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The Effect of Carbonization Time on the Quality of Coconut Shell and Melinjo Shell Briquettes

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Abstract

This study explores the impact of different durations of carbonization on the production of briquettes. Briquettes are produced through carbonization process conducted at different time intervals, including 30, 60, 90, 120, and 150 minutes, with a ratio composition of coconut shells and melinjo shells is 90:10. Various carbonization durations were examined to determine their influence on briquette properties, consisting of calorific value, water content, ash content, volatile matter, and density. The conclusion of this study reveals that a longer duration of carbonization results in higher values of calorific and ash content compared to shorter durations. Moreover, longer carbonization periods are associated with reductions in water content, volatile matter, and density of the briquettes. Through experimental analysis, the research indicates that the most effective duration of carbonization is 150 minutes. The briquettes produced with a 150-minute carbonization period possess a calorific value 6.004 cal/g, water content 4.65 %, ash content 4.78 %, volatile matter 6.17 %, and density 0.86 gr/cm^3.

INTRODUCTION

The exploration and development of sustainable energy sources are imperative to address the mounting environmental challenges and energy security concerns posed by the extensive reliance on fossil fuels. Biomass energy, as a renewable energy source, offers a promising alternative to fossil fuels, contributing to climate change mitigation, improving air quality, and ensuring a more sustainable use of resources (Tun et al., 2019). The specific aspects of biomass energy, as highlighted in the provided sources, encompass a wide range of topics including the conversion processes (Chait et al., 2023) , economic feasibility (Khambalkar et al., 2013), environmental benefits (Song & Aguilar, 2017), and challenges associated with its implementation (Rocha-Meneses et al., 2023). Briquettes from biomass are a promising alternative fuel source that can contribute to sustainable energy production (Handra et al., 2023). Abundant biomass, recognized for their carbon-rich, sustainable, and renewable nature, present a wide array of opportunities for developing advanced materials for energy conversion, storage, and environmental remediation (Zhou et al., 2019). Coconut shells are abundant and widely available, making them an attractive option for the production of briquettes. These briquettes can be used as a substitute for traditional fossil fuels, reducing greenhouse gas emissions and promoting environmental sustainability. The production of

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coconut shell briquettes involves several steps, including charcoal making, milling, dough making, molding, and drying (Sudding & Jamaluddin, 2016). Briquettes as an alternative fuel are typically made by combining coconut shell charcoal with an adhesive, such as tapioca flour, in a specific ratio (Santoso, 2022). The mixture is then formed into briquettes using a mold, which are then dried to lower moisture content (Sudding & Jamaluddin, 2016).

