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Characterization of Coconut Shell - Plantain Peel as a Dual Potential Biochar Catalyst of Biodiesel Application

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DECLARATION

I declare that this thesis entitled "Characterization of coconut shell - plantain peel as a dual potential biochar catalyst of biodiesel application" is the results of my own research except as cited in the references.

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Characterization of Coconut Shell - Plantain Peel as a Dual Potential Biochar Catalyst of Biodiesel Application

ABSTRACT

This study aims to synthesize a bifunctional catalyst from a mixture of powdered coconut shell and plantain peel, denoted as coconut-banana peel biochar (CP). The focus is on characterizing CP, particularly the CP2 sample heated to 700 degrees Celsius, using FT-IR, XRD, TGA and BET analyses. The experimental setup highlights the significance of CP2 in biodiesel applications. The results reveal the superior performance of CP2 over CP1 and CP3, specifically showcasing its enhanced catalytic activity. The comprehensive characterization employs FTIR, BET, TGA, and XRD techniques, providing numerical values for essential properties of CP2, such as surface area (147.179 m2/g) and pore diameter (76.04478 Å). CP2 properties, including its high catalytic activity, suitable surface area, and sufficient pore diameter, make it promising for biodiesel applications, particularly in catalysis and gas separation processes. The optimal balance achieved by CP2 in surface activity, adsorption capacity, and the ability to accommodate larger molecules further emphasizes its potential. In conclusion, CP2 emerges as a dual-functional biochar catalyst with promising applications in biodiesel production. Acknowledging the unique features of CP1 and CP3 in different contexts underscores the versatility and potential broader applicability of the synthesized biochar catalysts.

Keywords: Biodiesel catalyst, Coconut shell, plantain peel, Characterization technique

Pencirian Kulit Kelapa-Pisang Sebagai Pemangkin Biochar Berpotensi Ganda Aplikasi Biodiesel

ABSTRAK

Kajian ini bertujuan untuk mensintesis pemangkin bifungsional dari campuran kulit kelapa serbuk dan kulit pisang, yang dilambangkan sebagai biochar kulit kelapa-pisang (CP). Fokusnya adalah untuk mencirikan CP, terutamanya sampel CP2 yang dipanaskan hingga 700 darjah Celsius, menggunakan analisis FT-IR, XRD,TGA dan BET. Persediaan eksperimen menekankan kepentingan CP2 dalam aplikasi biodiesel. Hasilnya mendedahkan prestasi unggul CP2 berbanding CP1 dan CP3, secara khusus mempamerkan aktiviti pemangkin yang dipertingkatkan. Karakteristik komprehensif menggunakan teknik FTIR, BET, TGA, dan XRD, memberikan nilai numerik untuk sifat penting CP2, seperti kawasan permukaan (147.179 m2/g) dan diameter liang (76.04478 gram). Sifat CP2, termasuk aktiviti pemangkin yang tinggi, kawasan permukaan yang sesuai, dan diameter liang yang mencukupi, menjadikannya menjanjikan untuk aplikasi biodiesel, terutamanya dalam proses pemangkin dan pemisahan gas. Keseimbangan optimum yang dicapai oleh CP2 dalam aktiviti permukaan, kapasiti penyerapan, dan keupayaan untuk menampung molekul yang lebih besar lebih menekankan potensinya. Kesimpulannya, CP2 muncul sebagai pemangkin biochar dua fungsi dengan aplikasi yang menjanjikan dalam pengeluaran biodiesel. Mengakui ciri - ciri unik CP1 dan CP3 dalam konteks yang berbeza menggariskan fleksibiliti dan potensi penerapan yang lebih luas dari pemangkin biochar yang disintesis.

Kata kunci: pemangkin Biodiesel, Tempurung kelapa, kulit pisang, teknik Pencirian

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LIST OF ABBREVIATIONS

CS	Coconut Shell
PP	Plantain peel
CP	Mixture Of Coconut Shell And Plantain Peel
FT-IR	Fourier Transform Infrared
XRD	X-ray Diffraction
BET	Brunauer - Emmett - Teller
WCO	Waste Cooking Oil
SiO_2	silicon dioxide
K	Potassium
HC	Hydro carbons
CO	Carbon Monoxide
K_2CO_3	Potassium Carbonate
KCI	Potassium chloride

LIST OF SYMBOLS

2θ	Diffraction Angle
Å	Angstrom Unit
°C	Degree Celsius
%	Percentage
cm^-1	Inverse Centimeters

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Since fossil fuels can be easily harnessed because of their high energy density and unopposed availability and have dominated as the primary sources of energy for many decades. But through their nonstop usage, a myriad of issues have arisen, including the degradation of the environment and the amplification of climate change. As combustion of fossil fuels these levels of beneficial compounds, including a lot of greenhouse gases most notably the carbon dioxide (co2), amass to the wind. Since it is one of the contributors to the intensification of the greenhouse effect, it also leads to global warming (Howard et al, 2022). Besides, mining, transportation, and the processing of fossil fuels result in diverse pollution patterns, disrupted ecosystems, and damaged habitat.

The urgent demand to level off climate change and reduce our utilization of the non-renewable resource has prompted improved enthusiasm towards the study of renewable and off the beaten track types of power generation. As a possible competitor of diesel fuel conventional diesel fuel, biodiesel is a type of diesel fuel alternative produced solely from renewable biological resources (None Monika et al., 2023).

Today's growth of economy is accompanied by switches in transportation and logistics basing on the innovations.Progress has continued. Yet with the interest in the renewable energy, electric and hybrid engines, fossil fuels are still a significant element of the economic growth which is fast expanding. Use of non-renewable resources has been overly used as a means of producing greenhouse gases. Greenhouse gas emissions associated with the combustion of fossil fuel contribute for about 30%. If it persists, the demand for stock markets will lead to 1.3 % rise in the consumption of fossil fuel every month, by 2030. Demand for diesel filed up with 6.7% every year between 2010 and 2017 upheld the trend. The rapid technological development in the development of engines, petrol catalysts, paints and air conditioning systems significantly increases the expected carbon footprint until and estimated at 80% by 2030 (Das and Chowdhury, 2023).

Biodiesel, a renewable energy alternative for diesel fuels is studied by researchers in the last few decades. Sustainable biofuel fuel is non-toxic, non-hazardous to wildlife, and eco-friendly. During biodiesel combustion, carbon monoxide (CO) and unburnt hydrocarbon (HC) emissions are reduced (2023, Raj Bukkarapu and Krishnasamy).Combustion efficiency increases. Diesel engine runs well on biodiesel without modification to the engines. Acrossed by the transesterification reaction, biodiesel is prepared due to a chemical reaction. Biodiesel and glycerine are formed by means of the reaction between feedstock triglycerides rendering vegetable oils or animal lipids and an alcohol, like methanol or ethanol with the catalyst. Vegetable oils and animal.

Stoichiocity, lower sulphur and aromatic content, higher specific number, low cost, and biodegradability are the benefits of biodiesel as fuel for diesel engines. Biodiesel cuts carbon emissions. Shedding less carbon dioxide, biodiesel is fractionally cleaner. Owing to traces less impurities and plenty of oxygen, it burns purer than natural gas which leads to less particulate matter, CO, SOx. Using biodiesel this would reduce the lifecycle GHG by 57% to 86% when compared to the petroleum diesel (Rocha-Meneses et al.). The use of biodiesel leads to decrease of smog-forming nitrogen oxides (NOx), volatile organic compounds (VOCs), up to 30 percent on this account. The municipal buses using biodiesel blends resulted in lower emissions of particulate matter, carbon monoxide, and hydrocarbons in comparison to diesel (Hosseinzadeh-Bandbafha et al., 2022).

Coconut shells (CS), often considered as a discarded byproduct in the coconut processing industry, have garnered considerable interest for their potential in biodiesel production. With a substantial lignocellulosic content, these shells represent an abundant and renewable biomass source. The repurposing of CS for biodiesel aligns with the escalating global demand for sustainable and environmentally friendly energy alternatives. The biodiesel extraction process from CS involves various chemical processes, such as transesterification, yielding a biofuel that serves as a greener substitute for conventional fossil fuels. Beyond their energy contribution, CS play a crucial role in waste reduction and environmental sustainability by transforming a material that would otherwise be considered waste. The investigation into CS as a biodiesel feedstock not only addresses energy security issues but also exemplifies a comprehensive approach to resource utilization and environmental responsibility (Archana et al., 2019).

Plantain peels (PP), often disregarded as agricultural waste, and are now gaining recognition as a promising and sustainable raw material for biodiesel production. Rich in cellulose and hemicellulose, these peels offer a valuable biomass source for renewable energy. The incorporation of PP into biodiesel aligns with the global drive towards environmentally friendly alternatives to conventional fossil fuels. Through processes such as transesterification, the transformation of PP into biodiesel not only provides a renewable energy solution but also tackles the environmental issue of disposing of agricultural waste. The investigation into the biodiesel potential of plantain peels reflects a forward-looking approach, contributing to the diversification of energy sources and addressing sustainability challenges in agriculture (Oshoma et al., 2019).

CS and PP, often considered agricultural leftovers, are now gaining recognition for their potential as biochar. Biochar, a carbon-rich material obtained through organic waste pyrolysis, can be effectively produced from both CS and PP due to their distinctive qualities. The robust composition of CS and the cellulose-rich nature of PP make them promising candidates for biochar production through controlled heating processes. The resultant biochar acts as a valuable soil amendment, improving soil fertility, water retention, and nutrient absorption. Moreover, the conversion of CS and PP into biochar contributes to sustainable waste management by repurposing agricultural byproducts that would otherwise be discarded. This exploration into the biochar potential of CS and PP underscores an inventive approach to simultaneously address agricultural waste challenges and promote soil health in an eco-friendly and sustainable manner (Undiandeye et al., 2020)

1.2 PROBLEM STATEMENT

The utilization of CS for biodiesel application encounters several challenges that necessitate careful consideration for successful and sustainable implementation. A primary issue lies in the extraction process, as the complex lignocellulose structure of CS requires advanced and cost-effective methods to ensure an optimal biodiesel yield (Fardhyanti et al., 2018). Scalability poses another challenge, with the need to address logistical and economic hurdles associated with large-scale coconut shell biodiesel production.

