleviate this issue by decreasing total viscosity and increasing fuel flow characteristics. Biodiesel has a somewhat greater density and is often golden or amber in colour, however this varies depending on the feedstock utilised. Biodiesel dissolves in diesel and other hydrocarbon-based fuels. In terms of chemical properties, biodiesel has oxygen atoms inside the fatty acid ester molecules. This oxygen concentration improves combustion efficiency and lowers emissions during burning. Because biodiesel has a greater flash point than petroleum diesel, it is less dangerous to handle and store. It also has good lubricating characteristics, which help fuel system components last longer by decreasing wear. Furthermore, unlike petroleum fuel, which includes fluctuating quantities of sulphur, biodiesel is practically sulfur-free. The lack of sulphur in biodiesel leads in lower sulphur dioxide emissions, which helps to minimise air pollution (Fan et al., 2019).

2.4 Heterogenous Catalyst

One of the foundations of the chemical and energy industries is heterogeneous catalysis, which will be a key science in facilitating the transition to their eventual carbon-neutral operation. The ultimate objective is to build active and reliable catalytic processes that will benefit society. For essential catalytic processes, it is ideal to design materials with self-regenerating active sites under operating circumstances. In the 1995 ACR papers by Breslow, Bard, and Fox, the pursuit of rational design in catalysis was one of the "holy grails"; the quest is still ongoing, but it is now more urgent. The growing urgency of catalyst development for essential processes such as biomass upgrading, CO_2 reduction, water splitting, and light alkanes activation is due to rising demand for energy, chemical goods, and food, as well as an increase in anthropogenic CO_2 emissions globally .

By removing the additional processing costs associated with homogeneous catalysis and lowering the production of pollutants, heterogeneous catalysts are known to enhance the transesterification process. Catalysts that are heterogeneous encourage simple recovery, reusability, and cost-effective green processes. High FFA and moisture content are tolerated by these catalysts. Heterogeneous catalysts that are effective and affordable aid in lowering the overall cost of making biodiesel. In some difficult circumstances, such as high temperature and pressure, heterogeneous catalysts are regarded as essential. These catalysts can tolerate water treatment procedures, are simple to recover from the reaction mixture, and may be modified to produce high activity, selectivity, and extended catalytic lifetimes (K et al., 2014).

In order to promote grafting and trapping of the active molecules on the surface or inside the pores of a solid support like silica, alumina, or ceria, heterogeneous catalysts can be created. Alkali metal compounds supported on alumina or zeolite, transition metal oxides, mixed metal oxides, alkali earth metal oxides, and ion exchange resins are used in a variety of chemical processes, including isomerization, aldol condensation, Knoevenagel condensation, Michael condensation, oxidation, and transesterification. Alkaline earth metal oxides, such as BeO, MgO, CaO, SrO, BaO, and RaO, are effectively utilised as catalysts. SrO and MgO. Due to its solubility in methanol and strong basicity, strontium oxide does not dissolve. Up to 10 cycles are possible before it loses efficiency. Effective heterogeneous catalysts for the transesterification process include modified zeolites, anionic clays (hydrotalcite), calcium carbonate rock, EST-4 (Eni Slurry Technology), Li/ CaO, MgO/KOH, and Na/NaOH/-Al2O3. For the generation of biodiesel from oils with a high FFA concentration, solid acid catalysts concurrently promote esterification and transesterification (Baskar Thangaraj et al., 2018).

Because of their high catalytic activity and simplicity of use, calcium (Ca) based catalysts are among the heterogeneous catalysts that are highly favoured in the transesterification reaction. It may be found in particular in egg shells, and eggs are one among the foods that are consumed in excess worldwide. Calcium oxide (CaO) was produced by the calcination of waste egg shell that is high in calcium. The quality of the reaction was improved using a high activity CaO catalyst. Solid base catalysts like calcium oxide (CaO), which have a long catalytic life, high activity, and mild reaction conditions, are preferred as environmentally benign materials. CaO is typically produced using calcium hydroxide and calcium nitrate as basic ingredients. Several calcium-rich waste products are also found in nature, including chicken eggshells (Merve elik Tolu & Oguz, 2018).

There are several types of heterogeneous catalysts used, each with its own set of benefits and drawbacks. High catalytic activity and stability are provided by metal oxide catalysts such as magnesium oxide and zinc oxide. They are reasonably priced and widely accessible. Metal oxides, on the other hand, can have lesser selectivity and may require higher temperatures or longer reaction times. They are also prone to deactivation over time. Amberlyst and other ion exchange resins are solid catalysts noted for their high activity and selectivity. Even with a high free fatty acid concentration in the feedstock, they can efficiently convert triglycerides into biodiesel. Although ion exchange resins are stable and may be reused, their activity may decrease owing to fouling or deterioration. They might be water sensitive and may require careful preparation before usage (Niju et al., 2014).

Silica-alumina catalysts have great surface area, superior heat stability, and acidic characteristics. They are capable of esterifying free fatty acids as well as transesterifying triglycerides. Catalytic activity, mechanical strength, and reusability are all advantages of silica- alumina catalysts. They may, however, necessitate greater temperatures and longer response times, and they may be water sensitive, demanding moisture management. Carbon-based catalysts obtained from sustainable biomass sources, such as activated carbon, are inexpensive and have high catalytic activity and selectivity in esterification processes. They are stable and can be regenerated several times for multiple reaction cycles. Carbon-based catalysts, on the other hand, may require higher temperatures or extra activation stages, and they may have lower transesterification rates than alkaline catalysts. Deactivation of the catalyst owing to carbon deposition or contaminants is a potential (Baskar Thangaraj et al., 2018).

2.5 Calcium Oxide (CaO) Catalyst

CaO, often known as quicklime or burned lime, is a heterogeneous catalyst used in the manufacture of biodiesel. CaO catalysts have unique properties that make them ideal for this purpose. CaO is extremely basic, allowing it to efficiently catalyse the transesterification step in the generation of biodiesel. It is made by calcining calcium carbonate, which results in a catalyst with a high concentration of active calcium oxide sites. CaO catalysts have a porous structure and a wide surface area, which allows for effective catalytic activity and improves the transesterification process. CaO catalysts are prepared using a variety of processes, and the method used can affect their physical qualities and catalytic activity. To improve the catalyst's efficacy, activation measures such as heat treatment or hydration-dehydration cycles may be necessary. CaO catalysts are most commonly employed in the transesterification of triglycerides in the production of biodiesel from vegetable oils, animal fats, or waste oils. They are appropriate for both low FFA and high-quality feedstocks, making them adaptable in various biodiesel synthesis techniques (Fan et al., 2019).

