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Characterization from Briquettes and Charcoal Derived from Buluh Madu (*Gigantochloa albociliata)*

Farahazirah Binti Mohd Shadan
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DECLARATION

I declare that this thesis entitled "Characterization from briquettes and charcoal derived from buluh madu (*Gigantochloa albociliata*)" is the results of my own research except as cited in the references.

Signature :

Student's Name : Farahazirah Binti Mohd Shadan

Date : 15 February 2024

Verified by:

Signature : ____________________________

Supervisor's Name : Prof. Madya Ts. Dr Sitti Fatimah Binti Mhd. Ramle

Stamp : ____________________________

Date : ____________________________

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ABSTRACT

This research's major aim is to produce briquettes and charcoal derived from *Gigantochloa albociliata* bamboo. Bamboo briquettes are eco-friendly grill fuel made from compressed bamboo. They burn long and hot, perfect for grilling, and produce minimal smoke and ash, making them ideal for indoor use. The goal is to evaluate the physicochemical characteristics such as moisture content, ash content, burning lifespan test, and thermogravimetric analysis (TGA) test of briquettes bamboo charcoal with containing binder or additives such as starch and sodium hydroxide and also without any additives. The results obtained from this study show that bamboo charcoal is a potential fuel, with characteristics like low moisture such as BS has 5.99% lower than BN has 10.50%, low ash such as BS has 0.15% lower than BN 0.3%, and usability in the burning period shows that BS is longer than BO and BN, which is within a period of 75 minutes. The use of TGA techniques has provided important information on the thermal behavior of bamboo charcoal and the influence of additives on the combustion process. This finding has implications for the selection of the bamboo charcoal in various combustion applications, as well as providing guidance for further research in the production of better bamboo charcoal.

Keyword : Bamboo, Physicochemical, Moisture content, Ash content, Thermogravimetric Analysis (TGA).

ABSTRAK

Matlamat utama penyelidikan ini adalah untuk menghasilkan briket dan arang yang diperoleh daripada buluh *Gigantochloa albociliata*. Briket buluh ialah bahan api gril mesra alam yang diperbuat daripada buluh mampat. Ia terbakar lama dan panas, sesuai untuk memanggang, dan menghasilkan asap dan abu yang minimum, menjadikannya sesuai untuk kegunaan dalaman. Matlamatnya adalah untuk menilai ciri-ciri fizikokimia seperti kandungan lembapan, kandungan abu, ujian jangka hayat pembakaran, dan ujian analisis termogravimetrik (TGA) briket arang buluh yang mengandungi bahan pengikat atau bahan tambahan seperti kanji dan natrium hidroksida dan juga tanpa sebarang bahan tambahan. Keputusan yang diperolehi daripada kajian ini menunjukkan bahawa arang buluh adalah bahan api yang berpotensi, dengan ciri-ciri seperti kelembapan rendah seperti BS mempunyai 5.99% lebih rendah daripada BN mempunyai 10.50%, abu rendah seperti BS mempunyai 0.15% lebih rendah daripada BN 0.3%, dan kebolehgunaan dalam tempoh pembakaran menunjukkan BS lebih lama daripada BO dan BN iaitu dalam tempoh 75 minit. Penggunaan teknik TGA telah memberikan maklumat penting tentang tingkah laku haba arang buluh dan pengaruh bahan tambahan terhadap proses pembakaran. Penemuan ini memberi implikasi kepada pemilihan arang buluh dalam pelbagai aplikasi pembakaran, serta memberi panduan untuk penyelidikan lanjut dalam penghasilan arang buluh yang lebih baik.

Kata kunci : Buluh, Fisikokimia, Kandungan lembapan, Kandungan abu, Analisis Termogravimetrik (TGA).

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LIST OF ABBREVIATIONS

NaOH	Sodium hydroxide
Na+	Sodium cations
OH-	Hydroxide anions
TGA	Thermogravimetric Analysis

LIST OF SYMBOLS

°C	Celcius
mm	Millimetre
g/m^2	Grams per square meter
cm	Centimetre
%	Percentage
g	Grams
min	Minutes

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Bambusoideae as shown in Figure 1.1 is the subfamily in the bamboo family. The subfamily Bambusoideae contains 3 tribes, around 100 genera, and 1,400 species of bamboo. (Hornaday, 2022) Bamboo is part of the Poaceae family. It flourishes in semi-tropical areas with a moderate climate that is open and well-drained. Bamboo has two categories of growth these include monopodial (single stem) and sympodial (clump). Bamboos grow in a sympodial manner in Malaysia. (Forestry Department Peninsular Malaysia, 2023).

Figure 1.1: A bamboo plant (Bamboo Trees for Sale | FastGrowingTrees.com, n.d.)

The term activated carbon, which also refers to activated charcoal, is frequently used to refer to carbon compounds, including charcoal. Due to its large surface area, activated carbon is effective at absorbing gases and other impurities from liquids. However, This benefit is heavily reliant on how bamboo charcoal is activated and carbonised. The optimum temperature and time must be used for production in a carefully regulated environment. (Ryan, 2023).

This research major aim is to produce briquettes charcoal derived from *Gigantochloa albociliata* bamboo. The goal is to evaluate the physicochemical characteristics of briquettes bamboo charcoal with containing binder or additves such as starch and sodium hydroxide and also without any additives. By going through moisture content tests by moisture analyzer, ash content test, burning lifespan test and thermogravimetric analysis (TGA) test of briquettes bamboo charcoal.

Briquettes bamboo charcoal is a type of charcoal that is produced from pressed and compressed bamboo, usually combined with additives such as sodium hydroxide (NaOH) and starch. The briquettes bamboo charcoal process uses modern technology to produce small, compact briquettes that burn more slowly than traditional charcoal. It is primarily used for heating, cooking, and barbecuing.

Briquettes bamboo charcoal is considered a more sustainable alternative to traditional charcoal, as it is produced from a renewable source like bamboo and does not require additional trees to be cut down. It is also considered to be more environmentally friendly than traditional charcoal.

1.2 Problem Statement

Bamboo has many benefits, particularly bamboo charcoal and biochar, such as water filtering, air purification, and soil enrichment. Charcoal is still used as fuel for cooking and heating in their homes in many tropical and underdeveloped countries. (Hornaday, 2022). However, traditional charcoal production methods are inefficient and polluting. Bamboo charcoal production could be a more sustainable and environmentally friendly way to produce charcoal. Besides, charcoal is significant for a number of reasons as well. Among them are deodorizing, freshen flower, pet cleanser, enhanced cooking, bath additive, reusable, and skincare. (Ryan, 2023). However, the potential of bamboo for charcoal production has not been fully explored. The newest study on this species was published in 2016 and was titled "Adsorption properties and potential applications of bamboo charcoal" (Isa et al., 2016). Therefore, there should be a strong need to solve problem statements about the potential and other benefits specific to this species (*Gigantochloa albociliata*). Thus, by conducting this research, researchers can learn about this species in terms of production methods, uses, potential, and benefit.

1.3 Objectives

In this research, there are three objectives which need to be achieved. The objectives are:

1. To determine the physical characteristics of briquettes bamboo charcoal.
2. To evaluate the physicochemical characteristics of briquettes bamboo charcoal.
3. To evaluate the influence of additives on burning of briquettes bamboo charcoal.

