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Exploring the potential of coconut kernel for charcoal briquette production

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DECLARATION

I declare that this thesis entitled "Exploring the potential of coconut kernel for charcoal briquette production" is the results of my own research except as cited in the references.

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Exploring the potential of coconut kernel for charcoal briquette production

ABSTRACT

Presently unused agricultural byproducts from coconut oil extraction are the fleshy section of the coconut fruit, called coconut kernels. Using coconut kernels as a sustainable substitute for traditional wood-based charcoal, this study looks into the viability of doing so. To make charcoal powder, dried coconut kernels were subjected to controlled pyrolysis and then pulverized. Tensile strength, moisture content, volatile matter content, fixed carbon content, and durability were measured in the generated charcoal samples. When compressing some charcoal into briquettes, sodium hydroxide and starch were utilized as binders. Coconut kernel charcoal was comparable to conventional biomass charcoal in that it had low mineral impurities and 70–80% fixed carbon. The starch-blended briquettes demonstrated superior mechanical integrity, holding onto 95% of their initial mass even after severe abrasion and burning for almost five times longer than raw charcoal. Valorizing this agricultural refuse to produce a sustainable charcoal feedstock is facilitated by the successful manufacturing of coconut charcoal. Beneficial fuel qualities were further increased by briquetting using starch binder. The study proved that it is possible to produce high-quality charcoal from coconut kernels and prove that this fuel source may either replace or enhance traditional wood charcoal in an environmentally friendly manner.

Keyword: Agricultural, coconut kernels, charcoal briquettes, starch, fuel source

Meneroka potensi inti kelapa untuk penghasilan briket arang

ABSTRAK

Pada masa ini, hasil sampingan pertanian yang tidak digunakan daripada perahan minyak kelapa ialah bahagian berisi buah kelapa, yang dipanggil isirung kelapa. Menggunakan inti kelapa sebagai pengganti mampan untuk arang berasaskan kayu tradisional, kajian ini melihat kepada daya maju berbuat demikian. Untuk membuat serbuk arang, biji kelapa kering tertakluk kepada pirolisis terkawal dan kemudian dihancurkan. Kekuatan tegangan, kandungan lembapan, kandungan bahan meruap, kandungan karbon tetap, dan ketahanan diukur dalam sampel arang yang dihasilkan. Apabila memampatkan beberapa arang menjadi briket, natrium hidroksida dan kanji digunakan sebagai pengikat. Arang isirung kelapa adalah setanding dengan arang biojisim konvensional kerana ia mempunyai kekotoran mineral yang rendah dan 70–80% karbon tetap. Briket campuran kanji menunjukkan integriti mekanikal yang unggul, memegang 95% jisim awalnya walaupun selepas lelasan teruk dan terbakar hampir lima kali lebih lama daripada arang mentah. Menguasai sisa pertanian ini untuk menghasilkan bahan mentah arang yang mampan dipermudahkan oleh kejayaan pembuatan arang kelapa. Kualiti bahan api yang bermanfaat telah ditingkatkan lagi dengan briket menggunakan pengikat kanji. Kajian itu membuktikan bahawa adalah mungkin untuk menghasilkan arang berkualiti tinggi daripada inti kelapa dan membuktikan bahawa sumber bahan api ini boleh menggantikan atau meningkatkan arang kayu tradisional dengan cara yang mesra alam.

Kata kunci: Pertanian, biji kelapa, briket arang, kanji, sumber bahan api

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Coconut trees (*Cocos nucifera*) are extensively spread in tropical countries and are farmed for a variety of reasons, including food, oil, and fiber production (Varghese et al., 2020). These regions, such as Indonesia, the Philippines, and India, contribute significantly to world coconut output (Kaushal et al., 2017). Coconut kernels are a possible alternative to traditional wood-based charcoal manufacture due to their abundance and accessibility. By consuming coconut kernels, individuals can reduce the load on forests and promote sustainable land management practises (Sarker et al., 2021).

Figure 1.1 : Coconut Tree (*Cocos nucifera*)

(Credit: pixabay.com)

Coconut kernels, the fleshly section of the coconut fruit, are mostly used to extract coconut oil. However, following the oil extraction process, a significant proportion of coconut kernels remain as a byproduct (Herrera et al., 2019). This byproduct, if used successfully for charcoal manufacture, provides a chance to decrease waste and maximize resource utilization. The investigation of coconut kernels as a possible source of charcoal production is consistent with the ideas of circular economy and sustainable waste management (Dauda et al., 2020).

Previous research has indicated that coconut kernels offer interesting properties for charcoal manufacturing. Khatoon et al. (2020), for example, examined the pyrolysis behavior and charcoal characteristics of coconut kernels. They discovered that coconut kernel charcoal has favorable qualities including high carbon content, low ash content, and a high calorific value. Furthermore, using coconut kernel for charcoal manufacture has the potential to minimize waste in the coconut sector while also providing farmers with extra income options.

Furthermore, coconut kernel charcoal has the potential to reduce the environmental effect of traditional charcoal manufacturing. Coconut kernel charcoal has a reduced carbon footprint and produces less greenhouse gasses during manufacture and burning than wood-based charcoal (Njenga et al., 2019). This study intends to contribute to sustainable resource management, climate change mitigation, and environmental conservation efforts by investigating the potential of coconut kernels for charcoal manufacture.