CaO catalysts are particularly effective in processes with high FFA concentration because they can catalyse both FFA esterification and triglyceride transesterification. They have been researched for continuous-flow procedures, which will allow for efficient and continuous biodiesel production. With the right regeneration methods, CaO catalysts may be regenerated and reused for several reaction cycles. CaO catalysts, on the other hand, have obstacles and restrictions. They are susceptible to deactivation as a result of carbonation, moisture, or saponification processes. To sustain catalytic activity and lifetime, proper catalyst maintenance, including regeneration or replacement, is required. When utilising CaO catalysts, optimising process parameters is critical to obtaining target biodiesel output and quality (Niju et al., 2014).

2.6 Characterisitic Analysis

Banana peel ash and chicken egg shell ash was studied using XRD, FT-IR and TGA techniques, respectively. X-ray diffraction (XRD) patterns were recorded on a D8 Xray diffractometer , to identify the composition and phase of sample. Fourier Transform Infrared Spectrometer (FTIR) was the type to judge the functional groups. Thermogravimetric analysis was applied to characterize the decomposition of dry banana peel and chicken egg shell.

2.7 XRD Analysis

To ascertain the crystallinity, crystal size, and shape of the metal oxide generated on the catalyst, the XRD examination was carried out. The banana peel ash catalyst's study revealed that it included potassium, calcium, and magnesium. The synthesis of methyl esters during the reaction is further proof that banana peel ash's potassium concentration makes it beneficial as a catalyst in the transesterifification process for the generation of biodiesel (None Meriatna et al., 2023)

2.8 FT-IR Analysis

To identify the kinds of chemical bonds in the material, FT-IR functional group analysis was used. The functional groupings are represented by the clear peaks. The peaks produced by the catalyst's functional groups at the proper wavelengths were adjusted, and the results were qualitatively analysed (None Meriatna et al., 2023).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

Waste chicken egg shell (ES) and ripe plantain peel (PP) which used as precursor materials for bifunctional catalyst were sourced from food stalls located in Jeli, Kelantan, Malaysia. The analytical grade of gamma-alumina (γ-Al_2O_3) was purchased from R&M Chemicals (Subang, SGR, MY) and was used directly without further treatment.

3.2 Methods

3.2.1 Preparation of The Catalyst from CES and PP

The waste CES was primarily soaked and thoroughly washed with clean water to remove surface impurities and white membrane from it. The cleaned CES was subsequently heated up in an oven overnight at 125 °C to get rid the water. Then, the dried CES was crushed into a powder with a mechanical grinder and was sieved through a 0.3 mm mesh to obtain the fine particles. The powdered CES was placed in a glass container, followed by calcination at temperature of 900 °C in a furnace for 4h.

The ripe plantain peel (PP) was manually separated from all dirt by hand and was cut into pieces to hasten the drying process of PP. After washing PP with distilled water several times for eliminating the residual impurities, the PP was dried at 100 °C for 12 hours in an oven. The dried PP was milled into powdery form using milling machine and was later sieved into smaller particle powder using a 0.3 mm mesh. The powdered PP was carbonized at 500 °C for 3 h in an oven. Both calcined CES and carbonized PP were allowed to cool and properly stored in silica gel desiccator prior to use.

In order to prepare the bifunctional catalyst, the calcined CES, carbonized PP and ɣ-Al_2O_3 (EPA) were mixed together (70%, 17% and 13%) in 100 ml of deionized water and then vigorously stirred for 2 h at 80 °C using a magnetic stirrer via incipient wet impregnation as reported by Yusuff et al. (2019). The slurry mixture was dried in an oven at 125 °C to dehydrate the sample and finally calcined for 4 h at 900 °C in a furnace at at heating rate of 10 °C/min. The calcined EPA sample was denoted as EPA catalyst, was then kept in a covered glass container and placed in a desiccator to prevent its contact with atmospheric moisture.

3.2.2 Characterization of Catalyst

The CES, PP and prepared EPA catalyst were characterized using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray diffraction (XRD)