Several studies have investigated briquettes from coconut shells and melinjo shells. Anggita et al. (2023) produced bio-briquette using LDPE, coconut husk, and coconut shell with tapioca adhesive. The result was that all samples were found to be non-compliant with both Indonesian National Standard (SNI) briquette standards and Ministry of Energy and Mineral Resources (ESDM) regulations. Another study by Anggita et al. (2023) creating briquettes from coconut shells and peanuts showed that the emissions of natural gas remained under the established threshold. Specifically, the emissions were within the range of 0-30 parts per million (ppm) for carbon monoxide (CO), 0-3.6 ppm for hydrogen sulfide (H_2S) and NO_X levels were undetectable. Following the assessment, the outcomes indicated that incorporating 30% biomass decreased ignition time and reduced unburned briquettes or bottom ash by 68.68 %. Moreover Ansar et al. (2023) examine the physical properties of coconut shell briquettes utilizing tapioca flour as a binder. The briquette production process involved applying compression force. The parameters examined included hardness and the flame produced by the briquettes. The results showed that increased compression force correlated with greater briquette hardness, resulting in a notably robust flame. The highest quality coconut shell briquettes were produced at a compression force of 12 kg/cm^2, yielding a hardness of 27.7 kg/cm^2 and a burn time of 112.61 minutes. In contrast, the lowest quality briquettes were obtained at a compression force of 4 kg/cm^2, resulting in a hardness of 16.5 kg/cm^2 and a burn time of 111.34 minutes. Concluded that development of refining briquette production methods remains imperative to establish a cost-effective alternative energy source. Furthermore, Siharath et al. (2024) investigate the calorific values of charcoal briquettes made from different materials. The experiments revealed that the calorific values of coconut shell briquettes (CBr1), bamboo charcoal briquettes (CBr2), and mixed charcoal briquettes (CBr3) are 6,682 MJ.kg^{-1}, 4,880 MJ.kg^{-1}, and 5,433 MJ.kg^{-1}, respectively. Additionally, the resulting ash residues are 77 g, 100 g, and 250 g for each type of briquette, respectively. Meanwhile Mulyanto et al. (2023) making briquettes from melinjo shells involves several steps, including preparing tools and materials, drying the constituent materials, carbonization, filtering, manufacturing adhesives, printing, and drying the briquettes. The test results showed that the impact on calorific value, burning rate, moisture content, and ash content. Calorific values range from 5713.40 to 6451.60 cal/gram, burning rates range from 0.26 to 0.30 gram/minute, moisture content ranges from 0.26 to 0.30 gram.minute^{-1}, moisture content ranges from 3.3417 % to 4.0556 % and ash content ranges from 4.0533 % to 4.9444 %. Optimal calorific value characteristic were achieved with a 5 % adhesive variation, yielding a calorific value of 6451.60 cal/gram, a burning rate of 0.30 gram.minute^{-1}, moisture content of 3.3417 % and ash content of 4.0533 %. Chairina et al. (2022) made bio pellet from melinjo seed shells. The results showed that the best composition of melinjo seed shells with starch adhesive is melinjo seed shells 50 gr material with 5 % starch adhesive gets 3.1 % water content, 10.6 % volatile content, 4.3 % ash content, 82 % bound carbon content, and resulted from calorific value is 1.7302 j.g^{-1} or 4.1352 cal.g^{-1}. Yerizam et al. (2021) performed research bio-pellets from coconut shells. This research intends to assess how varying temperatures by SNI standards impact the effectiveness of coconut shell bio-pellets. Producing bio-pellets from coconut shell raw materials involves modifying temperature parameters, specifically at 300 °C, 400 °C, 500 °C and 600 °C, while maintaining a consistent duration of 1 hour. The adhesive applied consists of tapioca flour at a 10 % concentration. The study reveal that the optimal quality of bio-pellets is achieved through specific temperature variations, the temperature parameter at 500 °C for 1 hour with a moisture content of 10.58 %, ash content 11.03 %, 30.01 % volatile matter content, fixed carbon content of 48.38 % and calorific value of 6564.88 cal/g. These specifications meet the requirements outlined in SNI 8021-2014 for bio-pellets and various other standards.

However, few studies haven't explored various carbonization times on the coconut shells and melinjo shells. Carbonization was obtained by varying the time from 30 to 150 minutes and using the optimal carbonization temperature of 300 ºC (Camarta et al., 2020) with a 90: 10 fixed ratio, based on a previous study (Manfaati et al., 2024).

MATERIALS AND METHOD

In this study, the production of activated carbons from coconut and melinjo shells utilized an eight-step methodology as subsequent steps adapted from Manfaati et al. (2024). The process began with raw material pre-treatment, followed by carbonization to convert the materials into char. The resulting char underwent size reduction and sieving to achieve a uniform particle size. Next, an adhesive was prepared to bind the materials, which were then shaped into briquettes. Finally, the briquettes were subjected to analysis to evaluate their properties and quality.

Pre-treatment

The process begins by preparing coconut and melinjo shells to remove contaminants using flowing water that might affect the quality of the briquettes. The coconut shells were then cut into smaller pieces, ranging from 9 to 16 cm², to speed up the drying process. The materials were dried in an oven at 60°C for 30 minutes to remove the 'free water' content from the raw material. Drying at low temperatures allows the free water to evaporate without causing material damage or loss of volatile compounds that could affect the quality of the briquettes.

Carbonization

The carbonization procedure involved heating the raw material in a furnace with a maximum capacity of 3 kg and an operating temperature range of 30 to 3000 ºC. The process was carried out under the lowest oxygen concentration over variable durations of 30, 60, 90, 120, and 150 minutes.