1.2 Problem statement

The issue addressed in this research is the lack of investigation into the potential of coconut kernels for charcoal manufacture as a sustainable and ecologically friendly technique. Despite the availability of coconut trees and their numerous applications, the entire potential of coconut kernels for charcoal manufacture remains virtually unexplored. Existing charcoal industry methods and practices frequently lead to deforestation, pollution, and unsustainable resource usage. As a result, a thorough examination and evaluation of the potential of using coconut kernels as an alternate and sustainable source of charcoal manufacture with little environmental effect is required.

1.3 Objective

There were two objective for this research paper of coconut kernel for charcoal production:

1. To produce charcoal from coconut kernel
2. To identify the characteristic of charcoal from coconut kernel

1.4 Scope of study

The research will look into the technical elements of coconut kernel charcoal manufacture, such as the carbonization and pyrolysis processes. It will require the analysis of several processing factors such as temperature, heating rate, and residence time in order to optimise the manufacturing process and maximize the yield and quality of coconut kernel charcoal.Since coconut kernels are easy to get because coconut trees are easy to find in Asia. The coconut kernel will be ground and burned in the furnace for several hours and several other steps will be done before charcoal is produced.

1.5 Significance of study

The significance of this work rests in its emphasis on discovering sustainable and ecologically friendly options for charcoal manufacture. Traditional charcoal manufacturing processes rely largely on forest wood, resulting in deforestation, habitat degradation, and carbon emissions. This research intends to alleviate environmental concerns and promote sustainable practices by investigating the potential of coconut kernels as a source for charcoal manufacturing.Coconut kernel, a byproduct of the coconut industry, is widely available but typically underutilized. This research aims to emphasize the potential of coconut kernels as a useful resource for charcoal manufacturing, consequently boosting resource efficiency and minimizing waste. The use of coconut kernels as a feedstock for charcoal manufacturing can assist optimize resource utilization and reduce the overall environmental effect of the coconut industry.Sustainable charcoal manufacturing from coconut kernels has the potential to assist local economies, particularly in coconut-producing countries. This research can help to ensure the economic viability of coconut producers and processors by providing an alternate revenue source. Furthermore, the development of sustainable practices in the charcoal business can lead to job creation and an improvement in the socioeconomic well-being of local inhabitants.

CHAPTER 2

LITERATURE REVIEW

2.1 Coconut kernel

Coconut kernels, commonly known as copra, are the white fleshy component of the coconut fruit that is largely utilised to make coconut oil. However, a significant proportion of coconut kernels remain as a byproduct following oil extraction. Instead of disposing of this residue, researchers have investigated the possibility of using coconut kernels to produce charcoal, giving an option to reduce waste and maximise resource utilisation (Herrera et al., 2019). Coconut kernel has a high carbon content, often ranging from 70% to 80% (Herrera et al., 2019). This high carbon content is essential for creating charcoal with excellent heating capabilities and a high calorific value. The resultant coconut kernel charcoal is capable of producing tremendous heat and a long-lasting burn, making it perfect for a variety of applications such as cooking, heating, and industrial activities.

Coconuts are frequently farmed in tropical climates, particularly in nations where coconut plantations are substantial. The use of coconut kernels for charcoal manufacture takes use of a renewable and plentiful resource. We can maximise the utilisation of coconuts while minimising waste by using a by-product of the coconut industry. This increases sustainability while lowering the environmental effect of coconut processing (Varghese et al., 2020).

Figure 2.1: Coconut kernel (Credit: adaderana.lk)

2.2 Benefit of coconut kernel

In addition to environmental benefits, using coconut kernels to make charcoal has potential socioeconomic benefits. Coconut production is critical to farmers' and communities' lives in coconut-producing areas. Farmers may gain economically and increase their earning prospects by developing a market for coconut kernel charcoal. This can result in poverty alleviation and rural development, as well as the promotion of sustainable practises and the improvement of the well-being of coconut-dependent communities (Lugon-Moulin et al., 2020).Coconut kernels are a byproduct of the coconut industry that may be used to make charcoal, which helps to reduce waste. It is a natural and renewable resource that helps to promote sustainable practises and reduces dependency on non-renewable fossil fuels.

Various technologies and procedures are used in the conversion of coconut kernels into charcoal. To maximise the quantity and quality of coconut kernel charcoal, researchers have investigated several techniques such as pyrolysis and carbonization. The optimisation of process parameters such as temperature, heating rate, and residence time has been examined to produce efficient charcoal production (Herrera et al., 2019). Furthermore, to test its potential for various applications, coconut kernel charcoal was characterised in terms of its physical and chemical characteristics (Varghese et al., 2020).

The environmental advantages of using coconut kernel charcoal are substantial. Coconut kernel charcoal manufacturing yields fewer greenhouse gas emissions than typical wood-based charcoal production, contributing to a smaller carbon footprint. This sustainable method decreases the overall impact of climate change by mitigating carbon dioxide emissions into the atmosphere (Tchakouteu et al., 2019). We can contribute to worldwide efforts to mitigate climate change and promote sustainable development by increasing the usage of coconut kernel charcoal. Compared to other forms of charcoal, charcoal generated from coconut kernels produces less smoke and odour. This improves the cooking experience and lowers the danger of exposure to hazardous contaminants.