Additionally, the potential competition for CS with other industries raises concerns about the feedstock's availability and affordability for biodiesel production. Tackling these challenges is imperative to fully realize the potential of coconut shells as a viable and eco-friendly source for biodiesel, ensuring practicality, economic viability, and minimal environmental impact.

The application of PP for biodiesel production encounters various challenges that demand thorough examination for a sustainable implementation. One notable obstacle lies in the efficient transformation of plantain peels into biodiesel, given their complex composition rich in cellulose and hemicellulose (Kitson-Hytey et al., 2022). Overcoming this challenge requires advanced and cost-effective processing methods to ensure an economically viable and environmentally sustainable biodiesel yield. The scalability of production poses another hurdle, necessitating solutions to address logistical and economic challenges associated with large-scale PP biodiesel production.

Moreover, the competition for PP with other potential uses, such as animal feed or organic fertilizers, raises concerns about resource availability and affordability for biodiesel production. Effectively addressing these challenges is pivotal to unlocking the full potential of PP as a renewable and eco-friendly feedstock for biodiesel, ensuring practicality, economic viability, and minimal environmental impact.

1.3 OBJECTIVE

The main purposes of the study are:

I. To synthesis bifunctional catalyst for mixture from powdered coconut shell and plantain peel.
II. To characterize coconut shell and plantain peel biochar catalyst using method FT-IR/XRD/TGA and BET for provide a comprehensive understanding of the biochar's crystalline structure, composition of a sample, identifying functional groups, and surface morphology.

1.4 SCOPE OF STUDIES

The study focuses on characterizing the dual potential of CS and PP biochar as a catalyst for biodiesel applications, offering a multifaceted investigation into their physical, chemical, and structural properties. The research aims to analyse the surface area, pore structure, and elemental composition of the biochar derived from these agricultural residues, emphasizing the synergistic effects resulting from their combination. This comprehensive examination seeks to identify optimal conditions for biochar production and its application in catalyzing biodiesel synthesis.

The scope of the study extends to evaluating the biochar's adsorption capacity and catalytic activity, considering its unique attributes arising from the combination of CS and PP. Special attention will be given to its performance in transesterification reactions, assessing parameters such as reaction kinetics, conversion efficiency, and the impact on biodiesel quality. The research also delves into the environmental implications, exploring the potential waste reduction and overall sustainability associated with using this dual-source biochar catalyst in biodiesel production.

In summary, this investigation aims to provide a comprehensive characterization of CS and PP biochar, uncovering its dual potential as a catalyst in biodiesel synthesis. The anticipated findings will contribute valuable insights to optimize biochar production processes and foster sustainable solutions within the realm of biodiesel applications.

1.5 SIGNIFICANCE OF STUDY

The analysis of CS and PP as a dual-purpose biochar catalyst in biodiesel applications is of significant importance for advancing sustainable energy solutions and optimizing waste utilization. Both CS and PP, often overlooked as agricultural waste, exhibit distinct qualities that make them promising candidates for biochar production. This study aims to scrutinize and comprehend the characteristics of biochar derived from these abundant biomass sources, evaluating their effectiveness as catalysts in the biodiesel production process.

The study holds importance on multiple fronts. Firstly, it contributes to the expanding knowledge base on alternative and environmentally friendly catalysts, addressing the demand for sustainable feedstocks in the energy sector. Secondly, the dual potential of CS and PP biochar introduces versatility to their applications, offering an innovative solution for both waste management and renewable energy generation. Thirdly, through the characterization of biochar, the study seeks to uncover specific properties that render these materials efficient catalysts, thereby laying the groundwork for enhanced and streamlined biodiesel production processes.

Moreover, the research bears practical implications for industries and policymakers, providing insights into the utilization of agricultural byproducts for value-added applications. It aligns with global objectives of promoting sustainable development by encouraging circular economy practices and reducing dependence on conventional fossil fuels. Ultimately, the study's outcomes can contribute to the development of environmentally conscious and economically feasible solutions, fostering a more sustainable and resilient energy landscape.

CHAPTER 2

LITERATURE REVIEW

2.1 BIODIESEL

Biodiesel is a type of fuel that may be produced from renewable resources and is becoming increasingly important. It is possible to produce it using recycled cooking oil, vegetable oils, or animal fats as the source material. Because it lowers emissions of greenhouse gases and lessens reliance on fossil fuels, it is an alternative to conventional diesel fuel that is better for the environment. This literature review's objective is to provide an overview of the production of biodiesel both globally and locally in Malaysia, with a particular emphasis on significant aspects, challenges, and trends (Knothe et al., 2018).

Malaysia has established itself as the main producer of palm oil in the world as a direct result of its production methods, which are more kind to the environment. This enables the nation to make a substantial contribution to the economy of the world. The principal feedstocks used in the manufacturing of biodiesel around the world in 2017 were palm oil (31%), soybean oil (27%), rapeseed oil (20%), waste cooking oil (WCO) (10%), and waste animal fats (7%), as stated by (Syafiuddin et al.,2020). These were the oils used in the production of biodiesel. Table 1 provides an overview of the key feedstocks used in the manufacturing of biodiesel and petrodiesel in Asian countries, as well as the present status of these fuels. The quantities of biodiesel produced in Indonesia, Thailand, and Malaysia are quite high in comparison to those generated in the other nations of Asia since feedstocks are readily available in those three countries. These details were taken from a study that was put out by the Agricultural Department of the United States of America (Mukherjee & Sovacool, 2018).

TABLE 1: Status of biodiesel and petrodiesel in Asian countries (Mahayuddin et al., 2022)

Country	Main Feedstock of Biodiesel	Production of Biodiesel (mil L)	Consumption of Petroldiesel (mil L)
Indonesia (main Palm oil producer)	Palm oil	5,600	32.1%
Thailand	Palm oil	1,567	23,602
Malaysia (second larger palm oil producer)	Palm oil	1,245	11,624
China	WCO	834	174,999
Philippines	Coconut oil	220	10158
India	WCO, non-edible industry oil, animal fast	185	102,079
Japan	WCO	17	60,573

By reducing its reliance on diesel fuel derived from petroleum, Malaysia has the potential to satisfy around 10 percent of the overall demand for biodiesel across the globe. The cost of the feedstock, as well as the productivity, yield, and efficiency of the process, are the factors that influence whether or not a certain feedstock can be utilised in the production of biodiesel. It is clear that oil palm is the crop that produces the most oil in the most efficient manner in the world today when the yields of other oil-bearing crops are compared to those of oil palm (Johari et al., 2017).

2.2 COCONUT SHELL (CS)

CS waste emerges as a byproduct from coconut processing, typically left aside after extracting coconut meat and water. Recently, it has garnered heightened interest owing to its potential applications in diverse industries, thereby contributing to sustainability and waste minimization initiatives. In the realm of agriculture, coconut shell waste proves to be a valuable asset. It functions as an organic fertilizer and soil enhancer, improving soil quality through the gradual release of nutrients. The porous composition of coconut shells also facilitates moisture retention, establishing them as a sustainable and efficient choice for environmentally friendly farming practices (Wu et al., 2019).

The substantial industrial utilization of CS waste involves its transformation into activated carbon. Due to the elevated carbon content and porous characteristics of CS, they prove to be well-suited for the production of activated carbon, which finds applications in water purification, air filtration, and diverse industrial processes. This not only enhances the value of the waste material but also encourages the adoption of environmentally friendly alternatives to traditional carbon sources (Islam et al., 2017).

Furthermore, CS waste has been applied in the realm of energy generation. Functioning as a biomass resource, it can undergo conversion into charcoal or serve as a renewable energy source through processes such as gasification or pyrolysis (Dwi Nuryana et al., 2020). This aligns with the increasing focus on employing biomass for environmentally friendly and sustainable energy solutions. In the field of materials science, researchers are actively exploring innovative approaches to leverage coconut shell waste for the creation of sustainable materials. These endeavors encompass incorporating coconut shells into the manufacturing of bioplastics, composites, and other environmentally conscious materials, contributing to a circular economy by diminishing reliance on conventional and less sustainable resources (Wu et al., 2019).

2.3 COCONUT SHELL IN BIODIESEL PRODUCTION

CS offer a promising avenue for biodiesel production, contributing to the pursuit of sustainable and renewable energy sources. Initially, the extraction of oil from coconut meat serves as a crucial step, with the resulting coconut oil serving as a viable feedstock for biodiesel (Fardhyanti et al., 2018). Transesterification, a chemical process involving the reaction of coconut oil with alcohol and a catalyst, produces biodiesel in the form of methyl or ethyl esters, accompanied by glycerol as a byproduct (A. O. et al., 2021).

Subsequent refinement steps, including washing, drying, and additional purification, may be employed to ensure the biodiesel meets quality standards. The use of CS for biodiesel production is advantageous due to the abundance of coconut trees in tropical regions, providing a readily available and sustainable source. Moreover, coconut biodiesel is recognized for its potential as a cleaner-burning alternative, which could contribute to reducing greenhouse gas emissions and lessening reliance on non-renewable resources. However, the sustainability of coconut biodiesel production necessitates careful consideration of factors like land use, water usage, and potential impacts on food production. This underscores the importance of adhering to sustainable practices and conducting comprehensive life cycle assessments (da Costa Nogueira et al., 2018).

2.4 PLANTAIN PEEL (PP)

In Malaysia, the disposal of PP constitutes a prevalent agricultural waste issue. Given that bananas contribute to 16% of the world's total fruit production, ranking second globally, they hold significant importance in the agricultural landscape. Notably, bananas stand out as the most widely consumed tropical fruit. The byproduct of this prolific fruit, namely banana peel, has garnered increased attention, as indicated by (Fan et al., 2019). The simplicity of the materials, coupled with their ready availability, cost-effectiveness, reusability, and the environmentally friendly nature of the process, has led to a limited but noteworthy number of reported instances where waste banana plant parts serve as catalysts for biodiesel synthesis. These catalysts demonstrate promising efficacy, as highlighted in the research conducted by (Zurena Mohd Salleh et al., 2021). The exploration of PP as a catalyst in biodiesel synthesis not only addresses waste management concerns but also underscores the potential for sustainable and cost-effective practices in the production of biodiesel.