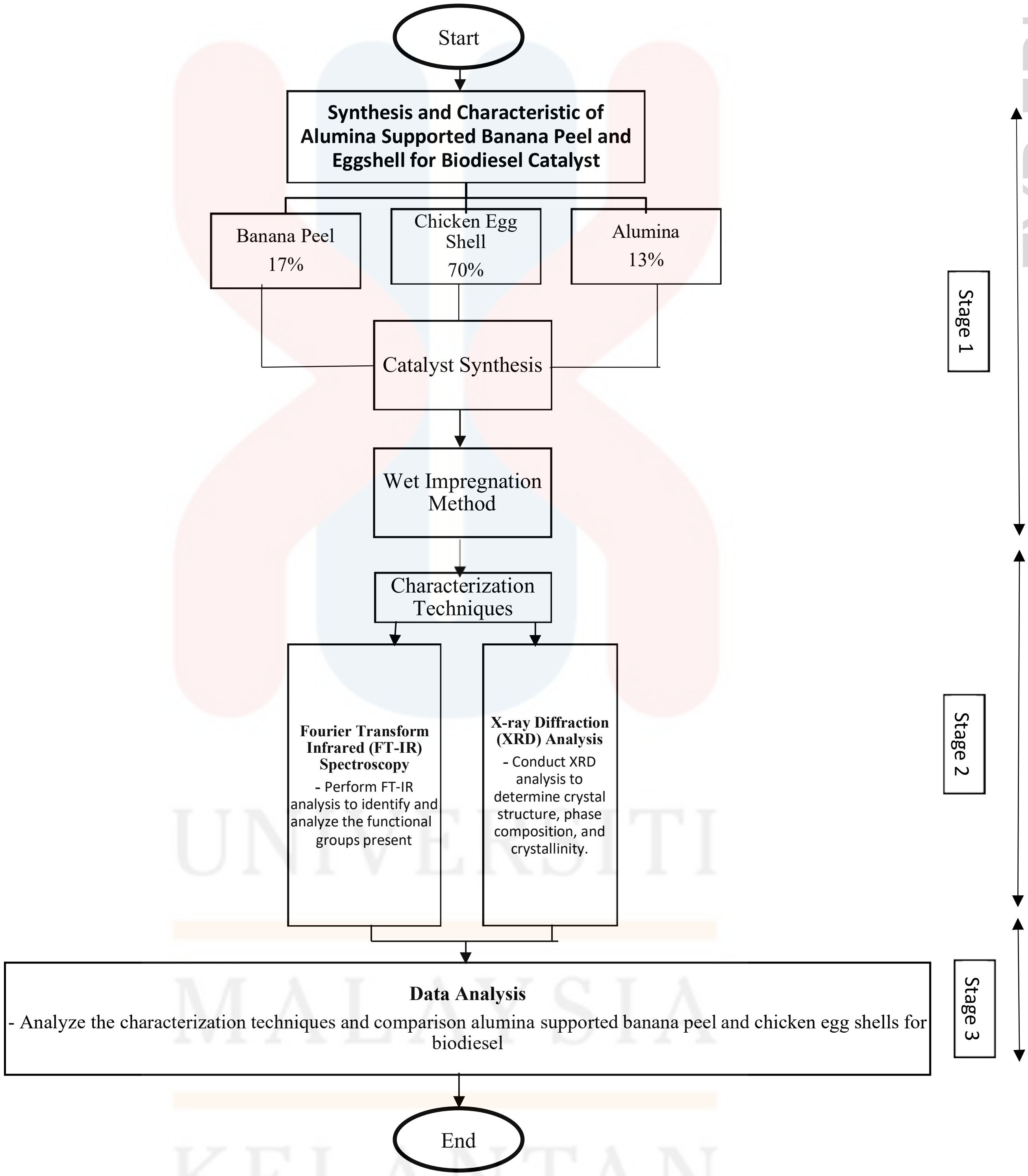
3.2.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

The method of Fourier Transform Infrared (FT-IR) analysis will be employed in this experimentation as to determine the types of the functional groups that will be found in the chicken egg shells and plaintain peel. Almost any contribution to the research will be achieved through assisting in understanding the chemical composition of the catalyst and its possible reactivity by means of this analysis. (Amenaghawon et al., 2022).

3.2.2.2 X-ray diffraction (XRD)

The other Phase is X-ray Diffraction (XRD) analysis available for the crystalline phase of catalytic support material. The first thing this particular XRD will do is search for any phase changes, changes in crystal size or impurities(Amenaghawon et al. 2022).

3.3 REASEARCH FLOW CHART



CHAPTER 4

RESULTS AND DISCUSSION

4.1 FTIR Analysis

The FTIR (Fourier Transform Infrared Spectroscopy) technique is of great contribution to the revealing of molecule structure as it does the vibrational modes study of these molecules. However, this tool is incredibly rich and is used in different areas, such as chemistry, biology and materials science, since it gives detailed information on functional groups, chemical bonds and molecular conformations. Key strength of the FTIR lies in its ability to distinguish chemical components in a sample as well as learn about its structure and composition.

The width of spectral peaks is a representation of the variations of molecular vibrations which are responsible for the absorption bands. The peaks of pure spectra should be sufficiently narrow in order not to interfere with neighboring bands and to give the ability to make the identification precise. The shape of the peaks of the FTIR spectrum is determined by the particularity of the molecule, its anharmonic vibrations, and the interaction between the neighboring molecules. In the perfect condition peaks are symmetrical or asymmetrical shapes depending on the molecular vibration. There may be deviations from the reference peak shapes due to multiple factors, for example, the sample impurities, surface modifications, or instrumental imperfections. This shape of asymmetries or distortions can be very revealing for studying the chemical environment and interactions inside the catalyst material, so it helps in detecting catalyst impurities or structural changes.

Through FTIR spectroscopy sample preparation, it is essential to carefully follow the instructions to avoid any errors. The first step of the analysis process is to position and align the samples carefully on the FTIR sample holder or stage to achieve proper alignment and spectral acquisition. Besides, the air samples should be handled carefully, keeping their exposure to air minimal, to prevent moisture absorption or contamination, which could be detrimental to the samples' integrity, consequently leading to less reliable spectral data. The instrument calibration, a very essential step in the FTIR analysis process, now aims at ensuring the accuracy and reliability of the spectral data. This procedure involves thorough calibration of the FTIR instrument as well as utilization of proper calibration standards like polystyrene film to obtain precise wavenumber calibration and spectral precision. Follow these calibration parameters to be able to reduce the deviations in spectral measurements which will allow accurate and consistent analysis.

An important aspect of the Fourier transform infrared (FTIR) spectral acquisition is covering the spectral range (4000–400 cm^{-1}) with the given attention to the resolution and the averaging parameters. A number of replicate spectra should be obtained for each sample to verify the reproducibility by minimizing the random noise and consequently increasing the credibility and robustness of analysis. The preliminary FTIR spectra are collected and the thorough data analysis is performed using dedicated software. This task involves doing baseline correction to obtain a stationary signal, followed by peak resolution and spectral interpretation. A discovery of characteristic peaks, which indicate the presence of functional groups and molecular vibrations of the banana peel and eggshell catalysts, can be achieved by means of this analysis, allowing the researchers to gain information about their chemical composition and structure and to learn about their catalytic properties.

From figure 1 infrared spectroscopy is one of the most potent analytical methods that make it possible to determine functional groups and molecular structures, due to absorbance of infrared radiation by chemical bonds. Region 4000.00 to 400 cm evaluated for the sample on a spectrum EPA is one of the amount of material substance composition. In this analysis we are glancing out the peaks found in the EPA spectrum, giving reference to their positions and intensities. The EPA was analyzed with respect to the absolute threshold of 98.514 and a sensitivity of 60 – the criteria applied to detect peaks in the data. The peak list displays various important components and their respective intensities which has given insight to the vibrational modes present in the sample. Paradoxically, peaks were noted in the lower wavenumbers at locations such as 40 1.90, 410.09, and 413.53 cm^{-1} with values of intensities measured as 38.807 and 46.007. Such peaks are likely to occur due to fundamental vibrations associated with functional groups or molecular bonds relating to sample detectable.