1.4 Scope of Study

This study was conducted to clarify the physicochemical characteristics and potential of bamboo (*Gigantochloa albociliata*) charcoal. Thermogravimetric analysis (TGA) tests are conducted to obtain physicochemical characteristics such as ash content, moisture content, volatile matter content and fixed carbon content. In addition, to explain the use and potential of briquettes bamboo charcoal to create a sustainable and environmentally friendly approach.

1.5 Significant of Study

Bamboo is a fast growing plant that contains a high concentration of cellulose and lignin, making it an ideal material for charcoal production. The potential of bamboo for charcoal production has gained significant attention due to its low carbon emissions and its ability to regenerate quickly. This has led to research studied aimed at exploring the potential of bamboo for briquettes charcoal production. Bamboo for briquettes charcoal production has been extensively studied in various parts of the world. Studies have shown that bamboo can produce high-quality charcoal with a low ash content, high carbon content, and high heat value. One study carried out in China, showed that bamboo charcoal has a higher specific surface area and a higher adsorption capacity compared to wood charcoal. This makes bamboo charcoal more suitable for use in a variety of applications such as water purification and air filtration. Therefore, bamboo for charcoal production has significant potential due to its environmental, socioeconomic and climate benefits. Various studies have shown that bamboo can produce high-quality charcoal with low carbon emissions, making it an attractive alternative to traditional charcoal production. Furthermore, its ability to grow in variety of climatic conditions and its carbon sequestration potential make it an important tool for climate change mitigation.

CHAPTER 2

LITERATURE REVIEW

2.1 Morphological Bamboo

Morphology refers to the outer appearance of the plant’s components. The primary components of a bamboo plant include leaves, culm, rhizomes, roots, branches, and flowers. A bamboo plant's main components are shown in Figure 2.1.

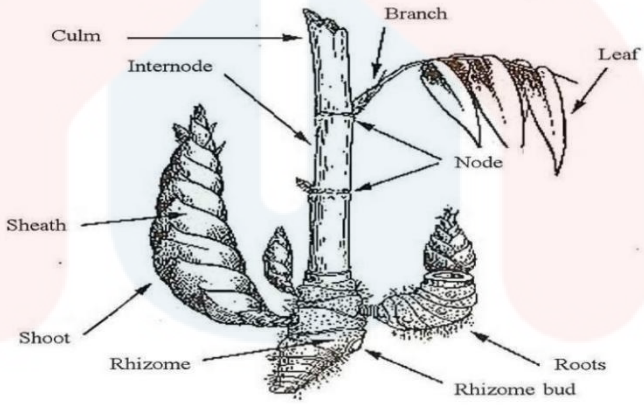


Figure 2.1: A bamboo plants main components (Roslan et al., 2018)

Bamboo is one of the most widespread plants in Malaysia. Bamboo is used for a variety of functions including architecture, transportation, and culture. About 70 different species of bamboo may be found in Malaysia, with 50 of them being found in Peninsular Malaysia, 30 in Sabah, and 20 in Sarawak. (Ameram et al., 2018).

The plant *Gigantochloa albociliata*, also called Buluh Madu. The majority of the G. albociliata growing in Malaysia is from Thailand, although some is also from China. It was taken to Malaysia and planted there. Bamboos are simple to cultivate and can be harvested in only a few months, usually 6 to 8 months. Although bamboo is a simple plant to grow, the right planting medium and enough fertilizer are still required for the plant to grow as well as possible. (Ismail, 2018).

2.2 Species Bamboo

Gigantochloa albociliata as shown in Figure 2.2 is the scientific name of White-fringe Gigantochloa. *Gigantochloa albociliata* is part of the Poaceae family. Low to moderate elevations in the dry tropical mixed forest are ideal for the natural growth of *Gigantochloa albociliata*. It grows when there is an average annual temperature of 28°C and an average annual rainfall of 800 to 1,300mm. Thrives in well-drained soils that range infertility from low to medium. 9 to 46 tonnes of culm are produced annually per hectare in natural stands. A 6-year-old clump of 27 culms that were developed from a rhizome cutting had an average height of 10.5 meters, with ranges between 5 and 16 meters, and an average diameter of 20 mm, with ranges between 10 and 30 mm. (*Gigantochloa Albociliata Clumping Bamboo PFAF Plant Database*, n.d.).

Figure 2.2: A *Gigantochloa albociliata* (*Gigantochloa Species List*, 2010)

2.3 Morphological Charcoal

Organic carbon compounds include charcoal. Charcoal is created when plant and animal products are burned insufficiently. Outdoor cooking frequently uses charcoal. Burning plant materials including wood, peat, bones, and cellulose results in the production of charcoal frequently. Its micro-crystalline structure is extremely permeable. Both the structure and the electric charge of charcoal are porous. When charcoal is extracted from coal, it is known as activated coal (*Charcoal*, n.d.).

Figure 2.3: Charcoal from bamboo

Gigantochloa albociliata is a type of bamboo native to Malaysia, was carbonized in order to compare the quality of bamboo charcoal produced based on proximate analysis and examine the attributes of bamboo charcoal. This bamboo successfully underwent carbonization at 750°C. Bamboo's morphological characteristics were diverse, and basic density increased with culm height. Due to their low ash, low moisture, low volatile matter and fixed carbon content, bamboo charcoal could be used as an alternative raw material for the production of charcoal in the charcoal industry. The lowest region of the culm generated the highest calibre charcoal. (Jarawi & Jusoh, 2023)

2.4 Charcoal Potential

Bamboo charcoal has been used in place of wood and mineral coal (M Parthiban, 2009). Bamboo is a plant that grows quickly, therefore it takes 3 to 4 years for bamboo culms to achieve the height and weight that are ideal for the manufacturing of charcoal for industrial use (Villazon, 2021). Compared with wood charcoal, several characteristics of bamboo charcoal make it superior. Bamboo charcoal has a few advantages over wood charcoal when compared to those advantages. Bamboo charcoal has a large surface area to mass ratio and a distinct microporous structure that both contribute to its high adsorption capability (Huang et al. 2014; Isa et al. 2017; Kaur et al. 2018). In comparison to wood charcoal, bamboo charcoal has a very high specific surface area of 150 to 400g/m^2, is around two or three times larger, and has about four times as many cavities, three times as much mineral content, and four times according to the bamboo charcoal's wide surface area and porosity, which can absorb a lot of carbon dioxide, emissions might be decreased. (Kaur et al. 2018) (Huang et al. 2014). Because of its ability to adsorb a wide range of things, including chemicals, minerals, radiowaves, odours, hazardous compounds, and humidity, it has been used in home items such as air fresheners, fruits and vegetable savers, humidity and odour adsorbents, and water filtering (Isa et al. 2017).

2.5 Morphology Briquettes Charcoal

According to the research (Thao, 2023) we can detemine that briquettes are small, compact blocks of flammable material that are easy to handle and use as fuel. The term "briquette" comes from the French word for "brick." These fuel blocks can be made from a variety of sources, including coal, coke, sawdust, wood chips, paper, charcoal, and agricultural waste. Charcoal briquettes are probably the most well-known and commonly utilized type of briquettes today. They are made by compressing and igniting charcoal particles in a mold, resulting in a solid, homogenous briquette. It is additionally made by compressing charcoal with a binder, allowing it to burn for an extended period of time. Additional materials are added to briquettes to improve their integrity and structure, making them more practical and user-friendly. (The Trellis, 2023). The benefits of using charcoal briquettes are numerous, including lower environmental impact and longer burn periods.