2.5 PLANTAIN PEEL IN BIODIESEL PRODUCTION

The incorporation of plantain peel in the production of biodiesel signifies a notable and sustainable strategy in the realm of biofuels. Despite being commonly regarded as agricultural waste, plantain peels emerge as a valuable resource for biodiesel synthesis due to their lipid content. The process entails extracting oil from the peels, followed by transesterification a chemical reaction involving alcohol and a catalyst to yield biodiesel (Saeed et al., 2021). Leveraging the lipids present in plantain peels offers a renewable feedstock, contributing to the creation of a biofuel that can be blended with traditional diesel. This not only reduces dependency on fossil fuels but also addresses waste management issues by repurposing discarded plantain peels. The exploration of plantain peel in biodiesel production aligns with sustainable practices, providing an environmentally friendly alternative with potential advantages for both energy production and waste reduction (Tock et al., 2018).

2.6 BIOCHAR

Biochar, a carbon-rich derivative produced through the pyrolysis of organic materials under low-oxygen conditions, has emerged as a versatile substance with applications spanning agriculture, environmental remediation, and carbon sequestration (Gupta et al., 2020). Derived from sources like agricultural residues, wood, or biomass, biochar proves valuable in agriculture by serving as a soil amendment that enhances fertility through the gradual release of essential nutrients. Its porous structure aids in water retention, contributing to improved drought resistance in plants (Videgain-Marco et al., 2020). Beyond agriculture, biochar plays a crucial role in carbon sequestration, acting as a long-term carbon sink to mitigate greenhouse gas emissions and contribute to climate change mitigation. It also finds applications in environmental remediation, where it can be utilized for water treatment to adsorb contaminants and pollutants and in the remediation of contaminated soils by immobilizing harmful substances (Nazir et al., 2021).

Biochar integrates into agricultural practices, enhancing manure management in livestock farming and improving compost quality. The pyrolysis process not only yields biochar but also generates bioenergy in the form of bio-oil and syngas, adding to its value in renewable energy production. Biochar's ability to create a favorable habitat for beneficial microbes promotes soil health and enhances plant-microbe interactions (Deshoux et al., 2023). Despite its diverse benefits, the effectiveness of biochar depends on factors such as feedstock, production conditions, and soil characteristics, necessitating tailored approaches for specific applications and environments. Ongoing research continues to reveal new possibilities, positioning biochar as a promising tool for sustainable agriculture and environmental management.

2.7 BIFUNCTIONAL CATALYST

Bifunctional catalysis involves the use of small, structurally defined molecules with two distinct functional groups to introduce new reactivity and selectivity in a specific process. Typically, polar addition reactions take place, with the involvement of pronucleophiles and electrophiles. The goal of a bifunctional catalytic system is to efficiently convert simple, low-value starting materials into stereochemically specified, high-value products (Dixon et al., 2016). Additionally, the effectiveness of bifunctional catalysts has been demonstrated in the synthesis of biodiesel, where their high surface area allows for the conversion of free fatty acids and triglycerides into valuable biodiesel products (Changmai et al., 2020).

CHAPTER 3

MATERIAL AND METHODS

3.1 Material

Coconut shell (CS) was sourced from local coconut milk shops located in Gemang, Jeli, Kelantan, Malaysia and ripe plantain peel (PP) was collected from stalls in the vicinity of the University Malaysia Kelantan, Jeli Campus, Kelantan, Malaysia.

3.2 Methodology

3.2.1 Biochar Catalyst Preparation from CS and PP

Initially, the CS were cleaned, dried in an oven at 80 ℃ for 8 hours. The dried CS was crushed and sieved through a 100-mesh sieve to obtain uniformly sized CS powder. The powdered CS was then rinsed with deionized water and dried once more. In parallel, the PP were washed with tap water, cut into pieces for easier drying. The PP was then dried at 100 °C for 12 h in an oven. Both the dried CS and PP were separately burned in open air to convert them into ash. The resulting ashes were then combined in equal proportions by weight. This mixture underwent a heat treatment process in a muffle furnace, ranging from 600,700 and 800˚C intervals, for 4 hours. Afterwards, the mixture was finely ground using a porcelain mortar and pestle and was denoted as biochar CP. The resulting material was carefully stored in a tightly sealed container within a desiccator for subsequent analysis.

3.2.2 Characterization of Biochar Catalyst

The CS, PP and prepared biochar CP catalyst were characterized using Fourier Transform Infrared Spectroscopy (FTIR), X-ray diffraction (XRD), Thermo-gravimetric analyses (TGA) and the Brunauer, Emmett and Teller (BET).

3.2.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

Mineral identification and determination of functional groups in coconut shell and plantain peel biochar were performed using Fourier Transform Infrared (FTIR) spectroscopy. This analysis aimed to identify changes in functional groups, chemical bonding variations, or the presence of contaminants within the biochar. The purpose was to gain insights into the biochar's chemical composition, focusing on alterations in functional groups and bonding, as well as identifying potential contaminants that could affect its structural properties and suitability for biodiesel applications.

3.2.2.2 X-ray diffraction (XRD)

Mineral identification and the elucidation of crystalline phases in coconut shell and plantain peel biochar were conducted utilizing X-Ray Diffraction (XRD). This XRD analysis aimed to initially examine any alterations in phases, variations in crystal size, or the existence of contaminants within the biochar derived from coconut shell and plantain peel. The purpose of this investigation was to gain insights into the structural composition of the biochar, specifically focusing on potential changes in crystalline phases and crystal size, as well as the presence of any contaminants that could influence its properties and applications.

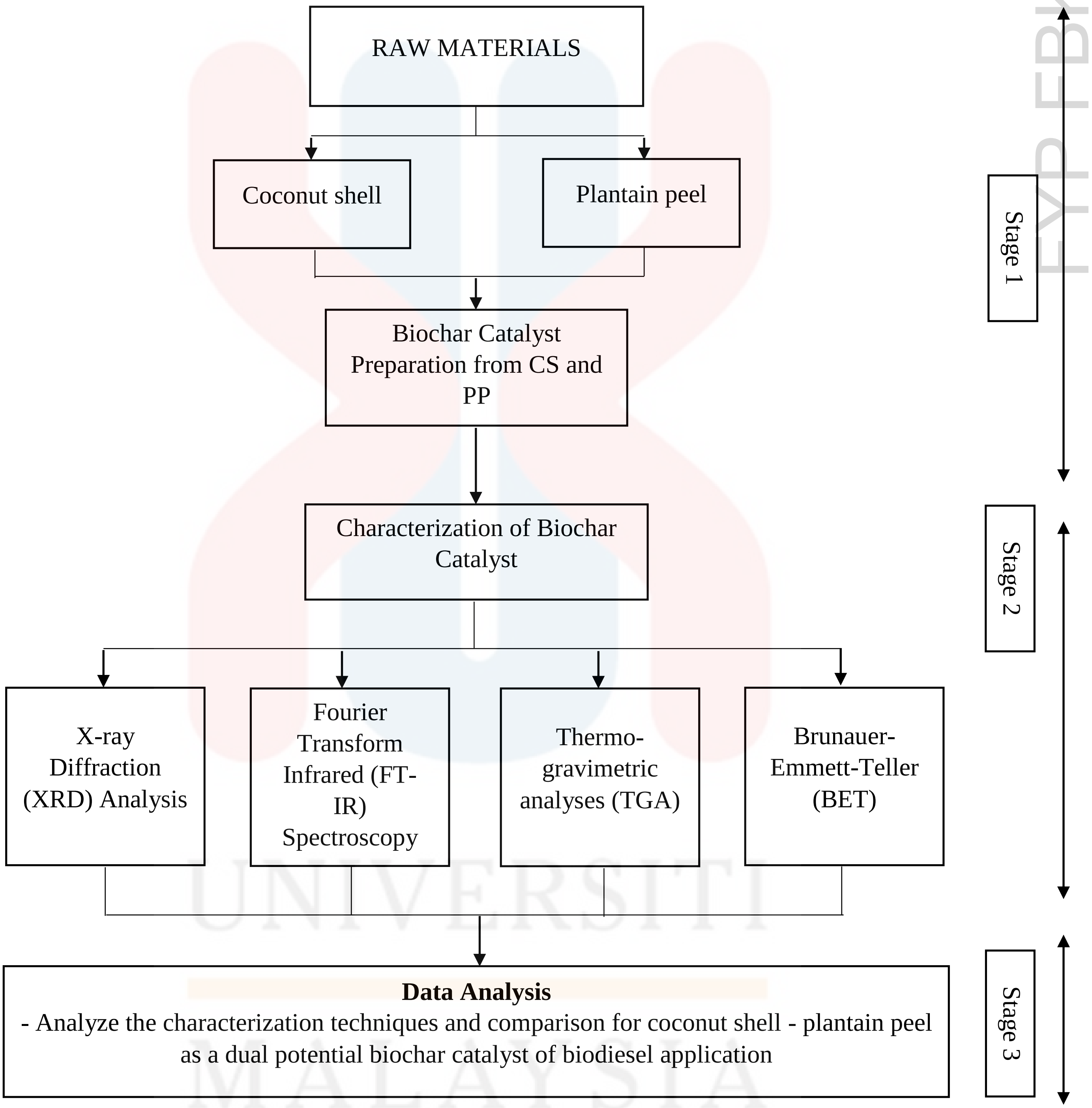
3.2.2.3 Brunauer, Emmett and Teller (BET)

The evaluation of total porosity and surface area available for catalytic reactions in coconut shell and ripe plantain peel can be achieved through Brunauer-Emmett-Teller (BET) analysis. Enhancing the porosity and surface area of the catalyst will contribute to an improved capacity for biodiesel production.