In moving towards higher wavenumbers, the spectrum has peaks at wavenumber positions such as 476.38, 494.58, and 505.37 cm -1, the wavenumber intensities increase between wavenumber of 57.663 to 58.486. Such peaks could hint at extra intricate molecular interplay's or structural moieties of the sample. Significantly, sharp peaks were seen at the positions 710.50, 772.36, 1053.32, and 1409.16 cm -1, with intensities exceeding 84.137, thus revealing considerable molecular vibrations or functional group characteristics in the sample.

In the higher region, peaks occurred at 2106.30 cm^{-1} and 2355.91 cm^{-1} with intensities exceeding 95.178 reflecting the presence of strong absorption bands due to the presence of certain chemical entities or structural features. Transmission of peaks based on the analysis of the spectrum EPA allows getting an accurate understanding of molecular content and structural features which the sample to be studied possesses. Through analysis of the positions and intensities of these peaks, researchers can develop a better understanding of the chemical composition and bonding around the sample, allowing for proper identification and characterization of the sample.

Calcium carbonate (CaCO3) contained in chicken egg shells tends to form spectra characteristics that comprise vibration peaks between 1400-1600 cm^{-1} for the stretching function and those between 700-900 cm^{-1} for the bending function. Al2O3 has peaks due to vibrations in Al-O bonds falling between 600-800 cm^{-1}, and hydroxyl groups (-OH) stretching vibrations, around 3200-3600 cm^{-1}, and their corresponding bending vibrations are in the range of 1600-1700 cm^{-1}. Peaks that relate to functional groups of a cellulose, hemicellulose, and others vibration bands of OH stretching at 3200-3600 cm^{-1} and C-O stretching at 1000-1200 cm^{-1} are manifest in the peak of an organic material known as the banana peel. It has bands of carboxylic acids.

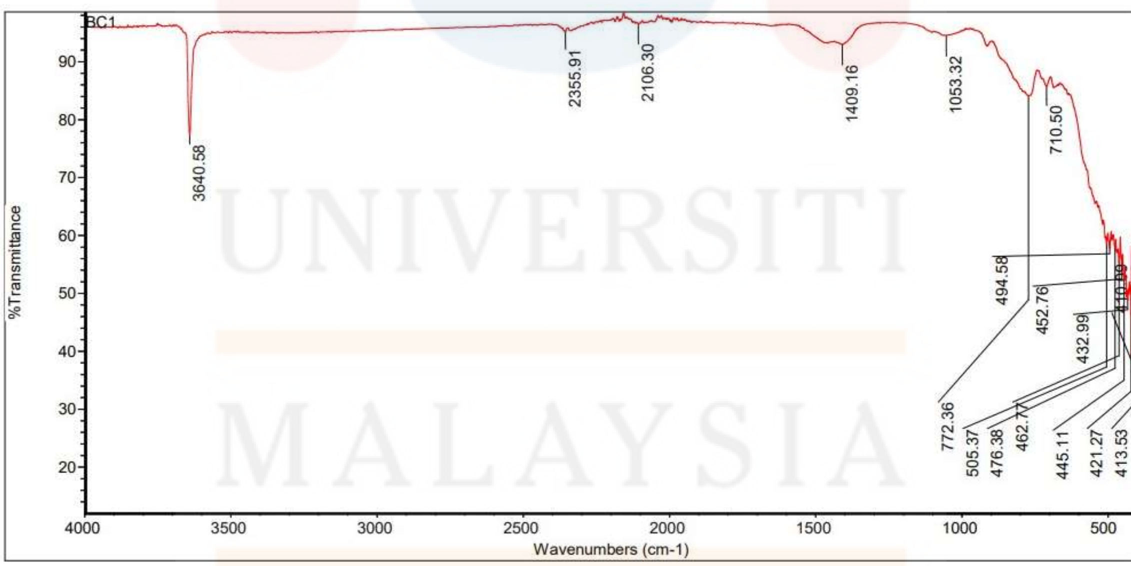


Figure 4.1 : Fourier Transform Infrared (FT-IR) of the EPA catalyst

Wavenumbers (cm-1)	%Transmittance
1409.16	92.951
1991.45	96.780
2106.30	96.562
2171.20	96.978
2355.91	95.178
3640.58	77.281

Table 4.1 : Transmittrance and Wavenumber (cm-1) Fourier Transform Infrared (FT-IR) of the EPA catalyst

4.2 XRD Analysis

X-ray diffraction (XRD) is an important technique in crystallography, performing the primary task of the investigation of crystal-type issues. By examining the X-ray diffraction pattern generated when X-rays interact with the atomic arrangement of a sample, XRD effectively allows for the crystalline phases, lattice parameters, and atomic positions to be identified, thus forming the basic of material characterization and structural investigation studies. XRD will be utilized in order to identify the crystalline phases presence in the catalyst material. This analysis will furnish information about the structure of the catalyst, shedding light on its physical properties, for instance, crystaitnal size, orientation, and crystallinity The molecular organization of the catalyst is a paramount issue in improving the catalytic activity and revealing the mechanism behind its effectiveness in biodiesel synthesis.

Through the X-ray diffraction analysis of biodiesel catalyst which uses EPA as components, the crystallographic details of each compound have the foremost impact in interpretation of their catalytic activity. Calcium carbonate with a typical trigonal crystal system and rhombohedral lattice pattern is present in every chicken eggshell. Its diffraction characteristics represented by its diffraction patterns, peak positions and crystallographic data give a clue as to what crystal phases it is made up of, which hence help in its characterization to find its purity and phase composition. Calcium hydroxide, that banana peel has, belongs to the class of substances with cubic crystal system and the space group of Fm-3m and has face-centered cubic lattice structure.

The diffraction spectra show specific peaks associated with the atom planes of crystallographic structure that help in qualitative phase determination and refinement of the structures. The hydrogenarnet structure, found in association with the other stable alumina oxide, shows a Pbnm orthorhombic crystal system with a perovskite-like lattice structure. The diffraction data of hydrogarnet reveals the crystallographic orientation of the compound and purity of the phase; consequently, it can be seen as a promising catalyst. Data's quality is analyzed through the sheer power and resolution of the diffraction peaks, this index is a number that refers to correctness of the captured data. The literature sources including scientific journals and textbooks are useful for obtaining additional details and background characteristics of the crystalographic properties of every part, which then facilitates the interpretation of XRD results for the catalyst in biodiesel production.