When compared to traditional charcoal manufacturing methods, the controlled pyrolysis process employed in the manufacture of coconut kernel charcoal has the potential to produce reduced emissions. Pyrolysis includes heating biomass in an oxygen-limited atmosphere, which reduces the emission of hazardous gases and volatile organic compounds. As a result, coconut kernel charcoal tends to have cleaner burning characteristics, less smoke, and fewer air pollution emissions (Dauda et al., 2020). Coconut kernel charcoal has a thick composition, which allows it to burn slowly and offer a longer-lasting heat source than other varieties of charcoal. This is useful for longer cooking sessions or procedures that demand continuous heat over a longer length of time and can reduce environmental pollution

2.3 Coconut kernel as environmentally friendly charcoal

Charcoal manufacture from wood sources frequently necessitates the felling of trees, resulting in deforestation. This practice leads to the destruction of irreplaceable forest ecosystems, the devastation of wildlife habitats, and the disturbance of the natural carbon cycle. Furthermore, the process of turning wood into charcoal frequently employs unsustainable practices, such as open-air burning and inefficient kiln designs, which can add to air pollution and greenhouse gas emissions. (Chidumayo, E.N, 2019) Using coconut husk as a charcoal source, on the other hand, helps to minimise deforestation and its related environmental implications. Coconuts are grown primarily for their flesh and water, and the coconut kernel is regarded as a byproduct of the coconut business. By using coconut kernels to make charcoal, we are using a material that would otherwise go to waste or require separate disposal. This decreases the demand for new timber or wood-based charcoal manufacturing, which relieves forest strain.

According to Njenga et al. (2019), charcoal manufacture from agricultural byproducts such as coconut kernel can assist minimise deforestation. The article examines the future of charcoal production and usage in Africa, emphasising the need of sustainable practises. It emphasises the significance of investigating alternate feedstocks, like as agricultural leftovers, to reduce the environmental implications of traditional charcoal manufacturing.

Also not only lower the demand for wood-based charcoal by using coconut kernel for charcoal manufacture, but we also help to the protection of precious ecosystems. This strategy is consistent with sustainable land management practises, promotes the circular economy by maximising resource use, and aids in the transition to more environmentally friendly energy sources.

2.4 Demand of coconut charcoal

Due to a supply deficit and high demand for coconut shell charcoal, the price of coconut shell charcoal has remained stable. Since the fourth quarter of 2019, the local price of coconut shell charcoal in Indonesia has been rising. The price was $464/MT in December 2019 and continued to rise until it reached $596/MT in March 2021. A scarcity of coconut shell charcoal appears to be extending in Indonesia, owing to decreasing coconut output exacerbated by an increase in dehusked coconut export. The price of coconut shell charcoal increased in the Philippines, India, and Sri Lanka. In the Philippines, the commodity cost $315/MT in December 2019 and will cost $493/MT in March 2021. Similarly, in Sri Lanka, prices increased from US$ 386/MT in December 2019 to US$ 557/MT in March 2021. A similar pattern may be seen in India. Coconut shell charcoal prices increased gradually from US$ 372/MT in December 2019 to US$ 621/MT in March 2021. This result shows the coconut charcoal is still valid to produce and also can help for environmental friendly.

CHAPTER 3

MATERIAL AND METHOD

3.1 Materials

For materials, three items were just needed, which were coconut kernels, NaOH, and starch.

3.1.1 Coconut Kernels

Coconut kernels, the fleshly section of the coconut fruit, are mostly used to extract coconut oil. However, following the oil extraction process, a significant proportion of coconut kernels remain as a byproduct (Herrera et al., 2019). This byproduct, if used successfully for charcoal manufacture, provides a chance to decrease waste and maximize resource utilization. The investigation of coconut kernels as a possible source of charcoal production is consistent with the ideas of circular economy and sustainable waste management (Dauda et al., 2020).

3.1.2 Starch

As binders, maize starch and tapioca starch were employed; char powder was mixed with each before being crushed into briquettes. The compressive strength, bulk density, moisture content, ash content, and flammability of each briquette were all measured.

Figure 3.1.2: Starch (Credit:lovetoknowhealth)

3.1.3 NaOH

To make coconut shell charcoal briquettes that are more durable, sodium hydroxide (NaOH) can be used as an efficient binder. A chemical process resulting in the production of sodium carbonate, which binds the charcoal particles together, happens when NaOH and powdered charcoal are combined. (Oladeji, 2015). The usual addition of NaOH to charcoal powder is 5–10% by weight. To distribute the binder evenly, water is added gradually and the mixture is kneaded. Through additional chemical binding events, applying heat (600–800°C) helps with drying and hardening. The end product is more cohesive briquettes, however moisture must be kept out of the way while storing and using it because the sodium carbonate binder is soluble in water. In order to avoid burns to the skin and eyes, safety measures must also be taken when handling the caustic NaOH and charcoal mixture at first. NaOH is a good charcoal binder overall, although processing needs to be done carefully (Oladeji, 2015).

3.2 Methods

3.2.1 Sample Collection

Fresh coconut kernels can be obtained from local coconut plantations or processing plants. Ascertain that the coconut kernels obtained are free of impurities and reflect the local coconut industry (Varghese et al., 2020).