Reduction and sieving

To achieve a smooth powder texture, the coconut shell and melinjo shell were finely milled and subsequently filtered through a 60-mesh sieve.

Preparation of adhesive

The adhesive was made by mixing 21 grams of tapioca flour with 70 ml of water until a uniform mixture was obtained. The adhesive ratio utilized is 21%.

Briquette production

This process comprises three consecutive stages: initially, the briquettes were created by thoroughly blending the carbonized material with the adhesive, ensuring complete integration. Subsequently, the mixture was formed using a cylindrical mold 5 cm in diameter and 12.3 cm in height. Precise compaction was achieved under a pressure of 1 ton/cm^2.

Briquette analysis

To evaluate the quality and effectiveness of the briquettes, it is essential to carry out a thorough series of test such as moisture content, ash content, density, and calorific value, aligning with the standards outlined in SNI 01-6235-2000. These tests provide valuable insights into the characteristic and performance of the briquettes.

RESULTS AND DISCUSSION

The calorific value of a briquette stands out as a important factor influencing its overall quality and performance. The calorific value is crucial for briquette quality, representing energy released during combustion. Longer drying reduces moisture, increasing calorific value (Handayani et al., 2019). The longer carbonization period of the raw materials for the briquettes results in a higher calorific value. Implies that fuels with higher calorific values have the potential to produce more heat energy per unit mass, making them more efficient and desirable for various applications (Namadi. et al., 2018). The results of sample E revealed that a longer drying duration can achieve the highest calorific value of 6004 cal/gr. Meanwhile, the lowest caloric of sample A value obtained was 5314 cal/gr. This indicates that the produced charcoal briquettes have the potential to serve as renewable energy sources for both households and industries. Figure 1 reveals the impact of carbonization duration on the calorific value of the briquettes produced in this study.

Based on the caloric performance data, the authors aimed to identify water content as one of the primary contributing factors. The water content of a material is a crucial factor influencing the quality of briquettes, as it directly affects their combustion efficiency and calorific value (Samudro et al., 2023). Water content refers to the proportion

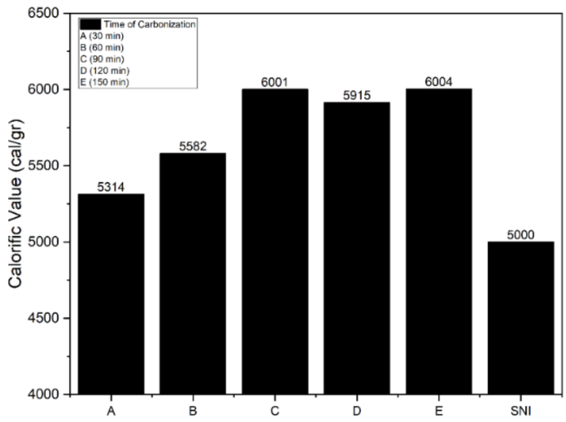

Figure 1. The calorific value of the carbonization effects at various time of briquettes.

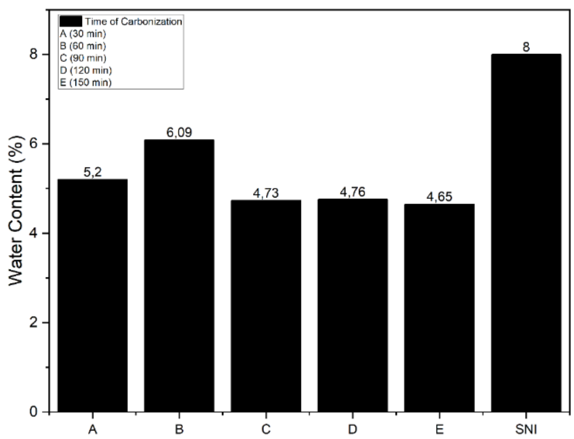

Figure 2. The water content of the carbonization effects at various time of briquettes.