Figure 2.4 : A briquettes charcoal

2.6 Morphology Bamboo Briquettes Charcoal

Bamboo briquettes charcoal are an environmentally friendly and sustainable fuel source since they are made entirely of compressed bamboo. For grilling or smoking foods, these briquettes are perfect because of their high density, which guarantees a long burn time. Additionally, bamboo briquettes are appropriate for interior use because they emit little to no smoke or ash. (Thao, 2023). A briquette is frequently defined as a block of highly combustible solid material used as fuel to start and keep a fire (Zubairu & Gana, 2014).

Figure 2.5 : A bamboo briquettes charcoal

2.7 Briquettes Bamboo Charcoal Vs Bamboo Charcoal

Briquettes bamboo charcoal and bamboo charcoal represent two distinct forms of charcoal derived from bamboo, each with its unique characteristics. In terms of form, bamboo charcoal encompasses the traditional, diverse shapes and sizes seen in chunks, sticks, or powder. On the other hand, briquettes bamboo charcoal undergoes a compression process, often involving binding agents, resulting in uniform shapes that are consistent and easy to handle.

Figure 2.6 : Comparison of briquettes bamboo charcoal and bamboo charcoal

Regarding composition, bamboo charcoal typically consists solely of bamboo material, processed through carbonization. This involves heating bamboo in the absence of oxygen to create charcoal. In contrast, briquettes bamboo charcoal may include a blend of bamboo charcoal with additives or binding agents, the composition of which can vary. These additives might be introduced to enhance properties such as ignition, burn time, or stability during combustion.

The manufacturing processes further differentiate the two forms. Bamboo charcoal is typically produced through the carbonization of bamboo, eliminating water and volatile organic compounds to yield carbonized material. However, briquettes bamboo charcoal, involves compressing charcoal, often incorporating binders or other ingredients to produce uniform and dense briquettes.

Consistency is a notable distinction, as traditional bamboo charcoal may exhibit variations in shape and size based on the production method. In contrast, briquettes bamboo charcoal is intentionally designed for uniformity, ensuring ease of handling and use through a standardized manufacturing process.

Applications vary between the two forms. Bamboo charcoal finds utility in diverse applications, including water purification, air freshening, and as a fuel for cooking or heating and industrial applications. Briquettes bamboo charcoal, specifically designed for use as a fuel source, is commonly employed in barbecues, grills, or stoves, especially in traditional setting. The uniform shape and composition of briquettes contribute to their convenience in specific applications.

The burning characteristics of Briquettes Bamboo Charcoal and traditional Bamboo Charcoal present distinct advantages and considerations, influencing their utility for various purposes. Briquettes Bamboo Charcoal, characterized by its denser form and controlled air flow, boasts a longer burning time. This extended burn is complemented by a more consistent heat output, providing a predictable and stable source of heat. Additionally, the use of binders in the manufacturing process contributes to a reduction in both smoke and ash formation, enhancing the overall combustion experience. The compact form of briquettes also renders them easier to handle and store, facilitating convenient transportation. In contrast, traditional Bamboo Charcoal exhibits a faster burning time, attributed to its looser form and increased air accessibility. However, this loose composition results in a more variable heat output, making the burning rate and intensity less predictable. The trade-off for this swifter burn is an elevated production of smoke and ash, especially when the carbonization process is not meticulous. Furthermore, the irregular shape and size of traditional Bamboo Charcoal make it bulkier and more challenging to handle, store, and transport. In essence, the choice between Briquettes Bamboo Charcoal and traditional Bamboo Charcoal hinges on factors such as burn time, heat consistency, smoke and ash production, and the convenience of handling and storage, catering to diverse needs and preferences.

Finally, the purpose of each form diverges. Bamboo charcoal extends beyond a fuel source, finding applications as natural deodorizers, soil amendments in gardening, or ingredients in health and beauty products. In contrast, "briquettes bamboo charcoal" is primarily designed for combustion, serving as an efficient and consistent source of heat for cooking or heating applications, though it may lack the versatile applications of traditional bamboo charcoal. In essence, while both derived from bamboo, these two forms cater to distinct needs and preferences based on their unique characteristics and intended uses.

2.8 Binder / Additive Material

2.8.1 Starch

As a natural polymer, or polysaccharide, starch is a lengthy chain made up of one kind of molecule which is glucose molecules. Starch comes in two forms such as amylose and amylopectin (Seitz et al., 2022). Starch is a common type of briquette binder. In general, about 4-8% of starch is needed to make the briquettes. This because, charcoal has no plasticity at all, therefore it requires the addition of binders to hold the briquettes together for transport, briquette formation and storage. Each charcoal particle is coated with a binder, which increases the adhesion of the charcoal and produces uniform briquettes. After the wet-pressed briquettes are dried, the binding operation is complete (Machines, 2018). Starch offers several advantages as a binder in charcoal briquettes. Its gelatinized network strengthens the briquettes, preventing crumbling and improving handling. Additionally, the pyrolyzed sugars released during combustion contribute to the fuel content, potentially extending the burning time compared to pure charcoal. Furthermore, starch generally produces less smoke and ash than other binders like clay, although proper charring and starch quality are crucial for minimizing ash formation (Borowski et al., 2017).

Figure 2.7 : A cornstarch solutions

2.8.2 Sodium Hydroxide (NaOH)

Sodium Hydroxide is the chemical term for NaOH. Also referred to as lye or caustic soda, sodium hydroxide is a powerful basic. It is frequently employed in a range of industrial and laboratory settings. With the formula NaOH, it is an inorganic material as well. It is a solid, white ionic material consisting of the sodium cations (Na^+) and the anions hydroxide ($OH^–$). (Gaur, 2023)

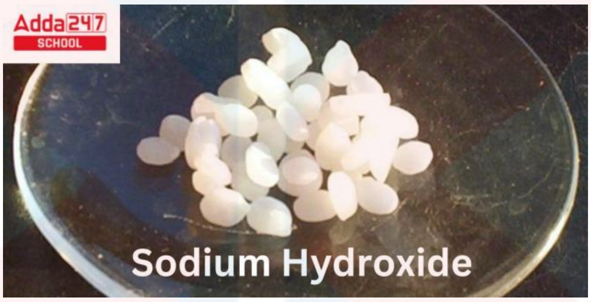


Figure 2.8 : Sodium hydroxide (NaOH)

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Bamboo culm

Samples of *Gigantochloa albociliata* culm was collected from Sungai Balang Besar, Muar, Johor as shown in Figure 3.1.

Figure 3.1 : A *Gigantochloa albociliata* bamboo samples

3.1.2 Brick stove

Brick stove as shown in Figure 3.2, was used for the pyrolysis or carbonization process. The thermal decomposition of bamboo biomass at high temperatures with no air or limited supply of air (oxygen).

Figure 3.2 : Brick stove

3.1.3 Grinder

Grinder was used to crush the bamboo culm charcoal to small particles or dust. Bamboo culm samples are frequently prepared in this manner in preparation for additional inspection or processing. The grinder crushes the bamboo culm to help the charcoal making process.