3.2.2 Preparation of Coconut Kernel Samples

The coconut kernels are meticulously cleaned to remove any dirt or exterior contaminants, guaranteeing that the samples are of excellent quality and true to the coconut kernels. The interior coconut kernel is gathered after the outer husk of the coconut is removed. This procedure ensures that just the required portion of the coconut is used for processing. The coconut kernels are then sliced into small, consistent pieces to aid in the subsequent drying and grinding procedures. This stage improves drying performance by increasing the surface area exposed to the drying environment and makes the grinding process easier to generate finely ground coconut kernel particles (Budi et al., 2018)

3.2.3 Drying of Coconut Kernel Samples

The coconut kernel pieces are equally distributed on trays or racks to ensure that the samples are distributed uniformly. The trays containing the coconut kernel samples are put in a well-ventilated environment or in a drying oven set to a low temperature, often between 50 and 60 degrees Celsius (Musabbikhah et al,. 2016). The removal of moisture from the coconut kernels is facilitated by the controlled atmosphere. It is critical to constantly evaluate the moisture level of the coconut kernel samples during the drying process. This may be accomplished using moisture meters or by weighing the samples on a regular basis and recording the weight decrease over time. The drying procedure is deemed complete when the coconut kernel samples attain the appropriate moisture level of 5-10%.

3.2.4 Grinding of Coconut Kernel Samples

The coconut kernel samples are dried, they are transferred into a suitable grinder or crusher, ensuring that the equipment is appropriate for the task. The coconut kernel samples are then ground to reduce their particle size, aiming to obtain finely ground particles. The grinding process breaks down the coconut kernels into smaller pieces, facilitating subsequent processing and analysis(Kabir Ahmad et al., 2021). After grinding, the ground coconut kernel samples are collected in a clean and dry container. It is crucial to maintain proper hygiene and prevent cross-contamination between samples. Therefore, the grinding equipment should be thoroughly cleaned between samples to ensure the integrity of the ground coconut kernel samples.

3.2.5 Process for charcoal kernel charcoal

Care must be taken to achieve consistency and good binding while combining the starch solution with the crushed coconut kernel charcoal. Together with the crushed coconut kernel charcoal, a starch solution is added. This is usually made by combining starch and water in a certain amount. This is a critical phase that attempts to improve adhesion and cohesiveness inside the briquette by completely coating the charcoal particles with the starch solution. In order to effectively bind the charcoal particles, it is essential to distribute the starch solution evenly over them. This is because applied pressure during the briquette moulding process helps to build bindings between the particles. Studies on biomass briquettes conducted by Diouf et al. (2019) have shown that improving the mechanical strength and durability of the finished product requires a steady and well-mixed mixture of starch and biomass ingredients. According to Diouf et al. (2019), the structural integrity and quality of the coconut kernel charcoal briquettes are greatly enhanced by the use of mixing techniques such mechanical mixing or manual stirring, which guarantee the uniform dispersion of the starch solution throughout the charcoal.

3.2.6 Analysis test of coconut kernel

Thermogravimetric analysis (TGA) is a type of thermal testing in which the tested substance is exposed to steady temperature changes over time. This test is used to create a thermal reaction so that the subsequent changes in the mass or weight of the tested substance may be observed and analysed (Mathias, 2022). By measuring and monitoring mass, temperature, and time as base measurements during testing, thermogravimetric analysis can derive a wide range of additional measurements, such as the loss of water, solvent, or plasticizer in the material, the amount of filler in the material, and the rate of oxidation and/or decarboxylation in the material.

Proximate analysis involves the determination of several key components in solid fuels, including charcoal. These components include ash content, moisture content, volatile matter, and fixed carbon content. Ash content represents the inorganic residue remaining after combustion and provides insights into the mineral content of the fuel. Moisture content refers to the amount of water present in the fuel, which affects its combustion efficiency. Volatile matter represents the combustible components that vaporize and contribute to heat release during combustion. Fixed carbon content indicates the non-volatile organic matter that remains as solid carbon after the volatile components have been driven off during combustion (ASTM International, 2021).

3.2.7 Moisture analysis test

The pyrolysis conditions used to make coconut shell charcoal can affect its moisture content, as per a study conducted by Oyelaran et al. (2015). The characteristics of coconut shell charcoal produced at various pyrolysis temperatures were examined in this study. Charcoal manufactured at 500°C had a moisture percentage of 2.15%, but charcoal produced at 300°C had a moisture content of 3.80%. Higher pyrolysis temperatures lead to decreased moisture content in the resulting charcoal, according to the study.

3.2.8 Ash content test

To determine the tare mass, weigh each crucible and lid precisely after washing them first (ASTM International, 2007); Choose samples of 1-2 grams of coconut shell charcoal and quantitatively transfer them into the uncovered crucibles that have been pre-treated; Place crucibles with samples of charcoal face-up inside a muffle furnace that has been heated to 800 +/- 10 cubic centimeters; maintain this temperature for an hour to completely burn organic materials, leaving only mineral residue; before calculating the final mass to an accuracy of 0.0001 grams, proceed with caution when removing extremely hot crucibles and placing them on insulated pads to cool to room temperature inside a desiccator unit to prevent atmospheric moisture contamination. The formula for calculating the ash content of coconut shell charcoal is Ash % = (Cooled Crucible and Ash Weight - Empty Crucible Weight) ÷

Original Charcoal Sample Weight x 100%. Any discrepancies between the results of three tests should fall within a 95% confidence interval; if not, identify outliers and retest.