of water present in a substance, typically measured as a percentage (Samudro et al., 2023). The lowerwater content makes the calorific value and combustion power higher (Ardiansyah et al., 2022). High water content can lead to difficulties in combustion, resulting in inefficient burning and lower calorific value. The analysis revealed that carbonization of sample E for 150 minutes had the lowest water content recorded at 4,65 %. The resulting water content decreases as the temperature and the carbonization time increase (Jaya & Khair, 2020). This occurs because water (H_2O) undergoes a chemical phase change into gas when it reaches boiling point at 100 ºC. At this stage, the free water molecules bound to carbon are liberated and transition into a gaseous state (Aulia et al., 2019). The research findings indicated that the highest water content was 5.2 %. According to SNI standard criteria, the highest water content permitted in bio-briquettes is below 8 %. The analysis results indicate that the water content of all produced samples still conforms to the standards. Figure 2 displays the influence of carbonization duration on the water content of the briquettes produced in this research.

The ash content observed in the results is closely related to the formation of inorganic oxides such as SiO_2 (silicon dioxide), Fe_2O_3 (iron oxide), Al_2O_3 (aluminum oxide), MgO (magnesium oxide), and CaO (calcium oxide) during the carbonization process (Sarkar, 2015). During carbonization under limited oxygen conditions, the organic components in the biomass (e.g., cellulose, hemicellulose, and lignin) undergo thermal decomposition (Wang et al., 2011). Higher temperatures and prolonged exposure during carbonization facilitate the breakdown of silicates, leading to increased SiO_2 content in the ash (Yan et al., 2017). Fe-containing minerals (e.g., iron sulfides or oxides) undergo oxidation at elevated temperatures to form Fe_2O_3. This process contributes to the ash content, especially with longer carbonization durations where oxidation is more complete. Al_2O_3 is derived from aluminum-bearing minerals present in the shells (Madakson et al., 2012). The thermal decomposition of these minerals during carbonization leaves Al_2O_3 as a residue in the ash (Sedres, 2016). MgO and CaO result from the thermal decomposition of carbonates such as magnesium carbonate ($MgCO_3$) (Devasahayam, 2019) and calcium carbonate ($CaCO_3$) (Mohamed et al., 2012), which are commonly present in biomass. These oxides are produced through thermal decomposition and oxidation reactions of mineral components present in the raw material. These findings indicate that the produced charcoal briquettes are suitable for both household and industrial use. Figure 3 showcases the impact of carbonization duration on the ash content of the briquettes generated in this study.

Volatile matter refers to substances capable of evaporating due to the decomposition of compounds within the briquette, excluding water, bound carbon, and ash (Wijaya et al., 2020). The purpose is to examine the volatile matter content in the produced briquettes (Yuliah et al., 2017). The amount of volatile matter influences both the thoroughness of combustion and the resulting flame, thereby impacting the marketability of the briquettes (Yuliah et al., 2017). The study explored the relationship between carbonization duration and the volatile matter content of briquettes.

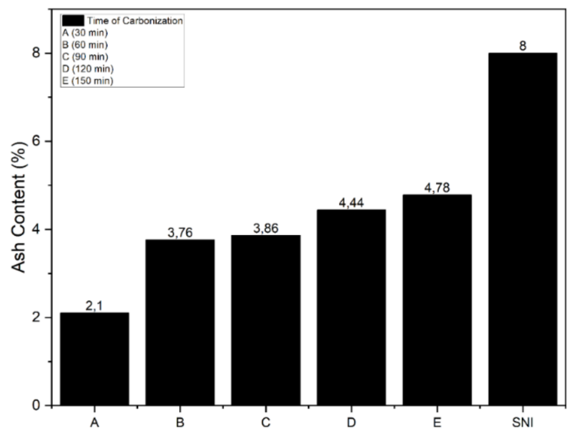

Figure 3. The ash content of the carbonization effects at various time of briquettes

Prolonged carbonization duration decreases volatile matter content, while shorter durations correspond to higher volatile matter levels. Specifically, the analysis indicated that a carbonization duration of 150 minutes yielded the lowest volatile substance content recorded, at 5.71 %. This suggests that the produced briquette is highly ignitable, burns rapidly, and exhibits a proportional increase in flame length (Inegbedion, 2022). This indicates that longer carbonization reduces volatile matter while increasing the calorific value. In contrast, a shorter 30-minute carbonization duration resulted in the highest volatile substance content observed, at 6.72 %. Standards limit briquette volatile content to 15%, depending on raw materials. It is evident that all produced samples still comply with SNI standards regarding volatile substance content. Figure 4 depicts the influence of carbonization duration on the volatile substance content of the briquettes created in this research.