3.2.2.4 Thermo-gravimetric analyses (TGA)

Using thermo-gravimetric analysis (TGA) to study coconut shells and ripe plantain peels as biochar catalysts is a valuable approach to understanding their thermal properties and behavior during temperature changes.

3.3 Research Flowchart



CHAPTER 4

RESULTS AND DISCUSSION

4.1 XRD analysis of CP

4.1.1 XRD analysis of CP1

This XRD pattern illustrates the crystalline composition of CP1, providing insights into the prominent compounds. The pattern exhibits well-defined peaks at specific 2θ values = 28.448°, 30.198°, and 40.453°. The peak at 40.453° corresponds to Tin Telluride (SnTe), known for its semiconductor properties with potential applications in thermoelectricity. While SnTe's role in biodiesel production is not fully established, some studies propose its potential as a co-catalyst, augmenting the activity and selectivity of other catalysts.

The peak at 30.198° is indicative of Potassium (K), a common element in biomass. In biodiesel production, K plays a crucial role by activating the catalyst, potentially promoting the transesterification reaction a pivotal step where triglycerides convert into fatty acid esters (biodiesel) and glycerol. At 28.448°, the XRD pattern reveals the presence of silicon dioxide (SiO_2) in the sample. SiO_2 is a prevalent component in biomass and can function as a beneficial catalyst by serving as a support material for other active catalyst components. This enhances their dispersion and stability during catalytic reactions.

The identification of Si, K, and SnTe in the sample suggests its potential as a catalyst for biodiesel production. Si and K are recognized for their established benefits, while SnTe introduces an intriguing, less-explored possibility. However, further investigation is imperative to determine the optimal composition and processing conditions that maximize the catalytic activity and selectivity of this material for biodiesel production.

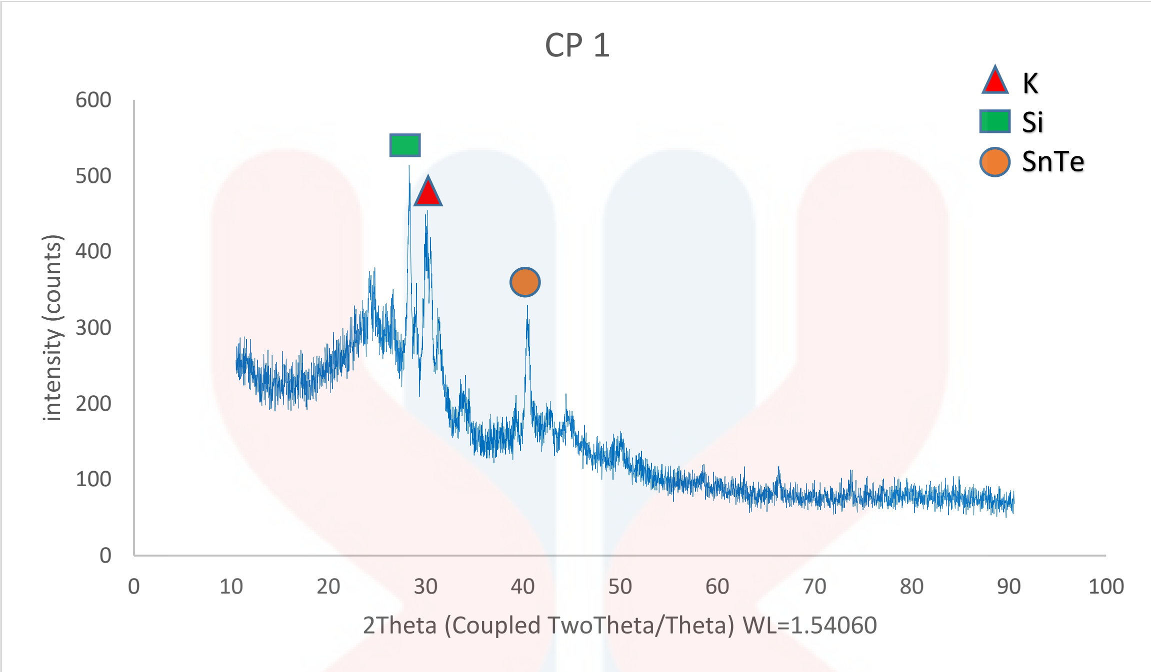


Figure 4.1: XRD chromatogram for CP1

4.1.2 XRD analysis of CP2

The presented XRD spectrum delineates distinct peaks corresponding to various crystallographic planes within the sample, and the peak intensities are indicative of the material abundance at specific 2θ values = 28.448°, 30.198°, 31.406°, 34.146°, 40.608°, and 24.231°. The peak at 28.448° signifies a substantial presence of silicon dioxide (SiO_2) in the sample, a common biomass component recognized for its potential as a catalyst in biodiesel production.

At 30.198°, the XRD pattern reveals the presence of potassium (K), suggesting a minor content of this element in the sample. Potassium is prevalent in biomass and can contribute to catalyst activation, enhancing its efficacy in biodiesel production. The peak at 40.608° corresponds to ClK Sylvite, a form of potassium chloride (KCl). The detection of KCl implies potential contamination of the sample with salt, which could impede catalyst activity. It is crucial to eliminate such contaminants from biomass before utilizing it in biodiesel production processes.

Additionally, peaks at 24.231°, 31.406°, and 34.146° signify the presence of $CHKO_3$ Kalicinite, a type of potassium carbonate (K_2CO_3). K_2CO_3 can function as a catalyst for biodiesel production, further indicating the diverse mixture of materials within the sample with potential catalytic roles.

In summary, the XRD analysis suggests that the sample comprises a blend of materials that could serve as catalysts for biodiesel production. However, the presence of KCl, an inhibitor of catalyst activity, underscores the necessity to thoroughly eliminate such contaminants from the sample before employing it in biodiesel production processes.

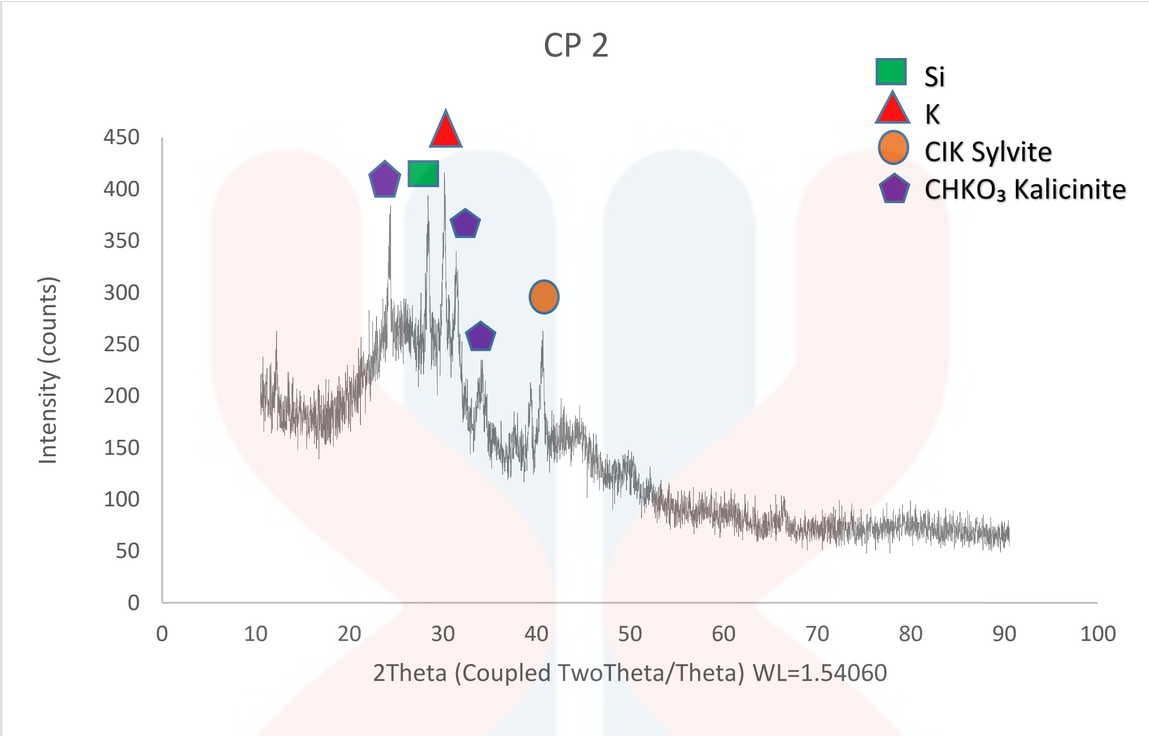


Figure 4.2: XRD chromatogram for CP2

4.1.3 XRD analysis of CP3

The depicted XRD spectrum reveals discernible peaks corresponding to specific crystallographic planes within the sample, with peak intensities reflective of the material abundance at distinct 2θ values = 24.231°, 28.448°, 30.198°, and 40.619°. The peak at 24.231° signifies the presence of $CHKO_3$ Kalicinite, a potassium carbonate (K_2CO_3). K_2CO_3, as suggested by this peak, holds potential as a catalyst for biodiesel production.

At 28.448°, the XRD pattern indicates the prevalence of silicon dioxide (SiO_2) in the sample. SiO_2, a customary component of biomass, stands as a promising catalyst for biodiesel production due to its catalytic properties. The peak at 30.198° represents potassium (K), denoting a minor content of this element in the sample. Potassium, abundantly found in biomass, can contribute to catalyst activation, enhancing its effectiveness in biodiesel production.

Notably, the peak at 40.619° corresponds to CIK Sylvite, a form of potassium chloride (KCl). The identification of KCl raises concerns about potential salt contamination in the sample, which could impede catalyst activity. It is imperative to thoroughly eliminate such contaminants from the biomass before utilizing it in biodiesel production processes.

In summary, the XRD analysis suggests that the sample comprises a heterogeneous mixture of materials with potential catalytic roles in biodiesel production. However, the presence of KCl raises a cautionary note, emphasizing the critical importance of removing KCl from the sample to optimize catalyst activity before initiating biodiesel production.