3.1.4 Chamber furnace machine

Chamber furnace machine as shown in Figure 3.3, used to determine the lifespan of briquettes charcoal used in a chamber furnace under specified operating conditions. The lifespan of the briquettes will vary depending on the type of charcoal, operating temperature, and furnace conditions. Higher temperatures will generally lead to shorter lifespans and faster burn rates. Different types of charcoal may exhibit different lifespans and burning characteristics.

Figure 3.3 : Chamber furnace machine

3.1.5 Thermogravimetric analysis (TGA) machine

Thermogravimetric analysis as shown in Figure 3.4, also referred to as "thermal gravimetric analysis" or "TGA," is a thermal testing method in which the material being analysed is continuously heated over an extended period of time. The purpose of this test is to create a thermal reaction so that any changes in the tested substance's mass or weight that arise from the reaction may be observed and analysed. Thermogravimetric analysis can yield a wide range of additional measures, including the amount of filler in the sample, the rate of oxidation and/or decarboxylation, and the loss of water, solvent, or plasticizer in the sample. By measuring and monitoring mass, temperature, and time as base measurements during testing (Mathias, 2022).

Figure 3.4 : Thermogravimetric Analysis (TGA) machine

3.1.6 Moisture analyzer machine

A moisture analyzer machineas shown in Figure 3.5, a device that uses a heating element and a weighing scale to measure the moisture content of a sample. When the sample heated to a constant weight, all of the moisture has evaporated. The difference between the sample's original and final weights is then used to compute the moisture content (awi-admin, 2022).

Figure 3.5 : Moisture analyzer machine

3.1.7 Starch as a binder in charcoal

The starch used in making briquettes is from cornstarch, cornstarch plays a crucial role in making briquettes, acting as a binder that holds the briquette together during formation and burning. The cornstarch grains act like glue, sticking together with the main briquette material which is bamboo charcoal during pressing. This produces solid and stable briquettes that do not crumble easily. The additive power of cornstarch is activated by water and heat. During briquette formation, water was added to the mixture, and the pressing process produces heat. This activates the cornstarch, allowing it to effectively bind the particles.

3.1.8 Sodium hydroxide (NaOH) as a binder in charcoal

The binding action of NaOH is attributed to its ability to partially dissolve lignin, a natural binder present in biomass. This dissolved lignin acts as a glue, holding the biomass particles together when the briquette is compressed.

3.2 Methods

3.2.1 Preparation Sample of charcoal and briquettes

For the purpose of making bamboo briquettes charcoal, the Buluh Madu (*Gigantochloa albociliata*) was collected from Sungai Balang Besar, Muar, Johor. The bamboo was selected as the main sample while it was between the ages of 2-4 years. After being cleaned, the bamboo culm was cut into 10cm segments. Then dried under the sun for around 7 days. After that, kept it in a ziplock plastic bag to avoid exposure to moisture and overgrown with fungus and used for analysis tests.

3.2.2 Pyrolysis or carbonization process

Bamboo charcoal is made through the pyrolysis or carbonization process, which complex carbonaceous substances are broken down into elemental carbon and chemical compounds by heating in the absence of oxygen. (Jarawi & Jusoh, 2023). The carbonization process typically lasts 3 hours at temperatures ranging from 400°C to

800°C. (Isa et al., 2017). In this experiment, the carbonization of bamboo culms was carried out within 3 hours at high temperature by used a brick stove at the UMK Campus Jeli wood workshop. Then, after 3 hours of the bamboo charcoal carbonation process, let the charcoal cooled and stored that in a container. The lid of the container was closed to prevent air from entering.

Figure 3.6 : Process of pyrolysis or carbonization of bamboo charcoal

3.2.3 Production of briquettes bamboo charcoal

The bamboo charcoal was crushed into smaller pieces by using hammer (ABC Machinery, 2023). Then the bamboo charcoal chips were put into a grinder to crush them into a fine powder. After that, the bamboo charcoal powder was divided into 4 samples as shown in Table 3.2.5, namely BO as original charcoal 100%, BN as charcoal 95% with NaOH 5%, BS as charcoal 95% with starch 5% and BSN as charcoal 80% with NaOH 5% and starch 5%. And each sample has the same average weight of charcoal powder which is 10g. Firstly, to produce briquettes charcoal BO which is 100% original charcoal need to mix 10g of charcoal powder with 12ml of water in a beaker and mix well. After that, put the mixture into the mold to form briquettes charcoal. (Aransiola et al., 2019) with slightly modification.

Secondly, produce briquettes charcoal BN which is 95% charcoal with 5% NaOH. Dissolve 3g of NaOH with 12ml of water in a beaker. After that, mixed 10g of charcoal with NaOH solution and mixed well. Put the mixture into the mold to form briquettes charcoal.

Third, produce briquettes charcoal BS which is 95% charcoal with 5% starch. 12ml of water was boiled in a beaker at a temperature of 70°C by using a hot plate. 3g of starch was mixed into the water and mixed until the texture become gel. When the starch gel solution had became warm, 10g of charcoal powder was mixed into the starch gel solution and mix well. Put the mixture into the mold to form briquettes charcoal.

Fourth, produced briquettes charcoal BSN which is 90% charcoal with 5% NaOH and 5% starch. 3g of NaOH was dissolved with 12ml of water in a beaker. 3g of starch was mixed into the NaOH solution until the texture became gel. 10g of charcoal powder was mixed into the starch gel solution and mix well. Put the mixture into the mold to form briquettes charcoal. The process was repeated for three samples. After all the samples are ready, the sample were put in the oven at a temperature of 80°C for the drying process within 24 hours. After 24 hours, the sample was removed from the oven. Let the briquettes charcoal cooled and stored that in a container. The lid of the container was closed to prevent air from entering.

Table 3.1: Mixing ratios of bamboo briquette sample with a binder which is sodium hydroxide (NaOH) and starch.

Sample	**Charcoal (%)**	**NaOH (%)**	**Starch (%)**
BO	100	-	-
BN	95	5	-
BS	95	-	5
BSN	90	5	5

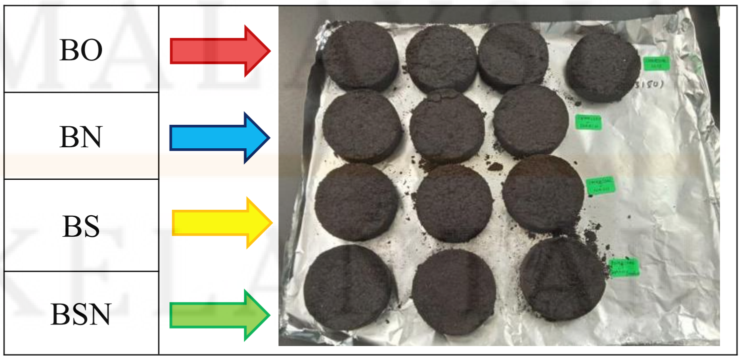


Figure 3.7 : Production of briquettes bamboo charcoal

3.2.4 Moisture content test using Moisture Analyzer

These are the steps for the moisture content test. Firstly, turn the moisture analyzer machines on and choose the mode, temperature, and time parameters that are best for the sample briquettes charcoal. After that, set up a sample pan that is dry and clean on the weight scale and tare it to zero. Then, weighed just a small amount of briquettes charcoal which is 1g and spread it out evenly on the sample pan. Next, the moisture analyzer machine's cover was closed to begin heating it. Further, wait until the screen showing the moisture content has appeared once the heating operation is finished. At last, record the amount of the moisture content as shown in Figure 3.2.4 and take the sample pan out of the moisture analyzer machine. The process was repeated for all samples, namely BO as original charcoal 100%, BN as charcoal 95% with NaOH 5%, BS as charcoal 95% with starch 5% and BSN as charcoal 90% with NaOH 5% and starch 5%.