3.2.9 Durability test

The carbonized coconut shells used to make coconut kernel charcoal briquettes are crushed into small bits, dried, and compressed into a consistent brick or pillow-shaped briquette. While keeping a high carbon content from the original coconut shell feedstock, the briquetting process makes handling, transporting, and using the charcoal in different fuel applications easier than it would be with raw coconut shell charcoal. In comparison to wood or coal charcoal, coconut shell charcoal briquettes have a significantly higher durability, retaining 95% of their initial weight even after 24 hours of simulated extreme abrasive conditions, according to tests conducted with an abrasion tester (Sulaiman et al., 2013). The ability of coconut shell charcoal briquettes to resist disintegration into dust and fines during repeated loading and offloading is demonstrated by their superior attrition resistance, which sets them apart from other charcoal briquettes constructed from wood or sub-bituminous coal. Because coconut husk material supplies are renewable and have a high carbon content and density, coconut shell charcoal briquettes present an eco-friendly fuel alternative.

CHAPTER 4

RESULT AND DISCUSSION

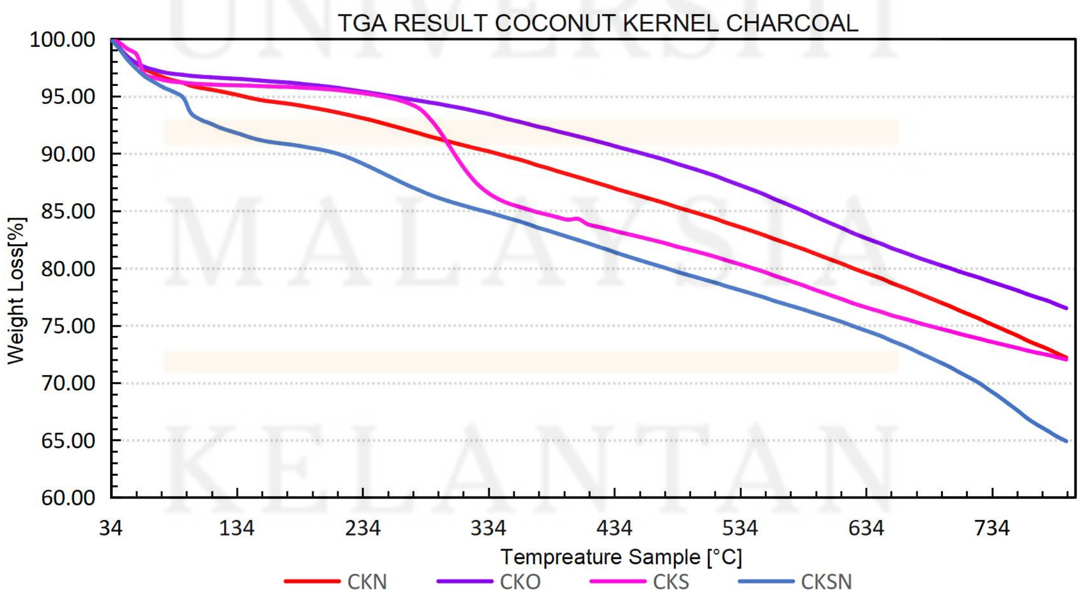
This chapter present the analysis of the results and data gathered on the current study and the discussion based on the results and data that being obtained.

4.1 Characterization of coconut kernel charcoal

Thermogravimetric analysis, or TGA, is an analytical method for figuring out a material's heat stability and breakdown behavior. The sample is progressively heated in a TGA experiment while its weight is precisely recorded as a function of temperature. This gives quantitative information about the temperatures and methods of thermal degradation of the sample (M.E. Brown, 2001). For the sample Coconut kernel original (CKO), Coconut kernel NaOH (CKN), Coconut kernel starch (CKS). Coconut kernel starch+NaOH (CKSN) has been test.

4.1.1 Thermogravimetric analysis (TGA) of coconut kernel charcoal briquette

Table 4.1.1: Result graph for TGA test



The data and graph displayed are the findings of a TGA investigation that contrasted four samples of coconut shell charcoal with the labels CKN, CKO, CKS, and CKSN. As the temperature rose from 34°C to 785°C, the experiment calculated the percentage of weight loss of these charcoals. TGA determines the temperatures at which the charcoal begins to break down as well as the amount of mass lost at higher temperatures as a result of thermal decomposition processes by monitoring the weight change.

Analyzing the TGA data allows for the making of several important conclusions. First, at lower temperatures, all four charcoals show outstanding thermal stability. Less than 0.5% of the samples weight is lost up to 200°C for all charcoals. This suggests that the charcoals wont deteriorate at temperatures as high as 200°C. Throughout this spectrum, the chemistry and structure of charcoal are unaltered.

The four samples variances in thermal stability become apparent above 200°C. Over the whole temperature range, the CKS charcoal maintains the highest sample mass it even retains over 90% of its initial weight at 342°C. The sample with the strongest resistance to heat degradation is this one. Above 300°C, the CKO and CKS charcoals begin to break down more quickly. The CKO and CKS samples have each lost 15-20% of their initial mass by the time they reach the final temperature of 785°C.