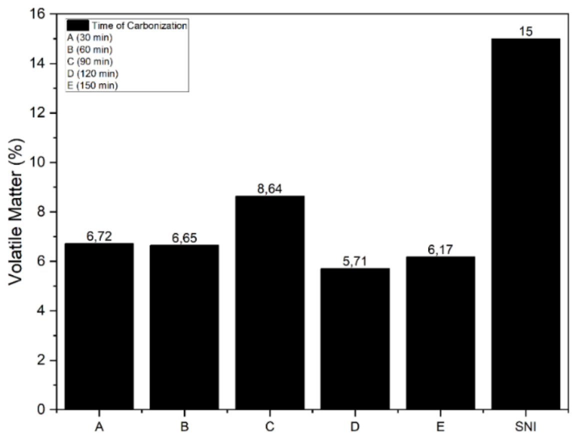

Figure 4. The volatile matter of the carbonization effects at various time of briquettes

The quality of briquettes is directly affected by their density (Ismayana & Moh, 2011). Density is determined by assessing the relationship between the weight and volume of the briquettes (Samudro et al., 2023). The magnitude or smallness of the density is influenced by the size and homogenity of the briquette constituens (Ismayana & Moh, 2011). Excessive density can cause charcoal briquette difficult to burn. In contrast, those with moderate density facilitate combustion by allowing more air cavities or gaps for oxygen to pass through during the burning process (Ismayana & Moh, 2011). The specific gravity of the raw materials influences the high or low density of the charcoal briquettes produced (Rindayatno & Lewar, 2017). The analysis revealed that a 150-minutes carbonization duration resulted in the lowest density listed at 0.86 gr/cm^3 The alterations in density observed after heat treatment can be elucidated by the chemical modifications that occur post-treatment (Shangguan et al., 2016). Cellulose, a part chemical composition, is present in coconut (Amaral et al., 2019) and melinjo shells (Desman, 2018). During heat treatment, cellulose, with its branched structure and amorphous tissues, undergoes gradual reduction because it is more vulnerable to thermal degradation than other components (Shangguan et al., 2016). The study revealed that the highest density was 0.93 gr/cm^3. Figure 5 represents how the duration of carbonization affects the density of the briquettes created in this investigation.

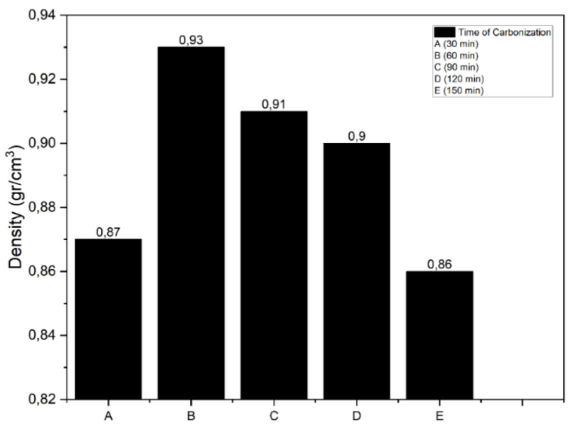

Figure 5. The density of the carbonization effects at various time of briquettes.

CONCLUSION

Pertaining to this study, the duration of carbonization plays a pivotal role in shaping the characteristics of briquettes. Variations in carbonization time directly impact crucial properties such as calorific value, water content, ash content, volatile matter and density highlighting the importance of precise control over this parameter in optimizing the quality and performance of briquettes. Overall, this study shows that a longer carbonization period correlates with reductions in water content, volatile matter, and density. However, a longer duration of carbonization gives a higher value of calorific and ash content than shorter duration. After observing various durations of carbonization for the coconut shell and melinjo shell in briquette production, it has been determined that the most optimal duration is 150 minutes. This duration yields the best results: calorific value 6,004 cal/g, water content 4.65 %, ash content 4.78 %, volatile matter 6.17 %, and density 0.86 gr/cm^3.

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