Table 3.2 : Moisture content test using Moisture Analyzer

BO	BN	BS	BSN
4.65%	9.37%	5.99%	10.50%

3.2.5 Ash content test of briquettes bamboo charcoal

This is the step in carrying out the ash content test of briquettes bamboo charcoal. Firstly, 10grams of each of four finely ground bamboo charcoal sample are weighed using a digital scale. Clean and dry crucibles are then weighed, and their weights are recorded. The weighed bamboo charcoal sample is placed into a pre-weighed crucible, and the crucible is positioned in a chamber furnace set at 800°C for 1 hours with heating rate 10min/800°C. The bamboo charcoal sample is ashed completely over a 1-hour period to ensure thorough combustion. Following the ashing process, the crucible is removed using tongs and allowed to cool in a desiccator to prevent moisture absorption. Subsequently, the crucible, now containing the ash bamboo charcoal sample, is weighed using the digital scale, and the weight is recorded. After that, calculate the ash content using the formula.

$$\% \text{ Ash} = \frac{\text{Weight of crucible with ash} - \text{Weight of crucible}}{\text{Weight of sample}} \text{ X } 100$$

3.2.6 Burning lifespan test of briquettes bamboo charcoal

This is the step in carrying out the burning lifespan test of briquettes bamboo charcoal for each four different samples. Firstly, take the briquettes bamboo charcoal samples and position them in an open space at a safe distance from any other flammable material. Then, quip the flame gun and position it in a safe angle to the briquettes bamboo charcoal samples. After that, aim the flame gun at the briquettes bamboo charcoal samples and hold down the trigger to continuously feed the flame to the samples. Observed the burning of the briquettes bamboo charcoal under constant flame. Finally, the results was observed and recorded of any changes in the charcoal to determine the duration of the burning process. The results was recorded in table 3.2.6 . (Stephanos & Associates, n.d.).

Table 3.3: Burning duration of four different sample of briquettes bamboo charcoal

Sample No.	Composition	Burning Duration (min)
BO	100% charcoal	20
BN	95% charcoal + 5% NaOH	15
BS	95% charcoal + 5% starch	75
BSN	90% charcoal + 5% NaOH + 5% starch	80

3.2.7 Analysis test by using Thermogravimetric Analysis (TGA)

This is the step in carrying out the ash content test of briquettes bamboo charcoal. Firstly, grind the bamboo charcoal briquettes into a fine powder using a mortar. This will ensure that the sample has a larger surface area and the decomposition products can easily escape. After that, place the empty crucible onto the analytical balance and tare the balance to zero. Carefully add the bamboo charcoal powder to the crucible, making sure the weight of the sample must be 0.0025g above. Place the crucible back onto the analytical balance and close the door. The substance was added until desired weight is reached, close the door and allow the reading to stabilize. The weight for each sample that has been weighed is different, each of which has an average weight of 0.003g, BO is 0.0031g, BN is 0.0033g, BS is 0.0039g and BSN is 0.0034g. Set the TGA program to heat the sample from room temperature to 800°C at a heating rate of 10min/800°C. Place the crucible back onto the balance and close the furnace. Once the program is set up, start the experiment and monitor the weight loss of the sample as a function of temperature. The TGA will automatically record the weight loss data and generate a thermogram. After the experiment is complete, analyze the thermogram to determine the thermal decomposition behavior of the bamboo charcoal. The combination of analysis data is shown in the form of a graph as shown in Figure 4.4 below. Before that, Figure 3.2.7 is the analysis data for each different sample of briquettes bamboo charcoal, which is BO containing 100% charcoal with no additives, BN containing 95% charcoal with 5% sodium hydroxide (NaOH), BS containing 95% charcoal with 5% starch and BSN containing 90% charcoal with 5% sodium hydroxide (NaOH) and 5% starch. The

TGA data can be used to calculate the activation energy of decomposition, the amount of volatile matter, and the char yield.

CHAPTER 4

4.0 RESULTS AND DICUSSION

4.1 RESULTS

4. 1. 1 Moisture content of briquettes and charcoal from bamboo (*Gigantochloa albociliata*)

The moisture content test was conducted on four different samples of briquettes bamboo charcoal, and the results are presented in table 4.1.

Table 4.1 : Moisture content test of briquettes bamboo charcoal

Sample	Moisture Content (%)
BO	4.65
BN	9.37
BS	5.99
BSN	10.50

The table 4.1 shows the moisture content test of four different samples of briquettes bamboo charcoal namely BO containing 100% charcoal with no additives, BN containing 95% charcoal with 5% sodium hydroxide (NaOH), BS containing 95% charcoal with 5% starch and BSN containing 90% charcoal with 5% sodium hydroxide (NaOH) and 5% starch.

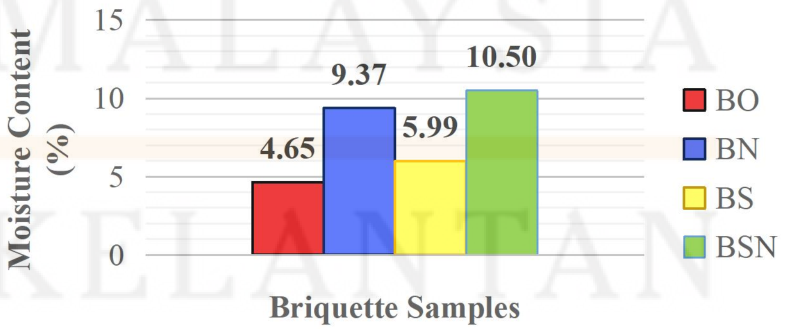


Figure 4.1 : Percentages moisture content of briquettes bamboo charcoal

Based on Figure 4.1, BO, the 100% charcoal with no additives, has the lowest moisture content at 4.65%. This is followed by BS, the 95% charcoal with 5% starch at 5.99%, BN, the 95% charcoal with 5% sodium hydroxide (NaOH) at 9.37%, and finally BSN, the 90% charcoal with 5% each of sodium hydroxide (NaOH) and starch at 10.50%.

The results obtained from this study indicate that briquettes bamboo charcoal has a low moisture content which is desirable for efficient burning characteristics. Charcoal moisture content standards are typically referred to for a charcoal's moisture content to between 5% and 15%. Charcoal that has a moisture percentage higher than 10% has been shown to be easily brittle and to produce ash when burnt in blast furnaces. The moisture content of the briquettes bamboo charcoal samples ranged from 4.65% to 10.50%, with BSN having the highest moisture content (10.50%) and BO having the lowest moisture content (4.65%).

The addition of NaOH and starch appears to have increased the moisture content of the briquettes. BN and BSN, which contained NaOH, had higher moisture contents than BO and BS, which did not contain NaOH. BS, which contained starch, also had a higher moisture content than BO, which did not contain starch.