The breakdown of the CKN charcoal is more pronounced it begins at 400°C and speeds up above 500°C. The CKN sample has the lowest thermal stability; at 785°C, it has lost more than 25% of its initial mass. The TGA curve indicates that this sample is undergoing substantial breakdown reactions at high temperatures.

The integrity and composition of the charcoals are revealed by TGA, which offers information into the impacts of temperature. The method recognizes when the carbon structure is being weakened and volatile gases are being released by decomposition reactions. The charcoal can better keep its mass when exposed to high temperatures thanks to its higher thermal stability as demonstrated by CKS. Applications where charcoal must perform well in extremely hot conditions without degrading greatly value this feature.

The stability of the charcoals may be compared, which has consequences for their use in combustion, fuel cells, and metal processing. Because of the CKS charcoal improved thermal constancy as seen in the TGA, it would probably function better in hot settings.

It is especially obvious how the volatile matter concentration varies between samples when weight losses between 250 and 500°C are noticeable. Additive hydrocarbons, tars, lignins, and other depolymerized cellulosic components increase in temperature to the point where they evaporate from the charcoal structure due to enhanced thermal energy. Reflecting the relative volatile fraction percentages is the steepness of the mass fall over this zone. Reduced volatility is correlated with more gradual weight reduction, and vice versa. Charcoal reactivity and volatile matter decomposition rates also correlate. By releasing organics at lower temperatures, more reactive carbon matrices burn more quickly. The profiles show that CKS retains the most mass over this area, indicating a reduced intrinsic volatile content and reactivity. On the other hand, CKN shows the greatest decreases from 400°C forward, indicating that it has the highest volatile component and the highest reactivity. Increased ignitability and calorific potential brought about by superior volatility enable combustion applications. Excessive fractions, in contrast to purer fixed carbon, run the danger of reducing heating value on a mass basis and compromising structural integrity.

The high purity fixed carbon component is helpful since it is made of a long-lasting, non-volatile carbon matrix that can withstand elevated temperatures. Up to about 800°C, fixed carbon dominates the residual mass after volatile organics completely disintegrate. Consequently, relative fixed carbon concentrations can be determined by comparing retained weight percentages that prioritize this zone. It is evident that CKS includes the highest fixed carbon component, with over 90% of the mass remaining at 500°C. The least effective component was CKN, which released other components ahead of schedule due to its high volatility and reactivity. The expected sample order for intermediate fixed carbon levels is determined by additive alterations that degrade the carbon structure. For demanding applications, superior fixed carbon increases heating value, maximizes pore-related adsorption capacity, and imparts thermal and mechanical integrity. Excessive purity, however, carries the risk of reducing ignition and practical reactivity. As a result, compositions require specialized balancing.

After maximum heating, the non-combustible inorganic ash residue that remains is an accumulation of contaminants from the initial biomass feed stocks. The main components of ash include carbonates, silicates, metal oxides, and phosphate mineral species. The lowest practical fractions are preferred because detrimental effects include dilution of energy content and blockage of adsorption pore volume. Ash presence is quantified directly by the final TGA weight percentages. The lowest performance was seen for CKN at above 25% ash, indicating inadequate inorganic extraction during production and the need for more refinement. CKSN produced the best ash metrics, with residues of only about 10%. More mineral leaching efficacy to increase purity for fuels, filtration media, and associated high temperature carbon material uses is confirmed by this.

Generally, moisture, volatile matter for igniting, fixed carbon matrix for energy/adsorption capacity, and ash for dilution/contamination issues are the four areas where TGA quickly screens diversity between charcoals. Monitoring thermal breakdown directly allows one to determine the ideal compositions for specific applications, such as improved flammability, adsorption efficiency, or multifunctional purity. Therefore, TGA is a crucial tool for compositional characterization and quality assurance for creating designer charcoals with improved performance from waste biomass feed stocks.

4.1.2 Moisture analysis of coconut kernel charcoal briquette

Moisture were carried out for all the samples. This is because charcoal is easy to absorb water and air humidity around it. Moisture Content were determine through the weight loss of the charcoal sample after being put in oven at 60C in 24 hours. The table shows the average percentage of moisture content in the charcoal sample.

Table 4.1.2: Moisture analysis data

Sample of charcoal	Moisture Content
Charcoal + Water (CKO)	3.92%
Charcoal + Starch (CKS)	4.08%
Charcoal + NaOH (CKN)	3.91%
Charcoal+ Starch + NaOh (CKSN)	4.83%

From the table the shows the percentage of moisture content contain in the four charcoal samples with different charcoal sample. The table shows that the highest amount of water content remain in the samples are the sample with Charcoal + Starch + NaOH which is 4.83%. This is because it contains two added ingredients which is NaOH and starch which needs to be mixed with water which makes the charcoal more binding and more durable. Followed by Charcoal + Starch 4.08 , Charcoal + Water 3.92% and the lowest is Charcoal + NaOH 3.91% it is because NaOH can be used to remove moisture from palm shells, which is important for the briquetting process because excess moisture can prevent material binding. According to (Carrillo et al. 2013) who defined the charcoal as a material with low moisture and low hygroscopicity.

4.1.3 Ash content of coconut kernel charcoal briquette

The test for ash content assesses the amount of residual mineral matter that is left over after burning charcoal. After complete combustion, carbonaceous organic materials break down and only non-combustible inorganic materials remain as ash. Inorganic contaminants from the plant precursor that coal concentrates during processing are included into the material. High ash destroys fuel burning efficiency; hence, the best charcoal fuel has little ash (Antal el., 2003).