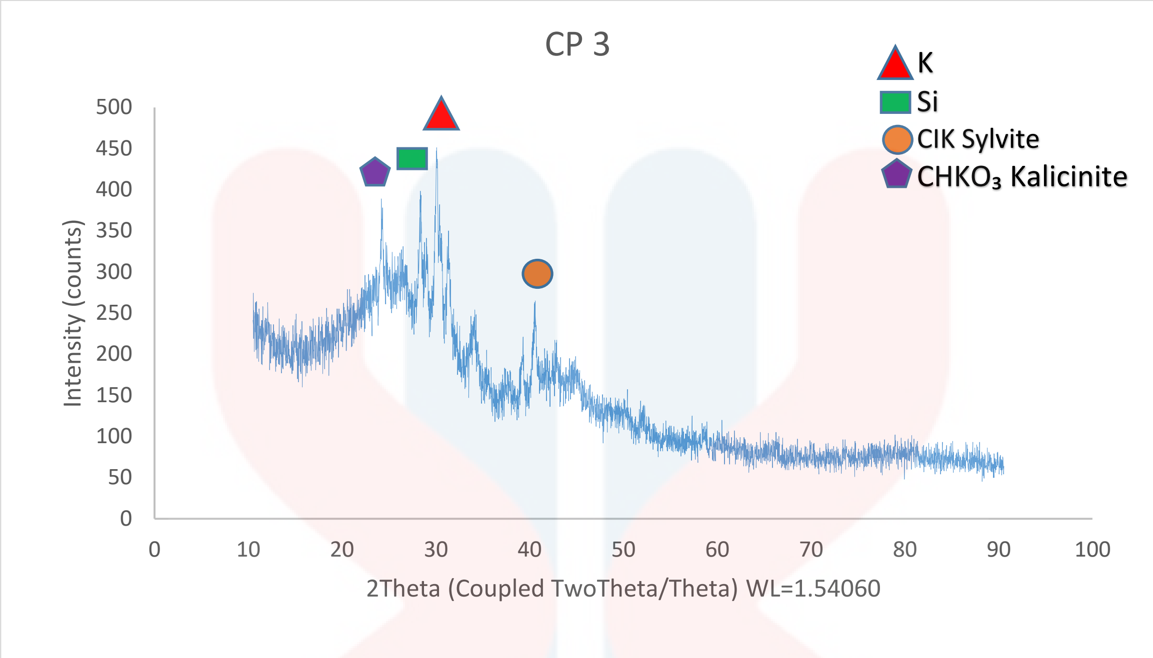


Figure 4.3: XRD chromatogram for CP3

4.1.4 XRD analysis CP1, CP2 and CP3

In the XRD analysis of CP1, the identified peaks at 2θ values of 24.231°, 28.448°, 30.198°, and 40.619° were associated with $CHKO_3$ Kalicinite, silicon dioxide (SiO_2), potassium (K), and CIK Sylvite, respectively. The peak identification process involved matching these compounds based on their characteristic patterns (Eriola Betiku et al., 2019). Variations in peak broadening or intensity were not observed in CP1, suggesting a consistent crystalline structure. This stability in the XRD pattern enhances the reliability of the identified compounds. While Tin Telluride (SnTe) was not explicitly mentioned in CP1, hypotheses or potential reasons behind its absence, considering its role in biodiesel production, would add depth to the discussion. Any existing literature supporting or refuting its presence could be briefly discussed. In conclusion, CP1 demonstrates a stable crystalline structure with identified compounds, indicating its potential as a biodiesel catalyst. However, further investigation is needed to understand the role, if any, of Tin Telluride (SnTe) in this context.

Moving to CP2, the presence of potassium chloride (KCl) raises concerns about potential negative impacts on catalyst activity. Salt contamination can interfere with biodiesel production processes, and further discussion on why KCl could be problematic is essential for a comprehensive understanding (Etim et al., 2018). CP2 at 700°C exhibits an optimal composition, as evidenced by distinct peaks aligning with potential catalysts for biodiesel production. The discussion should explicitly state the significance of this optimal composition and its potential contribution to catalytic activity. To strengthen the discussion, relevant references within the CP2 analysis should be integrated to support claims about the identified compounds (Eriola Betiku et al., 2019).

In CP3, the presence of potassium chloride (KCl) should be clearly addressed, emphasizing the potential negative consequences and discussing its importance in the context of catalyst activity. Consider the impact of KCl on biodiesel production processes (Etim et al., 2018). Expanding on the potential synergies or interactions between the identified compounds in CP3, creating a more holistic view of it as a catalyst, is crucial. Discuss how the heterogeneous mixture may influence catalytic activity. Conclude the CP3 section with a strong call to action, highlighting the importance of removing contaminants, especially KCl, for optimal catalyst performance in biodiesel production.

In a comparative analysis of CP1, CP2, and CP3, a more in-depth discussion on the influence of different temperatures on the crystalline structures and how this affects catalytic activity is needed. Explore how temperature variations impact the composition and catalytic activity of each biochar catalyst. Provide a structured comparative analysis of CP1, CP2, and CP3, focusing on key differences and similarities in their XRD patterns. Discuss the implications of these variations in terms of catalytic potential and biodiesel production (Olatundun et al., 2020).

4.2 FTIR analysis of CP1, CP2 and CP3

The infrared (IR) spectrum analysis of banana peel and coconut shell biochar following furnace treatment reveals significant vibrational modes at various frequencies, providing insights into the chemical bonds and functional groups present in these materials. The peaks at 3851.17 cm^-1 and 3740.96 cm^-1 indicate the presence of hydroxyl (-OH) groups, a common feature in plant-derived materials, suggesting the potential contribution of moisture or water content to the overall composition. Additionally, the frequency at 3643.77 cm^-1 suggests the existence of amine or amide groups, potentially linked to proteins or amino acids in the organic components of the biochar.

A sharp peak at 2360.43 cm^-1 suggests the occurrence of a carbon-carbon triple bond (C≡C), possibly associated with alkynes and indicative of structural transformations during the carbonization process. Frequencies at 2086.67 cm^-1 and 485.36 cm^-1 may signify carbonyl (C=O) stretching vibrations, providing insights into the presence of carbonyl groups, possibly associated with more intense or conjugated carbonyl systems and aromatic structures. The peaks at 464.76 cm^-1, 447.1 cm^-1, and 417.98 cm^-1 indicate the presence of carbon-heteroatom bonds, such as C-O or C-N stretching vibrations, suggesting diverse functional groups like ethers or amines within the biochar.

Comparing these results with existing research, the study by (Tritti Siengchum et al., 2018) emphasizes that coconut biochar possesses hydroxyl, methyl, ethyl, and carbonyl functional groups, aligning with the discussion on hydroxyl groups and carbonyl stretching vibrations in coconut shell biochar. The findings contribute additional insights into the chemical composition and potential applications of coconut biochar.

In a related study by (Abdullah et al., 2023), which investigates banana pseudo-stem (BPS) biochar derived from slow and fast pyrolysis processes, differences in surface morphology and pore characteristics are highlighted. This comparison offers valuable context for understanding the structural properties of banana peel biochar, contributing to a broader comprehension of the impact of various pyrolysis methods on resulting biochar properties.

In summary, the IR spectrum analysis of banana peel and coconut shell biochar provides a detailed overview of their chemical composition, and by drawing parallels with existing research, enhances our understanding of their potential applications and structural properties.

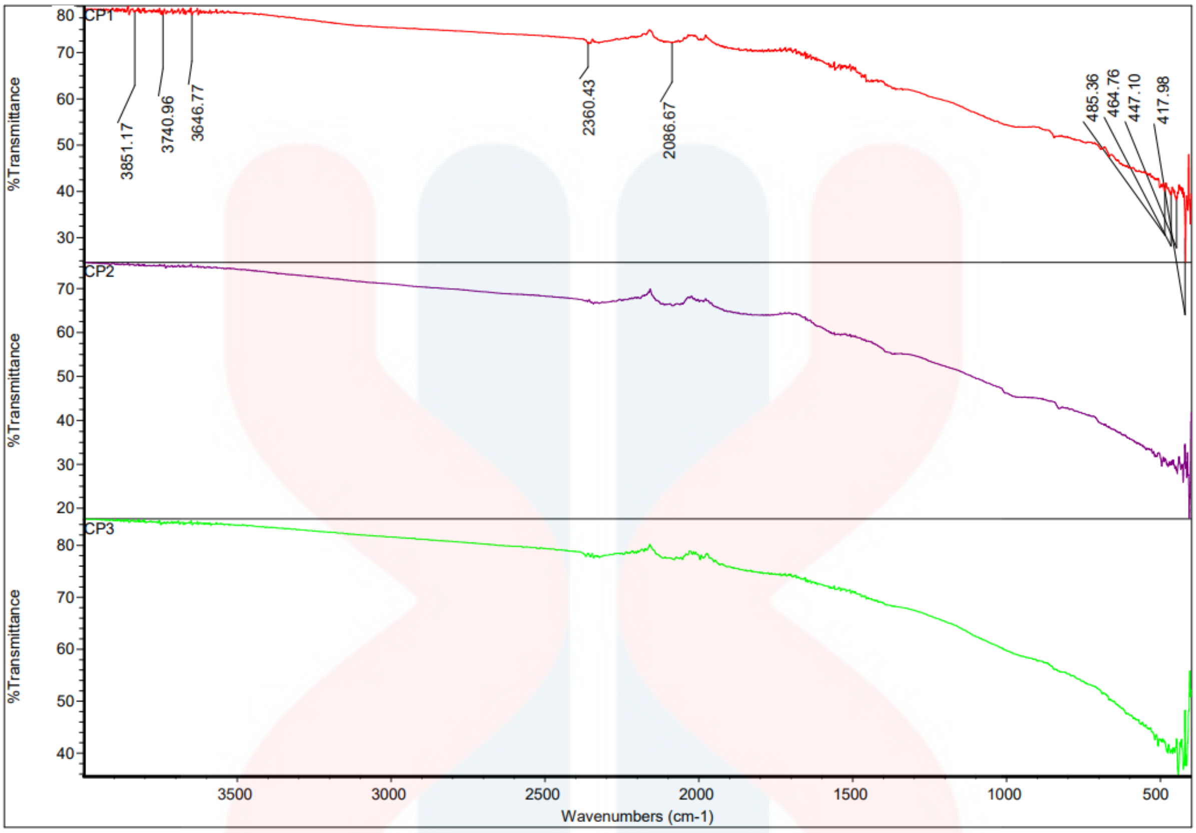


Figure 4.4: IR spectrum for CP1, CP2, and CP3

4.3 BET analysis of CP

4.3.1 BET analysis of CP1

The BET analysis for CP1 revealed compelling characteristics that suggest its potential suitability for various applications. With a notable surface area of 7.240 m²/g, CP1 exhibits a substantial capacity for active sites, which is particularly advantageous for catalytic reactions. The high pore volume of 0.99186 cm³/g indicates a significant porous structure, making CP1 a promising candidate for adsorption or storage applications. Additionally, the sizable pore diameter of 7.36156 Å suggests that CP1 can accommodate relatively large molecules, enhancing its versatility for specific tasks such as selective adsorption or controlled release. Collectively, these findings highlight CP1 as a material with desirable features for applications where surface activity, adsorption capacity, and pore size are critical considerations.