Sodium hydroxide (NaOH) is a strong base, and when it reacts with organic materials like starch, it can result in saponification. Saponification is a process in which a base reacts with fats or oils to produce soap and glycerol. Starch, being a carbohydrate, may not directly undergo saponification but can be affected by the alkaline conditions provided by NaOH. In the context of briquettes bamboo charcoal, the addition of NaOH has influenced the composition of the briquettes, altering the structure of the organic components, including any binders or additives that might be present. This could lead to changes in the briquettes' physical properties, including moisture content. The increase in moisture content observed in samples containing NaOH, such as BN and BSN, compared to those without NaOH, such as BO and BS, may suggest that the NaOH treatment somehow affected the water retention properties of the briquettes or the interaction between the briquette components and moisture. Starch, being a polysaccharide, can absorb and hold water. The higher moisture content in BS containing starch compared to BO without starch might be attributed to the water-absorbing properties of starch. In summary, the observed increase in moisture content in briquettes containing NaOH and starch suggests that these substances have influenced the water retention properties of briquettes bamboo charcoal.

4. 1. 2 Ash content of briquettes bamboo charcoal

The ash content test was conducted on four different samples of briquettes bamboo charcoal, and the results are presented in table 4.2.

Table 4.2 : Results of the ash content test of briquettes bamboo charcoal

Sample	Ash content (%)
BO (100% charcoal)	0.2
BN (95% charcoal + 5% NaOH)	0.3
BS (95% charcoal + 5% starch)	0.15
BSN (90% charcoal + 5% NaOH + 5% starch)	0.25

Sample 1 Sample 2 Sample3 Sample 4

Figure 4.2 : Ash content test briquettes bamboo charcoal

Based on Figure 4.2, the ash content of the briquettes bamboo charcoal samples ranged from 0.15% to 0.3%, with BS as 90% charcoal with 5% starch having the lowest content and BN as 95% charcoal with 5% NaOH the highest. Interestingly, despite containing starch, BS as 95% charcoal with 5% starch had a slightly lower ash content which is 0.15% compared to BO as 100% charcoal is 0.2% ash content.

The ash content of briquettes bamboo charcoal samples appears to be influenced by the additive used in the charcoal. The highest ash content was observed with the sample containing sodium hydroxide (NaOH), which has a stronger chemical reaction with the organic materials, including starch. The presence of starch can reduce the ash content of briquettes bamboo charcoal as it acts as an additional fuel source, allowing some of the organic materials to be burned off instead of becoming ash. The additional fuel source can also explain why BO, which contains only charcoal, had a higher ash content than BS, which contains starch.

The ash content of briquettes bamboo charcoal varies depending on the additives added to the charcoal. For BN, which is 95% charcoal with 5% sodium hydroxide (NaOH), the ash content is higher due to the presence of sodium hydroxide (NaOH) in the briquettes. Sodium hydroxide (NaOH) is a strong chemical that reacts with the carbon in the charcoal to form sodium carbonate, which leaves behind ash as a byproduct. While BS, which contains 95% charcoal with 5% starch, has a lower ash content likely due to the starch acting as a binder.

The ash content test results for briquettes bamboo charcoal show that the samples with additives such as sodium hydroxide and starch have a lower ash content than those with no additives. This is due to the chemical reaction between sodium hydroxide (NaOH) and starch, which affects the composition of the briquettes bamboo charcoal. When sodium hydroxide (NaOH) reacts with starch molecules, it breaks the starch down into its component molecules and releases heat energy that is necessary for burning. This breakdown of starch helps to reduce the ash content in the briquettes bamboo charcoal sample by leaving less unburned material behind.

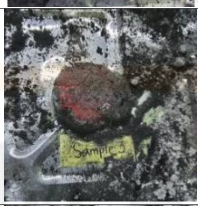
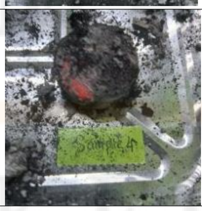
The ash content of the briquettes bamboo charcoal samples is affected by the additives namely NaOH and starch added to the charcoal. As NaOH has a strong chemical reaction with starch, it increases the ash content of the briquettes bamboo charcoal sample, as the addition of NaOH acts as a catalytic converter that stimulates wood combustion. In contrast, the presence of starch in the briquettes bamboo charcoal sample acts as a slow-burning fuel that suppresses combustion and releases less ash. This explains why the sample with starch and NaOH has the lowest ash content as the two ingredients cancel each other out.

The percentage of ash is significant when choosing a biomass fuel. In genarally, high ash content biomass is not recommended since it affects the calorific value and combustion quality of the charcoal. High ash concentration can lead to the accumulation of ashes, which disrupts the flow of combustion gases inside biomass boiler. High-ash charcoal can also induce corrosion, erosion, and abrasion.

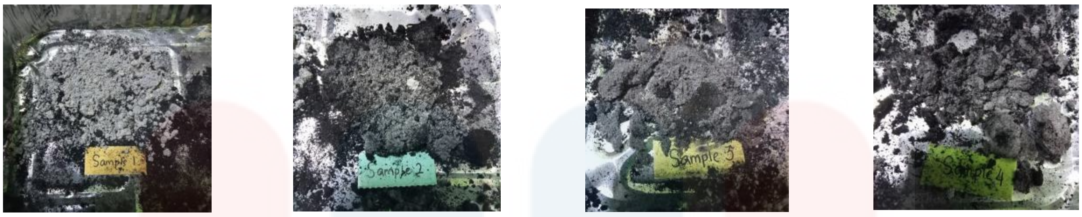
4. 1. 3 Burning lifespan of briquettes bamboo charcoal

The burning lifespan of briquettes bamboo charcoal was conducted on four different samples of briquettes bamboo charcoal, and the results are presented in the Table 4.3.

Table 4.3 : Results of the burning lifespan test of briquettes bamboo charcoal

Sample	Premilinary Burning Lifespan for 10 min	Burning Duration (min)	Ash Formation	durability	Observation
BO (100% charcoal)		20	More	More brittle than BN	Steady burn
BN (95% charcoal + 5% NaOH)		15	Medium	Brittle	Slower burn compared to BO
BS (95% charcoal + 5% starch)		75	Minimal	Solid	Faster burn than BO
BSN (90% charcoal + 5% NaOH + 5% starch)		80	Medium	More solid than BS	Longer burn than BS

Observation after turning to ashes



BO	BN	BS	BSN

- BO : 100% charcoal
- BN : 95% charcoal + 5% NaOH
- BS : 95% charcoal + 5% starch
- BSN : 90% charcoal + 5% NaOH + 5% starch

Figure 4.3 : Observation of burning lifespan test of briquettes bamboo charcoal

Based on Figure 4.3, BN, made of 95% charcoal with 5% sodium hydroxide (NaOH) has the shortest burning lifespan test at 15 minutes. This is followed by BO, the 100% charcoal with no additives at 20 minutes, BS, the 95% charcoal with 5% starch at 75 minutes, and finally BSN, the 80% charcoal with 5% each of sodium hydroxide (NaOH) and starch at 80 minutes.

Based on the Table 4.3, the burning lifespan test of four samples of bamboo charcoal briquettes showed that the burning duration and ash content varied depending on the composition of the briquettes. The results obtained from this study indicate that briquettes bamboo charcoal has the BN with 95% charcoal and 5% NaOH, this sample had a shortest burning duration in 15 minutes of all the sample, but it also had medium ash and was slower burning. It had a brittle compared to BO. BO with 100% charcoal had the longer burning duration in 20 minutes and more ash formation. It also had a steady burn and was more brittle than the other samples. BS with 95% charcoal and 5% starch, this sample had the longest burning duration in 75 minutes of all the samples, but it also had the minimal ash formation. It burned faster than BO and was more solid. BSN with 90% charcoal and 5% NaOH and 5% starch, this sample had a second-longest burning duration in 80 minutes and medium ash formation. It burned longer than BS and had more solid than BS.