In biodiesel catalysts there are three important components namely calcium hydroxide, calcium carbonate, and hydrogenate. The roles of these components in the catalytic activity are made evident by the appropriate crystallographic features. Calcium carbonate exists as many polytypes such as calcite, aragonite and vaterite, each with their different competitive crystal structures. Thereby, prevents them from immobilizing rapidly. Calcite is usually characterized by three-dimensional crystal truncations in the trigonal system while aragonite exhibits along the conventional orthorhombic. Vaterie which has the most unstable polymorph of the hexagonal crystal system is among the signs of yellow colour. The structure of calcium hydroxide, … The structure of calcium hydroxide, portlandite, is usually in the form of hexagonal crystals frequently found in hydrated Portland cement. Hydrogarnet demonstrates the whole spectrum of different crystallographic properties because of its chemical composition. It is a subset of minerals within the broader garnet family and it is one of the most common minerals. Such crystallographic characteristics of catalyst are of vital importance because they govern the productivity and performance of biodiesel catalyst through surface area, active sites and reaction kinetics. Recognizing the characteristics of each sublimate at a crystallographic level is critical for developing optimal design procedure to increase the activity of catalyst and efficiency of biodiesel production processes.

From the figure 4.2 XRD analysis of catalyzer contains X-ray it provides the diffraction data offers valuable insights into a crystallographic feature of Calcium Carbonate (CaCO3), Calcium Hydroxide (CaH_2O_2) also known as Portlandite and Hydrogarnet (Al_2O_3). Among them are diffraction patterns, peak positions and crystallographic information. XRD data therefore control the crystal phases and compositions of the studied samples. The diffraction pattern analysis along with the peaks position and crystallographic parameters show us the atomic positions and crystal structures of those materials.

The diffraction pattern from Calcium Carbonate exhibits distinct peaks at different 2θ angles, implying that some crystallographic planes are present in the sample. The excerpt lacks details like lattice structure and space groups which are very important. Data quality index is assigned the string " Quality Unknown," in the case, data or sample quality are not specified. Additionally, the main reference for Calcium Oxide is not mentioned which creates a lack in the entire knowledge of the material.

Passing on to Calcium Hydroxide (Portlandite), the diffraction pattern also exhibits peaks corresponding to crystallographic planes. The lattice structure is defined as hexagonal with the space group P -3 m 1 (164) supported by details like molecular weight and volume parameters. Despite the detailed structural information, the quality of the diffraction data remained "Unknown Quality", making it unclear either about the quality of the data or the sample. The main reference by Desgranges L et al. deals with hydrogen thermal motion within calcium hydroxide determining the Portlandite crystallography.

As regards Hydrogarnet (Al_2O_3) the diffraction pattern presents peaks at various 2θ angles indicating specific planes present in the sample. The architecture of the structure is determined as cubic with the space group Ia3¯d (230), and the parameters of the mass and volume are complemented. Lager GA et al.'s main reference provides a detailed neutron and X-ray diffraction study of Hydrogarnet, yielding a thorough view of the crystal structure of the mineral at the designated temperature.

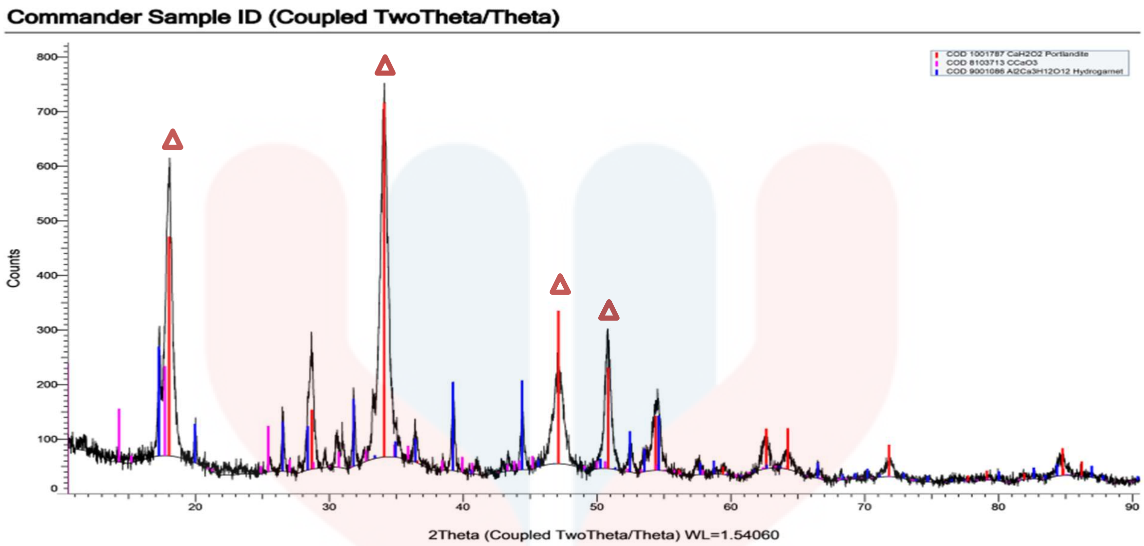


Figure 4.2 : XRD analysis for EPA catalyst

4.3 TGA Analysis

Thermogravimetrization (TGA) is an important technique for the analysis and characterization of biodiesel catalysts prepared from EPA catalyst. TGA is an advanced methodology that reveals the part played by mass during the process consist of heating or time course under the fellowship of particular atmosphere conditions. The TGA analysis of catalyst parameters is a vital tool which gives key information on the structure stability, decomposition process, and components properties of the catalyst materials. This technique targets catalyst samples in a controlled temperature ramp that is in line with the rate of mass loss variations for an object. TGA allows for the differentiating key thermal events such as decomposition, desorption and oxidation processes. Thus they are especially important regarding the thermal properties of the catalyst components, selecting optimal temperatures for a catalytic reaction, defining catalyst stability at operating conditions, and uncovering the presence of pollutants or the residual. The use of TGA for assessing the thermal properties of banana peel, chicken egg shell, and alumina oxide based catalysts is quintessential for guaranteeing their suitability for biodiesel production. Therefore TGA plays a critical role and guarantees efficient and reliable biodiesel production processes.