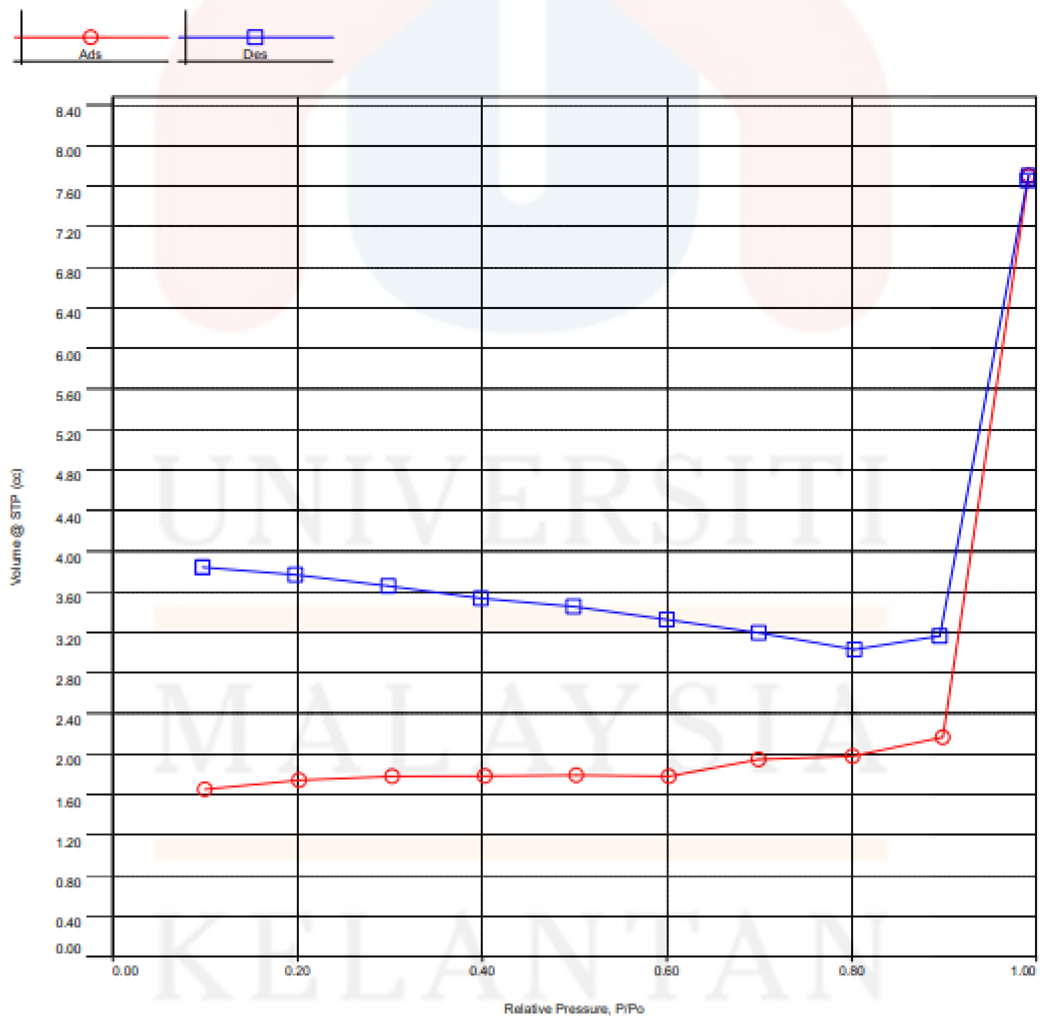


Figure 4.5: Raw linear for CP1

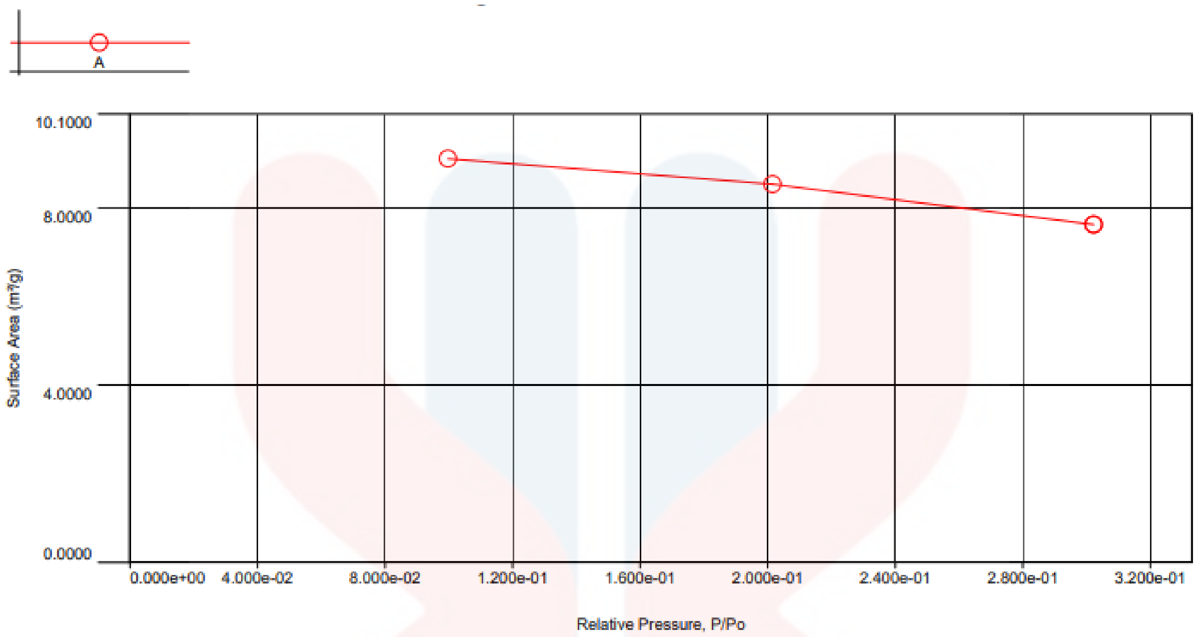


Figure 4.6: Single point surface area for CP1

4.3.2 BET analysis for CP2

The BET analysis of CP2 manifests remarkable characteristics that underscore its potential for diverse applications. Notably, the surface area of 147.179 m^2/g positions CP2 as a material with an exceptionally high number of active sites, making it particularly attractive for catalytic processes where enhanced reactivity is desired. The significant pore volume of 0.99156 cm^3/g suggests a notable capacity for adsorption or storage, implying potential utility in environments requiring efficient gas sorption or separation. Equally noteworthy is the large pore diameter of 76.04478 Å, indicating that CP2 can accommodate larger molecules, a feature pertinent to applications involving the adsorption or transport of bulkier substances. While these BET analysis results paint a promising picture of CP2 surface properties, comprehensive evaluations and application-specific testing are essential for a nuanced understanding of its performance and suitability in targeted tasks. In essence, CP2 exceptional surface area, substantial pore volume, and large pore diameter position it as a material with great potential for catalysis, gas adsorption, and other applications where these characteristics are pivotal. Further exploration and validation in specific applications will be crucial to unlock the full range of CP2 capabilities.