Based on the Figure 4.3, it appears that BN containing 95% charcoal and 5% sodium hydroxide (NaOH) experienced the shortest burning lifespan at 15 minutes. This appears to be due to the reaction between the sodium hydroxide (NaOH) and the charcoal, which likely reduced the burning lifespan of the briquettes. The absence of the sodium hydroxide (NaOH) in BO containing 100% charcoal led to a longer burning lifespan at 20 minutes. Additionally, the addition of starch in BS and BSN likely increased the burning lifespan of the briquettes.

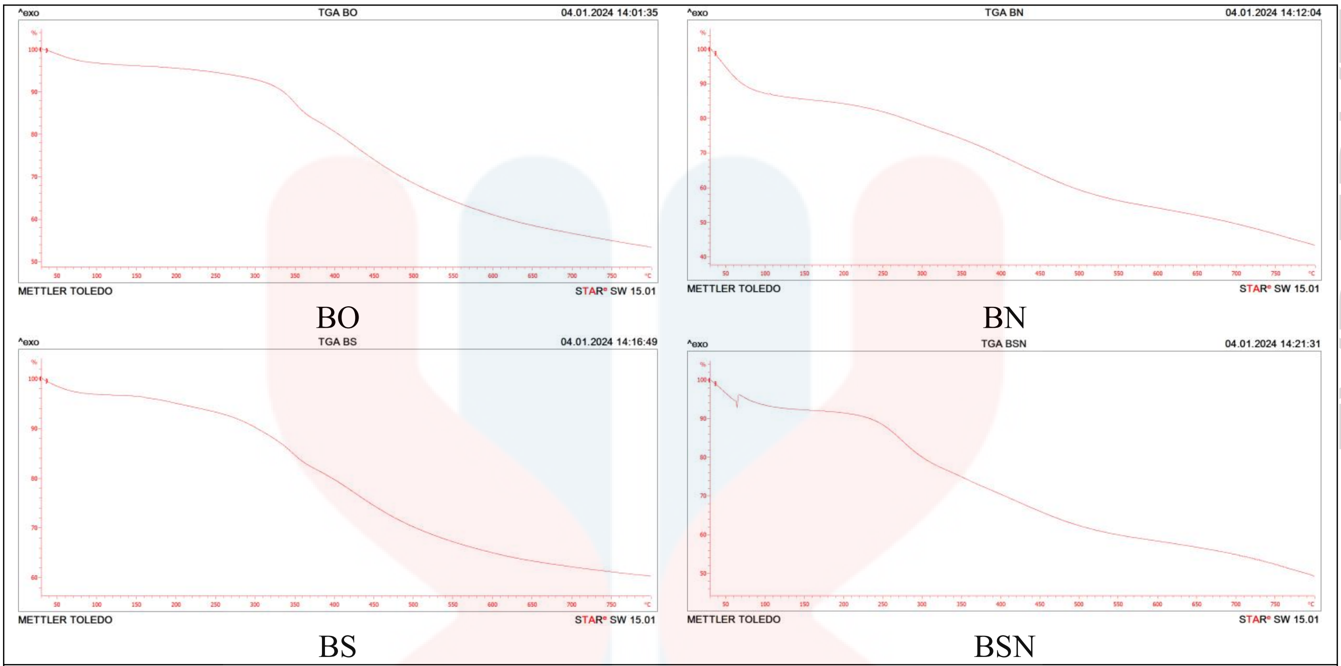
The burning lifespan test of briquettes bamboo charcoal is influenced by the additives added to the charcoal, namely sodium hydroxide (NaOH) and starch. Sodium hydroxide (NaOH) has a strong chemical reaction with starch, which causes the briquettes to burn more rapidly than the 100% charcoal sample. This reaction occurs when sodium hydroxide (NaOH) reacts with the starch molecules, causing them to break down and releasing heat energy that is necessary for burning. The presence of starch in the briquettes bamboo charcoal sample increases the burning lifespan as starch is a slowly burning fuel that releases heat over a longer period of time.

These additives also can affect the burning rate, causing variations in the briquettes' lifespan. NaOH is a base and reacts with starch, forming the salt of sucrose, a type of sugar. This reaction can affect the burning rate as the briquettes contain multiple organic compounds, including hemicellulose, cellulose and lignin, all which can react with NaOH to produce carbon dioxide, reducing the burning lifespan.

From the observation of the burning lifespan test, we can see a tendency that the presence of sodium hydroxide (NaOH) and starch reduces the burning lifespan time of briquettes bamboo charcoal. BSN, which has 5% each of sodium hydroxide (NaOH) and starch, has a burning lifespan of 80 minutes, while BS, which has 5% starch and no sodium hydroxide (NaOH), has a burning lifespan of 75 minutes. This indicates that the presence of sodium hydroxide (NaOH) in briquettes bamboo charcoal reduces its burning lifespan. (Stephanos & Associates, n.d.).

4. 1. 4 Analysis test by using Thermogravimetric Analysis (TGA)

The thermogravimetric analysis test (TGA) was conducted on four different samples of briquettes bamboo charcoal, and the results are presented in Figure 4.4.



- BO : 100% charcoal
- BN : 95% charcoal + 5% NaOH
- BS : 95% charcoal + 5% starch
- BSN : 90% charcoal + 5% NaOH + 5% starch

Figure 4.4 : Analysis data for each different sample of briquettes bamboo charcoal

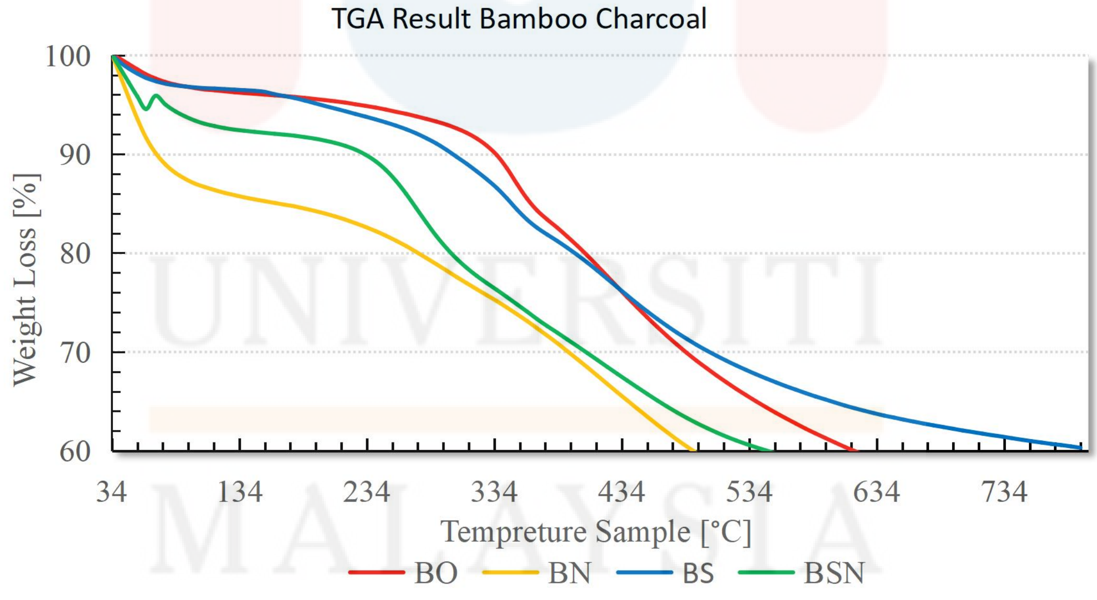


Figure 4.5 : TGA analysis of different samples of briquettes bamboo charcoal

The thermogravimetric analysis (TGA) test provides insights into the thermal decomposition behavior of the different briquette samples. As the temperature increases, the weight of the samples decreases due to the loss of volatile components. The rate and extent of this weight loss can reveal valuable information about the samples' properties as shown in Figure 4.4.