Sample preparation for TGA analysis is a crucial step that help in improving the reliability and accuracy of the result. To begin with, the catalysts of EPA catalyst are chosen at random from a representative sample which is free of any contaminants and homogeneous. Following that, the appropriate amounts of each sample are measured on a precision analytical balance, mindful of the TGA instrument sensitivity and the anticipated mass loss during analysis. Cleanliness of samples is ensured by handling them carefully and by using measures such as wearing gloves. The samples with moisture are pre-dried to remove any moisture content by keeping them in an oven at a temperature below the composition temperature until achieving a constant weight. Based on the type of samples utilized and the TGA device used, the samples may require encapsulation, or they may be placed in appropriate sample pans/crucibles made of chemically inert materials. Once weighed properly samples into the prepared pans or crucibles are then allowed to settle down and equilibrate to the environment and temperature conditions of the TGA design ahead of the experiment to minimize transient effects. To finish, the content on each sampling pan or crucible is carefully labeled with all the necessary data for the record and later use during interpretation and analysis. Executing these particular sample preparation procedures make possible quick and accurate gas thermal analysis results by conditioning the catalyst samples adequately.

The results of the thermal analysis process reveal significant findings. The analysis showed a step change in weight loss of 17.8243%, equivalent to a decrease in weight of 0.4278 milligrams. The temperature range for the analysis was between 39.54 degrees Celsius and 495.43 degrees Celsius, with a constant heating rate of 10.00 degrees Celsius per minute. The analysis type was categorized as horizontal, and an inflection point was observed at 419.56 degrees Celsius. The midpoint temperature recorded during the analysis was 402.17 degrees Celsius. Additionally, another step change in weight loss was noted, with a percentage decrease of 24.9595% or a weight loss of 0.5990 milligrams. A residue of 57.2045% or 1.3729 milligrams was left after the analysis, with temperature limits of 495.90 degrees Celsius to 896.72 degrees Celsius for this step. The inflection point for the second step was at 634.95 degrees Celsius, and the midpoint temperature was recorded at 632.28 degrees Celsius. These results provide detailed insights into the weight changes, temperature parameters, inflection points, and residue observed during the thermal analysis process.

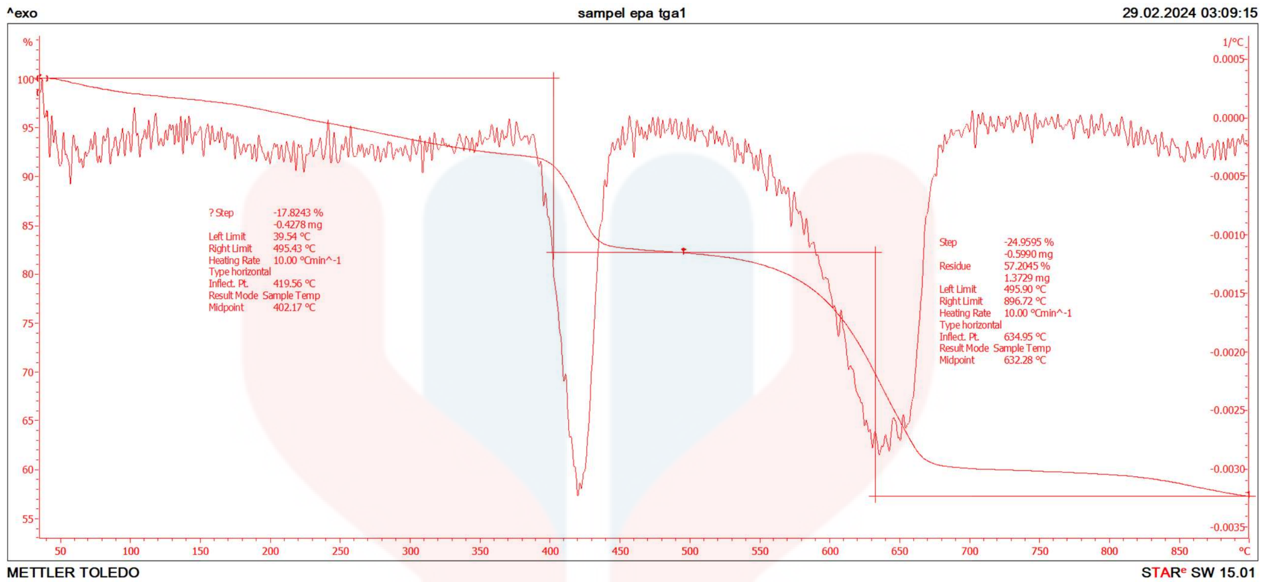


Figure 4.3 : TGA analysis for EPA catalyst

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For the conclusion, carried out comprehensive research on the characterization of alumina-supported catalysts obtained from chicken eggshells and plaintain peel as a potential biodiesel production. The application of different techniques including the wet one revealed careful examination. Impregnation, aimed to unravel the structural and compositional properties of the developed catalyst. The first phase in undertaking this thesis is to thoughtfully gather raw materials, especially chicken eggshells and potato skins. The washing, drying, grinding and filtering eliminates impurities and produces microparticles. Heat treatment and carbonization at hightemperatures are the critical stages that lead to transformations in the material and are the responsible ones for that. Foundation for the subsequent catalytic activity.

This thesis was thus devoted to the study of the characterization of the alumina-supported catalysts from chicken eggshells and plaintain peel through which to produce sustainable and efficient catalysts for biodiesel production. A comprehensive knowledge of the catalysts composition, the desired structure and the catalytic ability was attained using different complicated methods, respectively. techniques like Fourier Transform Infrared (FT-IR) spectroscopy and X-ray Diffraction (XRD).

The choice of alumina as a support is due to its known characteristics among others. catalytic properties and stability. The wet impregnation technique enhances the uniform eggshells distribution, plaintain peel', and aluminium oxides in the catalyst composition. The selected proportions 70% chicken eggshells, 17% plaintain peel and 13% alumina oxide (Al_2O_3) were optimized for catalytic efficiency considering the synergistic effects of each component.