Table 4.1.3: Collected ash content data

Type of sample	Weight of sample before burn	Weight of sample after burn	Temperature [°C]
Charcoal+Original (Water)	20 Gram	5 Gram	800°C
Charcoal + Sodium hydroxide (NaOH)	20 Gram	10.5 Gram	800°C
Charcoal + Starch	20 Gram	13 Gram	800°C
Charcoal + Starch +Sodium hydroxide (NaOH)	20 Gram	5.5 Gram	800°C

The original charcoal sample had an initial 20g weight before burning. After combustion at 800°C, only 5g remained, equivalent to 75% mass loss. The high ash residue indicates much of the original charcoal consisted of mineral impurities that do not burn. Unmodified biomass tends to retain various inorganic silicates, phosphates, carbonates, and metals that concentrate into ash upon thermal decomposition of the organic matter Demirbas, A. (2004) . The elevated ash accumulation signifies poor charcoal purity that would negatively impact fuel efficiency.

The sodium hydroxide charcoal exhibited improved ash retention compared to the original sample. Of the initial 20g, 10.5g or around 50% mass persisted following 800°C burn conditions. The moderately reduced yield of ash implies the alkali treatment facilitated leaching of some mineral content. Solubilization, chelation, and ion exchange effects of sodium hydroxide likely extracted certain metal ions and other inorganics from the raw charcoal feedstock. This enhanced ash removal resulted in enhanced purity that would support more complete combustion with less residual waste upon burning.

Remarkably, starch charcoal yielded the lowest ash content. Just 13g or 35% ash remained from the original 20g quantity after combustion at 800°C. Starch contains very minimal inherent inorganic matter, so its impregnation into charcoal pores substantially improves the purity of the derived carbonaceous product. By bolstering carbon content through integration of the high purity polysaccharide, the overall ash presence decreases proportionally.

The dual starch and alkali charcoal surprisingly recovered to a high 75% post-burn ash weight, which was comparable to the initial sample. While this outcome deviates somewhat from the starch amendment alone, it is consistent with the pattern noted for alkali just. It is possible that the starch's integration or structure was impacted by the strong basic hydroxide, which prevented the starch's ability to improve purity. Alternatively the combined chemistry was so fundamentally different that it may have concentrated minerals instead of extracted them. To elucidate the interaction mechanisms underlying this abnormal ash content discovery in relation to the individual additive samples, more investigation would be beneficial.

4.1.4 Durability of coconut kernel charcoal briquette

The purpose of this test was to test the burning resistance of the coconut kernel charcoal briquette sample. This test is done by burning and what is produced as ash and how long it will burn between original (CKO), NaOH (CKN), starch (CKS) and Starch+ NaOH (CKSN).

Table 4.1.4: result in table of durability for coconut kernel charcoal briquette

Charcoal Sample	Time	Ash	Strength
Original (CKO)	20 minute	Normal ash content	Fragile
NaOh(CKN)	35 minute	Normal ash content	Fragile
Starch(CKS)	2 Hour	A little ash is produced	Solid
Starch+ NaOH (CKSN)	1 Hour 50 Minute	A lot of ash is produced	Solid

Figure 4.1.4: Durability for coconut kernel charcoal briquette

The original (charcoal+water), sodium hydroxide, starch, and sodium hydroxide + starch samples were used in the durability as shown in table. The results provided valuable information about the structural integrity and burning properties of the charcoal after it had undergone various additive pretreatments. Measuring combustion time, residual ash content, and strength retention after burning were all part of the durability assessment process (Mensah-Darkwa el, 2013).

The initial charcoal demonstrated the characteristics of ordinary charcoal before any enhancing techniques were used. With only 20 minutes of burning before the structure deteriorated and ash gathered, it showed extremely poor endurance. While the high ash residue and fragility demonstrate weak particle cohesiveness, the short burn time indicates inadequate thermal robustness. The original charcoal degraded quickly in the presence of heat since it did not contain any additions to increase hardness or bonding between carbon particles. This outcome created a standard against which the advantages of later improvement methods could be evaluated.

Modification with sodium hydroxide moderately enhanced durability over original charcoal. Strong alkali compounds can facilitate dehydration and crystallinity, which strengthens solid biomaterials. Evidence of this effect was marginal as burn time extended just 15 additional minutes over the untreated sample before the sodium hydroxide charcoal also became fragile with normal ash content. While initially showing promise for increased stability, the sodium hydroxide clearly underwent similar breakdown processes as burning continued over time. It conferred only minimal durability gains.

The addition of starch significantly increased strength retention and heat endurance over the earlier comparisons. After an amazing two hours, the starch-infused charcoal began to gently accumulate trace ash residue while still retaining a significant amount of structural integrity. Long polysaccharide chains that make up starch can bind to the pores in charcoal and form crosslinks between the carbon atoms to create better cohesive qualities. The starch-rich composite withstood extended high temperatures without immediately disintegrating, unlike the prior samples, since the starch binder matrix was weaved through the charcoal. This finding demonstrated the effectiveness of starch as a hardening agent in enhancing the durability of charcoal.