The results obtained from this study indicate that briquettes bamboo charcoal BO containing 100% charcoal shows a steady weight loss throughout the temperature range. This indicates a gradual and controlled decomposition of the charcoal. While, BN containing 95% charcoal and 5% NaOH exhibits a slightly slower weight loss compared to BO. This suggests that the presence of NaOH might inhibit the thermal decomposition of charcoal to some extent. Beside that, BS containing 95% charcoal and 5% starch undergoes a more rapid weight loss at lower temperatures compared to the other samples. This indicates that the starch readily decomposes at these temperatures, releasing volatile components and contributing to a faster mass loss. Whereas, BSN containing 90% charcoal and 5% NaOH and 5% starch shows a weight loss profile that combines features of both BN and BS. The initial weight loss is slightly slower than BS, potentially due to the NaOH influence, but then proceeds at a faster rate than BN. This suggests a complex interplay between the decomposition of charcoal, starch, and the potential interaction with NaOH.

The TGA results offer valuable insights into the thermal behavior of the briquettes. BO with pure charcoal serves as a baseline, exhibiting a steady and controlled decomposition. The addition of NaOH in BN appears to slightly slow down the decomposition process, possibly due to its flame-retardant properties. In contrast, the addition of starch in BS readily decomposes at lower temperatures, leading to a faster initial weight loss. BSN, with both NaOH and starch, presents a combination of these effects, highlighting the complex interplay between the additives and charcoal.

From these results, it has potential implications for understanding the combustion behavior and performance of the briquettes. Charcoal with controlled decomposition, as seen in BO and potentially influenced by NaOH in BN, could contribute to a more stable and sustained burning process. However, rapid decomposition, as in BS with starch, might lead to faster burnout. BSN, with its balanced weight loss profile, might offer a potential compromise between burning stability and duration.

Thermogravimetric Analysis is now one of the most widely used methods of testing in industrial manufacturing. Thermogravimetric analysis, often known as thermal gravimetric analysis or TGA. Thermogravimetric is a method of thermal testing in which the tested substance is exposed to steady variations in temperature over time. This test is used to cause a thermal reaction so that variations in the mass or weight of the tested material as a result of the reaction may be observed and analysed. Thermogravimetric analysis can derive a wide range of additional measurements from the base measurements of mass, temperature, and time during testing, including the amount of filler in the sample, the rate of oxidation or decarboxylation of the sample, and the loss of water, solvent, or plasticizer. (Mathias, 2022). A material analysis technique called thermogravimetric analysis (TGA) involves heating a sample under controlled conditions and measuring its mass as a function of temperature or time. The temperature and weight loss are tracked over time as the material's constituent parts volatilize. By measuring and tracking mass, temperature, and time as the primary measurements during testing, thermogravimetric analysis can derive a wide range of additional measurements, including 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. (TGA Analysis: What, How and Why, 2021)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

In conclusion, the result of the study on the production of bamboo charcoal in the form of briquettes and physicochemical characteristics, the influence of binders on combustion, as well as testing the usability of bamboo charcoal in practical applications has been achieved. This study shows that bamboo charcoal is a potential fuel, with characteristics such as low moisture which is BS has 5.99% lower than BN which recorded 10.50%, low ash such as BS has 0.15% lower than BN (0.3%), and usability in the burning period shows that BS was longer than BO and BN, within a period of 75 minutes. The use of additives such as sodium hydroxide (NaOH) and starch has affected the characteristics of bamboo charcoal, including moisture content, ash content, and burning time. The use of thermogravimetric analysis techniques had provided important information on the thermal behavior of bamboo charcoal and the influence of additives on the combustion process. According to the result, BS was observed as the best material to utilize in the environment since it does not contains sodium hydroxide (NaOH), like BN and BSN. In actuality, BS out performs BO and BN in terms of strength and durability. BO and BN were not suitable to use in making charcoal briquettes. With this finding, this study gives implications for the selection of bamboo charcoal in various combustion applications, as well as providing guidance for further research in the production of better bamboo charcoal.

5.2 RECOMMENDATION

For further studies, it is recommended to use binders made from safe materials such as corn starch, potato starch, molasses or gum arabic rather than using chemicals that are self-destructive and caused air pollution. This is because charcoal briquettes that contains chemicals such as sodium hydroxide (NaOH) can produced a strong odour and a lot of smoke compared to using starch. Starch does not produced much smoke. In addition, to test the durability of charcoal briquettes, it is recommended to use the bending test and tensile test methods to test the strength of the briquettes. Whereas, to study the structure or characteristics found in the briquettes, it may be possible to use the method proximate analysis test, Fourier Transform Infrared Spectrocopy (FTIR) test, Scanning electron microscopy (SEM) test or else.

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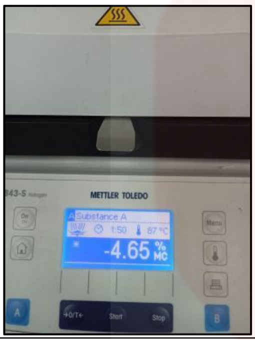
APPENDIX

Moisture content test by using Moisture Analyzer



BO

BN

BS

BSN

Weight of four different sample of briquettes bamboo charcoal

Sample	**Weight of crucible**	**Weight of crucible with sample**	**Weight of crucible with ash**	**Weight of ash**	**Weight of sample**
BO	20	30	22	2	10
BN	20	30	23	3	10
BS	20	30	22.5	2.5	10
BSN	20	30	21.5	1.5	10

Calculations of Ash Content:

1) BO

$$\% \text{ Ash} = \frac{22-20}{10} \text{ X } 100$$

$$= 0.2\%$$

2) BN

$$\% \text{ Ash} = \frac{23-20}{10} \text{ X } 100$$

$$= 0.3\%$$

3) BS

$$\% \text{ Ash} = \frac{22.5-20}{10} \text{ X } 100$$

$$= 0.25\%$$

4) BSN

$$\% \text{ Ash} = \frac{21.5-20}{10} \text{ X } 100$$

$$= 0.15\%$$

Results of the ash content test of briquettes bamboo charcoal

Sample	Weight before tuning to ashes (g)	Heavy after turning to ashes (g)
BO (100% charcoal)	10	2
BN (95% charcoal + 5% NaOH)	10	3
BS (95% charcoal + 5% starch)	10	2.5
BSN (80% charcoal + 5% NaOH + 5% starch)	10	1.5