The required percentage of 70% chicken eggshells, 17% plantains peel, and 13% alumina oxide used in the biodiesel catalyst formulation are selectively chosen to maximize catalytic activity and performance. Every one of these and other components makes its special contribution to the improvement of the catalyst's performance in all stages of biodiesel production. The main element of the eggshell, which is the crushed up chicken eggshells, accounts for a large fraction of the total activity of the catalyst. The calcium carbonate present in eggshells serves as a heterogeneous catalyst, with its active sites being the points for conversion of triglycerides into biodiesel and glycerol by aided transesterification reaction. Eggshell-origin $CaCO_3$ high surface area and pore structure are responsible for the faster reaction rates and better yields of biodiesel laced with enhanced catalytic efficiency.

Overall, the chicken egg shells holds about 83% of the catalyst material with the remaining 17% being contributed by the plantain peels which functions as a valuable co-catalyst, boosting the catalytic activity of the primary catalyst. Plantain peel contains a lot of organic components like hemicellulose, cellulose and lignin which can go through hydrolysis and acid-catalyzed reactions to give more acidic sites. Among the elements that help to enhance the acidity and surface activity of the catalyst is the presence the active groups such as hydroxyl (-OH) and Carboxyl (-COOH) that speed up the transesterification process leading to quality biodiesel yield. Alumina oxide, which is a 13% constituent of the formulation acts as a stabilizing agent and catalyst for the promoter system. Alumina oxide helps to distribute the catalyst load unto the matrix ensuring that the active components do not agglomerate into a mass or sinter during reaction temperatures. Moreover, alumina oxide is able to influence the surface properties of the catalyst, thus contributing to the improvement of its high temperature stability, acidity and resistance to catalyst deactivation. That way there is a long use life and high performance of the catalyst that results in a stable and reliable biodiesel manufacturing process.

The combination of chicken eggshells, plantain peel and alumina oxide is cleverly blended by the researcher to boost catalytic efficiency, reaction rates and product selectivity in biodiesel production processes. The catalyst formulation is designed to use the special features of each component in order to achieve the best possible performance. The catalyst maximizes the yield of biodiesel production, reduces production costs, and minimizes the environmental impact at the same time.

Alumina, or aluminum oxide, was selected as a catalyst support material in the research since it has certain characteristics that make it distinguished among other catalysts and more stable, too. Conventionally used in numerous chemical processes, alumina is a well-rounded molecule with a wide range of advantages. First of all, its high surface area features a lot of active sites which are capable of carrying out catalytic reactions, making the process of chemical occurrence more efficient. Besides, alumina shows unafraid thermal stability, being suitable for resist huge temperature without being not destroyed so far to make the process of catalytic materials much longer and stably. Not only that, the opposite of chemical reactivity assures that the enzyme remains intact by not undergoing side reactions during the procedure. Moreover, its ability of being the Dual base for acidic and basic reactions make the substance the ideal choice for a number of catalytic reactions which are very diverse and therefore cater to different reaction requirements. Besides, by far, its regenerability feature is another factor that permits the performance of multiple cycles of catalytic reactions without high losses in function, making the implementation of the industrial process feasible. Generally we may ascertain the selection of that alumina as a catalyst support is due really to its favorable features that are really valuable and its versatility. Thus, no doubt it is the suitable agent for achieving the conversion utilized in biodiesel manufacture.

Lastly, integrating different characterization methods has created a general picture. knowledge on alumina-supported catalysts produced from chicken eggshells and plaintain peel. Characterization that was reliable and complete opens up room for possible deep sense technology application in biodiesel production. This work not only moves the field of catalysis but also synchronizes with sustainable practices using agricultural waste as catalyst component.The findings the present research paves the way for future studies and the continued progression of ecological and productive catalysts having application in renewable energy.

5.2 Recommendation

The presentation of alumina supported catalysts as developed using chicken eggshells and plaintain peel that could be employed in the production of biodiesel has opened up various lanes of possibilities of future studies and utilization. This research focuses on the sustainable use of waste as catalyst and offers several dissertations in the development and usage of catalyst henceforth.

It is the first proposal to focus on the deeper aspects of the catalyst synthesis supposition. Although the current study has provided a good basis, parameters namely calcination temperature, impregnation techniques, and support to waste ratio can always be further optimized. This fine-tuning of these parameters would see to it that one would improve catalytic activity and stability, hence, pushing the efficiency of the catalyst to the limit.

The following knowledge is essential to enhance the fields, is the knowledge of the complications in the catalytic processes that occur during the production of biodiesel. By next generations researchers should be concentrated on mechanistic studies, which allow to clarify the relationships between the catalyst and the reactants; discussing not only a reaction's pathways but provided selectivity as well.

A key factor to consider in practical usages is long-term alumina-supported catalyst stability assessment. Potential deactivation mechanisms should be considered, and ways should be devised for regeneration of the catalyst should be looked at by the researchers. Exploring the feasibility of reusing, while recycling catalysts where possible.

Although that aside, scale-up studies are conducted in order to move from the lab to the actual application. While these studies will test the applicability of alumina-supported catalysts on larger scales of biodiesel production they will be guided by considerations of scalability and applicability within industrial conditions. Ever concurrently, complete economic valuations must be made the cost-effectiveness of biodiesel production with these catalysts based on traditional methods has to be compared CR02.

Eventually, by widening the study to include other waste materials as catalyst precursors, the scope of undeveloped catalysts spanning sustainability is widened. By carrying out an extensive analysis of agricultural as well as food industry waste, researchers can find alternatives sources of catalyst synthesis. Particularly, the partnerships with biodiesel producers guarantee that research is based on problems in real life and lays the ground for the easy incorporation of innovative catalysts in industrial processes.