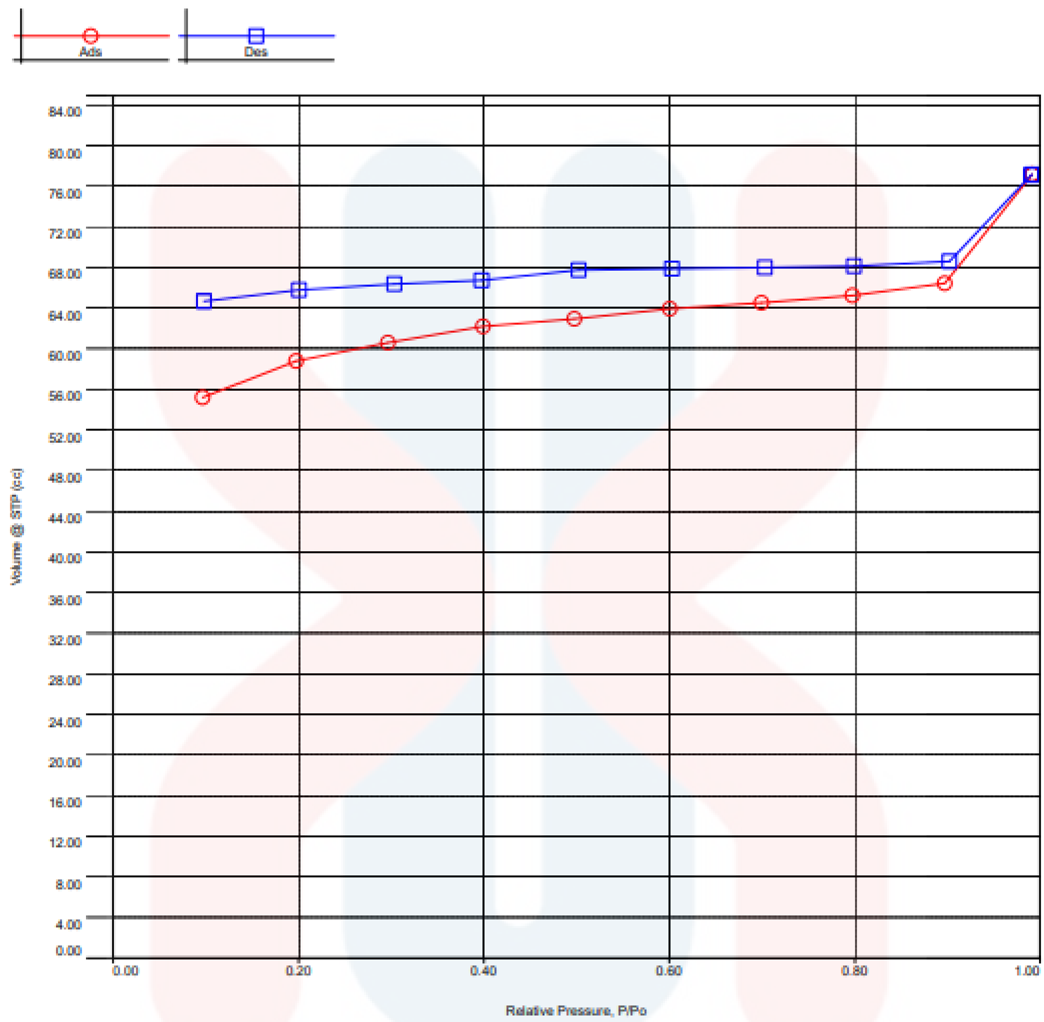


Figure 4.7: Raw linear for CP2

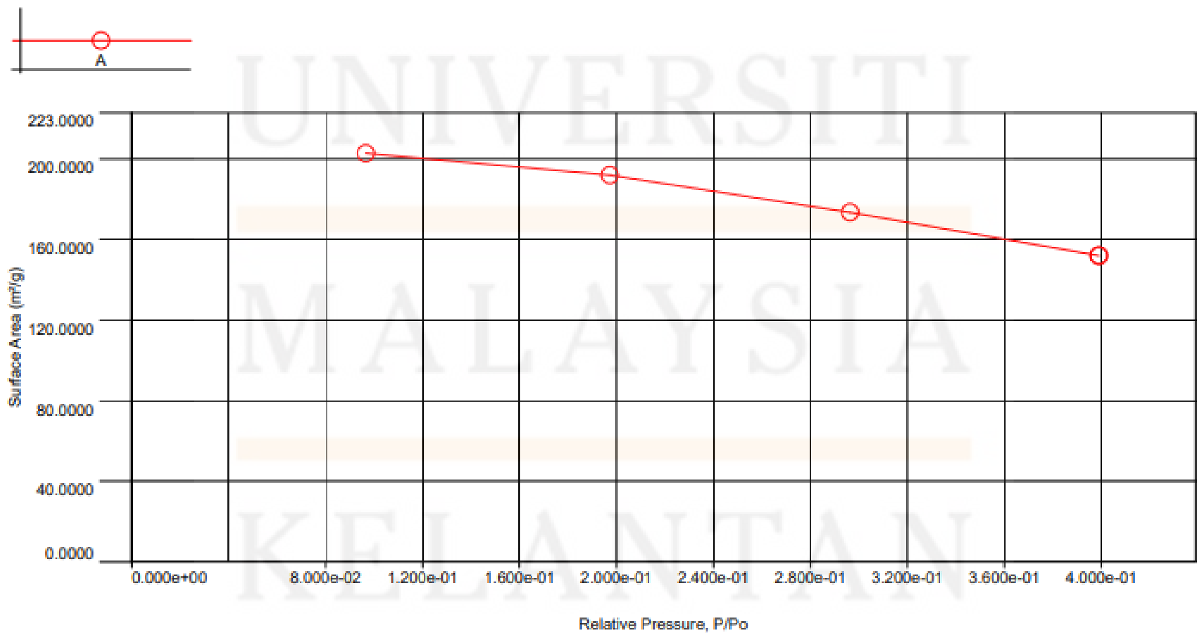


Figure 4.8: Single point surface area for CP2

4.3.3 BET analysis for CP3

The BET analysis results for CP3 reveal distinctive characteristics that shape its potential applications. With a surface area of 45.809 m^2/g, CP3 exhibits a moderate yet substantial number of active sites, positioning it favorably for applications requiring a balance between surface activity and material availability. The notable pore volume of 0.99082 cm^3/g indicates a significant porous structure, suggesting CP 3 suitability for tasks involving efficient gas sorption or separation. Furthermore, the relatively small pore diameter of 6.00452 Å signifies a specialized feature, implying CP3 effectiveness in selectively adsorbing smaller molecules. This specificity in pore size could prove beneficial in applications such as molecular sieving or separation processes. While the BET analysis provides foundational insights, the full scope of CP3 capabilities will be better understood through comprehensive, application-specific testing. In essence, CP3 emerges as a versatile material, offering a balanced combination of surface activity and selectivity, making it a promising candidate for diverse industrial or scientific applications that demand such nuanced characteristics. Further exploration and targeted assessments will be essential to unlock the complete potential of CP3 in specific contexts.