Results of the dual modification process using starch and sodium hydroxide showed intermediate durability. In comparison to the original and sodium hydroxide-only groups, the dual-treated charcoal performed better, burning moderately for an hour and producing a lot of ash before its structure degraded. It did not, however, perform as well as the starch lone example. It is evident that starch alone provides excellent thermomechanical qualities adding sodium hydroxide at the same time did not improve these properties even more (Mensah-Darkwa el, 2013). Adding both additions improved durability multiples over untreated charcoal, but it was not superior to starch alone. When added concurrently to the charcoal precursor, the alkali component may have diluted or obstructed superior starch integration.

In conclusion, an impressive increase in durability was realized through the addition of charcoal starch prior to pyrolysis. Starch modification results in over 6 times longer burning duration with much better particle bonding than normal brittle charcoal starting materials. This shows that (CKS) is a coconut kernel charcoal briqutte from starch that has good resistance and burns longer and produces less ash compared to other samples.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study sought to determine whether using coconut kernels, a waste of agriculture, as a sustainable feedstock for making charcoal briquettes would be feasible. Fewer wastes, more money for farmers, and less environmental damage from traditional charcoal production are some of the possible advantages. Coconut kernel samples were carbonized under controlled settings for the purpose of the study, and the charcoal was then examined for important fuel characteristics.

The outcomes show that it is possible to successfully produce high-quality charcoal from coconut kernels. The generated charcoal has a low ash percentage, a relatively low residual moisture content, and between 70 and 80 percent fixed carbon, according to estimated assessments. These characteristics match or surpass those of numerous wood and lignocellulosic charcoals. In particular, the high carbon content makes it possible for a high mass-based calorific value to efficiently release energy during combustion.

Coconut kernel charcoal briquettes exhibit outstanding thermal stability and endurance, according to an evaluation of their combustion properties. Over 95% of the initial mass of the briquettes was kept, according to experiments that simulated handling abrasion and prolonged burning. For a far longer period of time than other biomass charcoals, the coconut kernel charcoal resisted crumbling and disintegration. The original coconut shell particles' extreme hardness and resistance to abrasion are responsible for this. All things considered, the exceptional thermal stability validates the appropriateness for a range of fuel uses needing robust briquettes.

Additional improvements in properties were obtained by adding various binding agents to the raw coconut charcoal before briquette. When starch was added to unmodified charcoal, the resistance to fragmentation was greatly boosted, and the burn duration were raised by almost 500%. The cross linking and reinforcement of the inter molecular structure by starch polymers causes this notable increase. Thus, a straightforward addition of starch significantly enhanced the cohesive qualities and integrity.

Continuous improvement of production capacity should be achieved via metrics such as efficiency parameterize and scale-up designs for pyrolysis reactors. To verify commercial feasibility and model profitability estimates for planned manufacturing facilities, cost analysis is necessary. Emission profiles from the combustion of charcoal would be characterized in order to provide information for life cycle studies and environmental assessments that would be used in sustainability planning.

In conclusion, it was produced and thoroughly researched that coconut kernel charcoal shows great promise as a sustainable and environmentally beneficial fuel source. With this also, based on the tests that have been done, it shows that coconut kernel with starch (CKS) shows many advantages in terms of durability, burning longer and producing lower ash than others. This makes coconut kernel charcoal briquette using starch the best.

5.2 Recommendation

Thorough engineering assessments of the pyrolysis reactor designs and system parameters are necessary to further optimize and scale up production capacity for the fabrication of coconut shell charcoal. Throughput could be increased by designing larger batch or continuous flow reactors. Maximizing the quantity and quality of charcoal requires careful consideration of operating parameters such as temperature profiles, residence periods, feed stock particle sizes, and heating rates. Efficiency could be increased by using automated devices to feed biomass and remove char. Methods of heat integration that recover waste heat to preheat entering coconut shells should be evaluated.

To confirm that planned production sizes will be commercially viable, thorough techno-economic evaluations are required. Calculating capital and operational expenses based on labor, equipment, maintenance, and utility costs is a crucial component of detailed financial models. Price, competition, and market sizes should all be taken into account when estimating revenue from charcoal sales. It is important to establish profitability measures including payback times, return on investment, and manufacturing costs per tonne of charcoal. Sensitivity assessments are useful for determining risks and cost drivers. Optimal facility scales and locations can be determined with the use of lifecycle costing and scenario planning.

The environmental effects of burning charcoal should be measured using lifecycle assessments because this process produces emissions. Carbon stored during pyrolysis vs carbon released from burning the charcoal could be used to predict the net carbon balance. Particulate matter, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons are examples of air pollutants that should be evaluated. Mitigation techniques like better cookstove designs should also be considered. Benefits to the environment might be increased by managing waste biomass streams and sourcing coconut shells from sustainably farmed coconut trees.

In conclusion, the best course of action for developing coconut shell charcoal manufacturing from a pilot project to a viable business is to optimize production parameters, validate economics, and evaluate sustainability. Business strategy and technology development will be guided by engineering evaluations, financial modeling, and environmental impact studies. This might establish coconut charcoal as a sustainable industry that turns agricultural waste into a solid fuel with high energy content.

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APPENDIX A

Process of coconut kernel charcoal briquette production

APPENDIX B

Thermogravimetric analysis (TGA) of coconut kernel charcoal briquette

APPENDIX C

Ash content of coconut kernel charcoal briquette