REFERENCE

Fekadu Ashine, Zebene Kiflie, Sundramurthy Venkatesa Prabhu, Belachew Zegale Tizazu, Venkatramanan Varadharajan, Manivasagan Rajasimman, Joo, S.-W., Yasser Vasseghian, & Jayakumar, M. (2023). *Biodiesel production from Argemone mexicana oil using chickeneggshell derived CaO catalyst*. *332*,126166–126166. https://doi.org/10.1016/j.fuel.2022.126166

Colombo, K., Ender, L., & Barros, A. S. (2017). *The study of biodiesel production using CaO as a heterogeneous catalytic reaction*. *26*(2),341–349. https://doi.org/10.1016/j.ejpe.2016.05.006

Kassian T.T. Amesho, Lin, Y.-C., Chen, C.-E., Cheng, P.-C., & Sumarlin Shangdiar. (2022). *Kinetics studies of sustainable biodiesel synthesis from Jatropha curcas oil by exploiting bio-waste derived CaO-based heterogeneous catalyst via microwave heating system as a green chemistry technique*. *323*, 123876–123876. https://doi.org/10.1016/j.fuel.2022.123876

Madhuri Pydimalla, Sadia Husaini, Akshara Kadire, & Raj Kumar Verma. (2023). *Sustainable biodiesel: A comprehensive review on feedstock, production methods, applications, challenges and opportunities*. https://doi.org/10.1016/j.matpr.2023.03.593

Lorena, C., Tulio Armando Lerma, & Manuel Palencia Luna. (2023). *Spectral dynamics analysisof pesticide residues in banana peel during the ripening process*. *121*, 105354–105354. https://doi.org/10.1016/j.jfca.2023.105354

Zurena Mohd Salleh, Noor Azlin Yahya, Muhammad Nasarudin, & Dea Natasha Herman. (2021). *Transesterification of used frying oil by activated banana peels waste catalyst for biodiesel production*. *57*, 1235–1240. https://doi.org/10.1016/j.matpr.2021.11.074

Adeyinka Sikiru Yusuff, Gbadamosi, A. O., & Neeraj Atray. (2022). *Development of a zeolite supported CaO derived from chicken eggshell as active base catalyst for used cooking oil biodiesel production*. *197*, 1151–1162. https://doi.org/10.1016/j.renene.2022.08.032

Minakshi Gohain, Devi, A., & Deka, D. (2017, August 13). *Musa balbisiana Colla peel as highly effective renewable heterogeneous base catalyst for biodiesel production*. ResearchGate; Elsevier. https://www.researchgate.net/publication/319116720_Musa_balbisiana_Colla_peel_as_highly_effective_renewable_heterogeneous_base_catalyst_for_biodiesel_production

Fan, M., Wu, H., Shi, M., & Jiang, P. (2019). *Well-dispersive K2O KCl alkaline catalyst derived from waste banana peel for biodiesel synthesis*. *4*(3), 322–327.

https://doi.org/10.1016/j.gee.2018.09.004

None Meriatna, Husni Husin, Riza, M., Faisal, M., Ahmadi, N., & None Sulastri. (2023). *Biodiesel production using waste banana peel as renewable base catalyst*. https://doi.org/10.1016/j.matpr.2023.02.400

Carine Tondo Alves, Peters, M. A., & Onwudili, J. A. (2022). *Application of thermogravimetric analysis method for the characterisation of products from triglycerides during biodiesel production*. *168*, 105766–105766. https://doi.org/10.1016/j.jaap.2022.105766

S. Niju, Meera, K. M., Begum, S., & Anantharaman, N. (2014). *Modification of egg shell and its application in biodiesel production*. *18*(5),702–706. https://doi.org/10.1016/j.jscs.2014.02.010

Prajapati, P., Shrivastava, S., Sharma, V., Srivastava, P., Virendra Shankhwar, Sharma, A., Srivastava, S. K., & Agarwal, D. D. (2023). *Karanja seed shell ash: A sustainable green heterogeneous catalyst for biodiesel production*. *18*, 101063–101063.

https://doi.org/10.1016/j.rineng.2023.101063

K, E. A., Kiros, Y., & Zanzi, R. (2014). Inorganic heterogeneous catalysts for biodiesel productionfrom vegetable oils. *Biomass and Bioenergy*, *35*(9), 3787–3809. https://www.cabdirect.org/cabdirect/abstract/20113311340

Friend, C. M., & Xu, B. (2017). Heterogeneous Catalysis: A Central Science for a Sustainable Future. *Accounts of Chemical Research*, *50*(3), 517–521. https://doi.org/10.1021/acs.accounts.6b00510

Saleem, M., Jamil, F., Obaid Ali Qamar, Akhter, P., Hussain, M., Muhammad Shahzad Khurram, Al-Muhtaseb, A. H., Abrar Inayat, & Noor Samad Shah. (2022). Enhancing the Catalytic Activity of Eggshell-Derived CaO Catalyst and Its Application in Biodiesel Production from Waste Chicken Fat. *Catalysts*, *12*(12), 1627–1627. https://doi.org/10.3390/catal12121627

T.E. Odetoye, Agu, J. O., & Ajala, E. O. (2021). Biodiesel production from poultry wastes: Waste chicken fat and eggshell. *Journal of Environmental Chemical Engineering*, *9*(4), 105654–105654. https://doi.org/10.1016/j.jece.2021.105654

Jutipong Poosumas, Kanokwan Ngaosuwan, Quitain, A. T., & Suttichai Assabumrungrat. (2016). Role of ultrasonic irradiation on transesterification of palm oil using calcium oxide as a solid base catalyst. *Energy Conversion and Management*, *120*, 62–70. https://doi.org/10.1016/j.enconman.2016.04.063

Nabilah Atiqah Zul, Ganesan, S., Tuan Sherwyn Hamidon, Oh, W.-D., & M. Hazwan Hussin. (2021). A review on the utilization of calcium oxide as a base catalyst in biodiesel production. *Journal of Environmental Chemical Engineering*, *9*(4), 105741–105741. https://doi.org/10.1016/j.jece.2021.105741

Muhammad Aamir Bashir, Wu, S., Zhu, J., Anilkumar Krosuri, Muhammad Usman Khan, & Ndeddy, J. (2022). Recent development of advanced processing technologies for biodiesel production: A critical review. *Fuel Processing Technology*, *227*, 107120–107120. https://doi.org/10.1016/j.fuproc.2021.107120

Etim, A. O., P. Musonge, & A.C. Eloka-Eboka. (2022). A green process synthesis of bio-composite heterogeneous catalyst for the transesterification of linseed-marula bi-oil methyl ester. *Results in Engineering*, *16*, 100645–100645. https://doi.org/10.1016/j.rineng.2022.100645

Baskar Thangaraj, Pravin Raj Solomon, Bagavathi Muniyandi, & Lin, L. (2018, December 17). *Catalysis in biodiesel production—a review*. ResearchGate; Oxford University Press. https://www.researchgate.net/publication/329869072_Catalysis_in_biodiesel_production-a_review