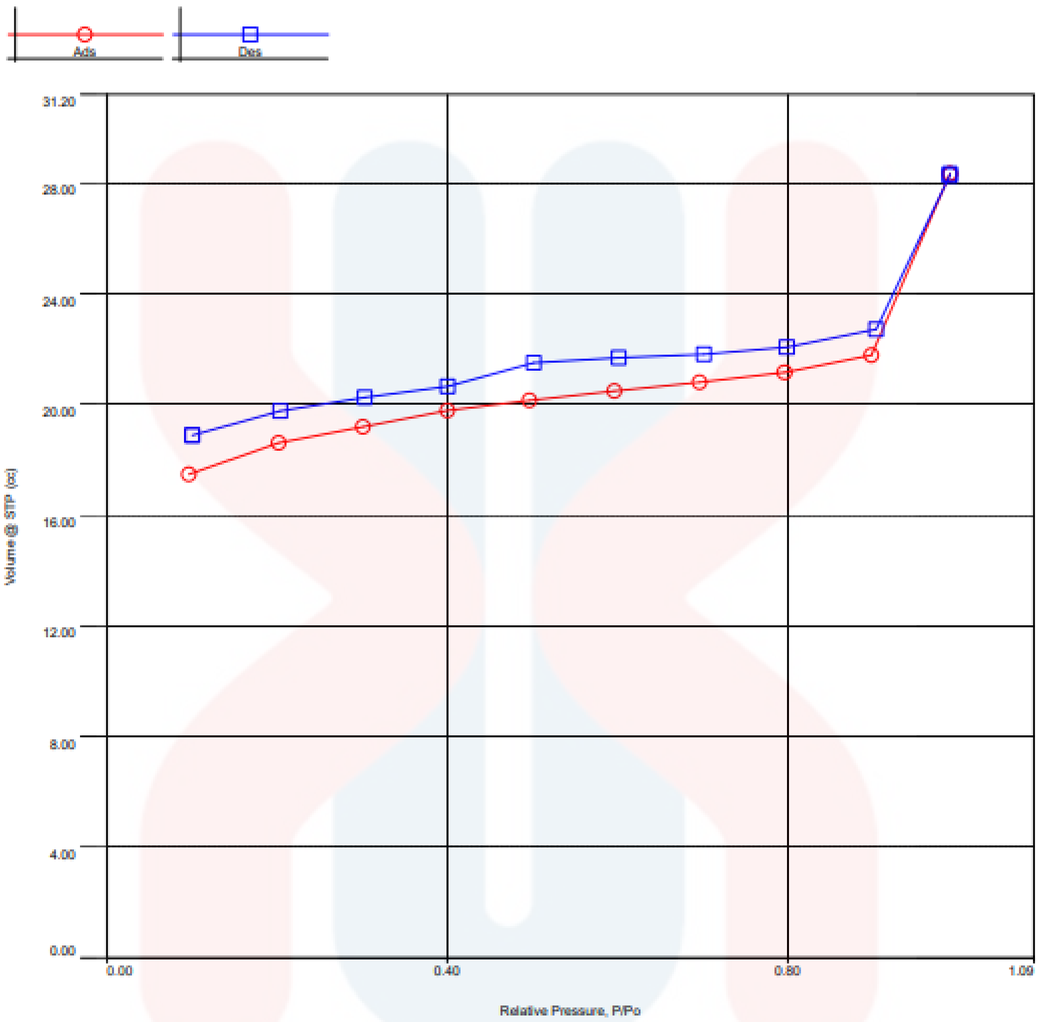


Figure 4.9: Raw linear for CP3

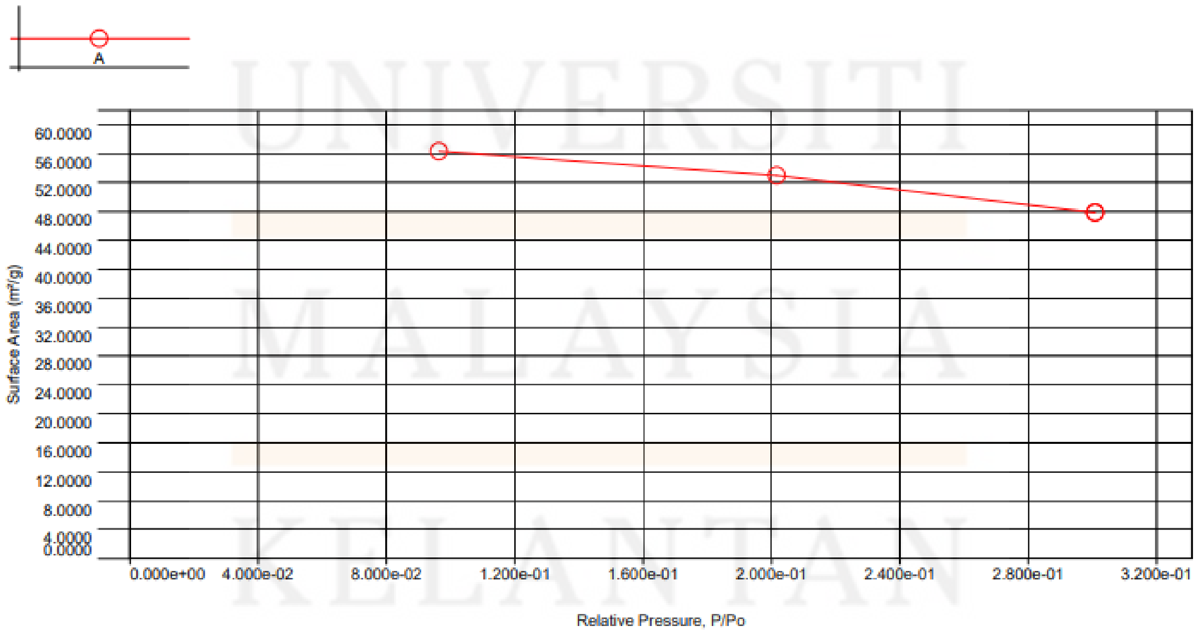


Figure 4.10: Single point surface area for CP3

4.3.4 BET analysis for CP1, CP2 and CP3

The BET analysis results of CP1 reveal a surface area of 7.240 m²/g, showcasing a moderate yet noteworthy capacity for active sites. Importantly, the pore diameter of CP1, measured at 7.36156 Å, holds significance in applications like adsorption or storage, contributing to its versatility. CP2, with an exceptional surface area of 147.179 m²/g, is highlighted for potential catalytic processes and gas-related applications. Emphasizing the importance of application-specific testing becomes essential to fully understand CP2 performance and functionality in diverse scenarios. CP3, with a surface area of 45.809 m²/g, strikes a balance between surface activity and material availability. Its smaller pore diameter offers advantages in applications involving selective adsorption, emphasizing the specificity of pore size in determining biochar suitability for different uses (Nath et al., 2019).

In comparison, when examining the surface characteristics of CCPA, a biomass-derived material from cocoa pod husk ash – plantain peel, it is crucial to draw parallels with the coconut shell-plantain peel biochar catalysts. CCPA exhibits a competitive surface area of 18.86 m²/g, demonstrating a mesoporous nature with a distinct pore diameter of 9.11 nm. While CCPA characteristics are notable, the exceptionally high surface area of CP2 at 147.179 m²/g surpasses both CP1 and CCPA, positioning CP2 as a promising material for catalytic processes and gas-related applications. The importance of considering specific surface features for targeted applications is emphasized, as evidenced by the unique characteristics of CCPA compared to CP2 (Olatundun et al., 2020).

In conclusion, the inclusion of CCPA in the discussion complements the analysis of coconut shell-plantain peel biochar catalysts, offering insights into the surface properties of another biomass-derived material. The collective understanding underscores the importance of surface characteristics in determining the suitability of biochar for various applications. Future studies should delve deeper into these surface features and their implications, providing a foundation for unlocking the full potential of biochar materials.

4.4 TGA analysis for CP

The thermogravimetric analysis (TGA) conducted on a blend of coconut shell and plantain peel biochar (CP) holds significant implications, particularly in the context of its potential application as a catalyst in biodiesel production. TGA, a method that measures mass loss during sample heating, proves invaluable for unraveling the thermal characteristics of the biochar mixture. The graph adeptly illustrates the relationship between the remaining mass percentage and temperature, revealing distinctive features in the CP biochar.

The TGA curve unfolds with a discernible pattern: a swift mass loss commencing around 100°C, attributed to the evaporation of water from the sample, followed by a deceleration until approximately 300°C. Beyond this point, there is an intensified mass loss, indicating the likely onset of organic decomposition. Two salient points on the graph enhance our understanding – the inflection point at 59°C, signifying a change in the rate of mass loss, and the midpoint at 814°C, marking the temperature at which half of the sample is lost. Additionally, the residue of 38.37% represents the remaining mass post-heating, providing a comprehensive overview of the thermal behavior of the CP biochar (Ghafar et al., 2020).

Interpreting these TGA outcomes becomes pivotal when considering the potential use of the coconut shell and plantain peel biochar blend as a catalyst in biodiesel production. The stability observed up to roughly 300°C is particularly noteworthy for engineers involved in the design of biodiesel processes. This information underscores the importance of avoiding application beyond this temperature range to ensure the sustained efficacy of the biochar as a catalyst in biodiesel production.

In essence, the detailed analysis of the TGA results not only sheds light on the thermal stability of the CP biochar but also serves as a guiding factor for engineers and researchers in optimizing its utilization as a catalyst in the biodiesel production process.

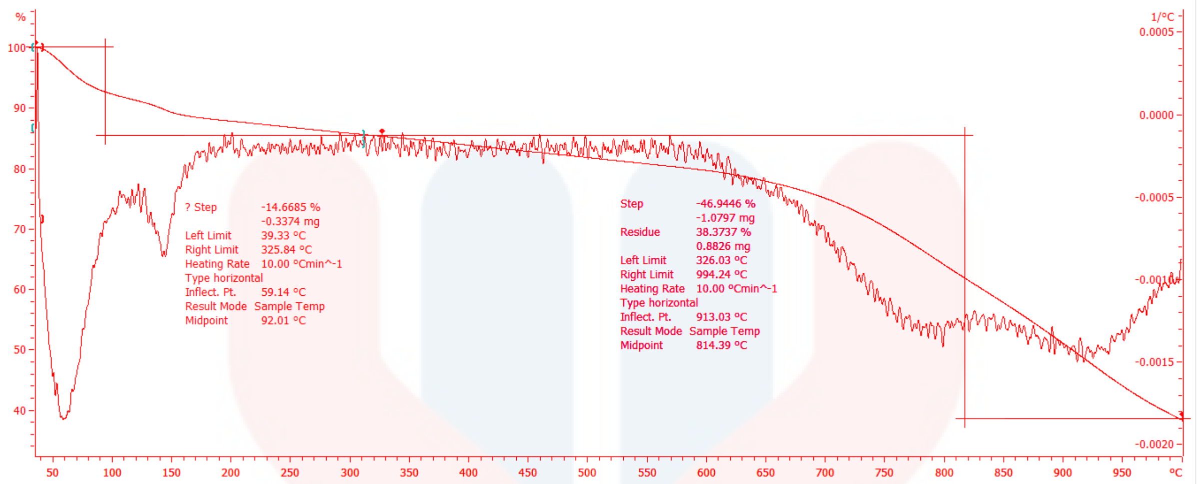


Figure 4.11 TGA analysis of CP

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

In summary, the comprehensive exploration of the biodiesel catalytic potential within coconut shell-plantain peel (CP) biochar catalysts, synthesized at distinct temperatures (CP1 at 600°C, CP2 at 700°C, and CP3 at 800°C), has provided profound insights through various analytical methodologies. Fourier Transform Infrared Spectroscopy (FTIR) analysis highlighted CP2 as possessing a diverse array of favorable functional groups conducive to efficient biodiesel catalysis. The Brunauer-Emmett-Teller (BET) surface area analysis meticulously revealed that CP2 exhibited the highest surface area, indicating an increased availability of active sites for catalytic reactions. Thermo gravimetric- Analysis (TGA) scrutinized the thermal stability of these biochar catalysts, with CP2 displaying an optimal stability profile under the experimental conditions.

Moving on to the X-ray Diffraction (XRD) analysis, CP2 exhibited a crystalline structure well-suited for effective biodiesel catalysis, contrasting sharply with CP1 and CP3. Therefore, in light of these multifaceted analyses, CP2, synthesized at 700°C, emerges as the epitome of biochar catalysts, strategically striking a delicate equilibrium between activation and thermal stability. These findings collectively underscore the immense potential of CP2 in the realm of biodiesel production. This optimal biochar catalyst, with its enriched functional groups, expansive surface area, and exemplary thermal stability, paves the way for promising avenues in biodiesel synthesis.

As a catalyst, CP2 not only showcases heightened efficacy but also beckons further exploration into the intricate mechanisms governing its superior catalytic properties. This invites the prospect of large-scale biodiesel production with enhanced efficiency, making CP2 a pivotal player in advancing sustainable and efficient biodiesel synthesis.

5.2 RECOMMENDATIONS

In light of the comprehensive characterization and performance assessment, the synthesis of coconut shell-plantain peel (CP) biochar catalyst at 700°C (CP2) stands out as the optimal candidate for biodiesel applications. Considering the favorable attributes revealed through Fourier Transform Infrared Spectroscopy (FTIR), Brunauer-Emmett-Teller (BET) surface area analysis, Thermogravimetric Analysis (TGA), X-ray Diffraction (XRD), and the notable absence of Scanning Electron Microscopy (SEM) analysis, it is proposed that SEM analysis be incorporated into the experimental protocol to further enhance the robustness of the results.

The utilization of CP2 as a biochar catalyst for biodiesel synthesis is highly recommended based on its superior performance across multiple parameters. The enriched functional groups identified through FTIR analysis, coupled with the substantial surface area revealed by BET analysis, position CP2 as a catalyst with enhanced catalytic activity. The optimal thermal stability indicated by TGA analysis further underscores its robustness under the conditions pertinent to biodiesel production.

Moreover, the crystalline structure highlighted by XRD analysis and the well-defined porous morphology observed in the anticipated SEM analysis are expected to collectively contribute to the catalyst's efficacy. In light of these findings and the proposed addition of SEM analysis, it is recommended that CP2 be further explored and implemented in large-scale biodiesel production processes. The balance it strikes between activation and thermal stability suggests its potential for efficient and sustainable catalysis.

To facilitate broader adoption, additional studies could delve into the scalability, cost-effectiveness, and long-term stability of CP2 as a biochar catalyst. Continuous monitoring and optimization of the catalyst synthesis process at 700°C, along with the inclusion of SEM analysis, may further enhance its catalytic efficiency. Overall, the robust performance of CP2 positions it as a promising catalyst for the biodiesel industry, warranting continued research and practical application.

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