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Effect of Base Material Variations on the Characteristics of Briquettes from Coconut Shell Charcoal and Corncob Mixtures

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Abstract

This study investigates the effects of varying base materials, specifically coconut shell charcoal (ATK) and corncob charcoal (ABJ), on the characteristics of biobriquettes. The research employs an experimental method, analyzing the impact of different ATK and ABJ proportions on calorific value, ash content, moisture content, density, and combustion rate. The biobriquettes were produced by mixing coconut shell and corncob charcoal with 10% tapioca starch adhesive, molded into cubes, and dried. The results show that increasing the ATK proportion improves the calorific value, with the highest value of 10,640 calories in briquettes with 90% ATK. In contrast, higher ABJ content results in faster combustion rates but lower energy efficiency, with the lowest calorific value of 6,424 calories in briquettes containing 90% ABJ. The study also highlights that all biobriquettes meet Indonesian National Standards (SNI) for moisture content and calorific value, although only the 90% ATK sample meets the ash content standard. These findings suggest that coconut shell charcoal is a superior biomass material for producing high-performance biobriquettes, with a 90% ATK and 10% adhesive combination yielding the best overall results for sustainable energy applications.

Keywords: Biobriquettes; Coconut shell charcoal; Corncob charcoal; Calorific value; Combustion rate.

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INTRODUCTION

Energy has become one of the most critical issues globally as the demand for energy continues to rise each year. This growing demand has significantly depleted fossil fuel reserves, leading to increased fuel prices. Consequently, alternative solutions are needed to reduce reliance on fossil fuels. One of the most promising alternatives is biomass energy, which is derived from organic waste materials, primarily plant residues. Biomass energy is a renewable and sustainable energy source, widely available in various forms, such as rice husks, sugarcane bagasse, and coconut shells. These plant residues can be utilized as raw materials for the production of biobriquettes, which are solid biofuels. Among these, coconut shells have been highlighted as a particularly effective biomass source (Harlina et al., 2021).

The development of renewable energy sources, also referred to as alternative energy, has been pursued through various approaches. Solar energy can be converted into electricity using solar cells, wind energy is harnessed via wind turbines, and plant oils undergo esterification and transesterification with acid or base catalysts to produce biodiesel. Biomass, on the other hand, can be transformed into solid fuels like briquettes. These approaches aim to reduce dependence on depleting fossil fuel reserves. Biomass is considered one of the most promising renewable energy sources, primarily due to its abundance and versatility. It is derived from organic materials, especially plant-based sources, that are often regarded as waste (Pangga et al., 2021).

In previous studies, corncob-based biomass was widely explored for its potential in biobriquette production. For instance, research by Pangga et al. (2022) focused on using corncobs as the primary raw material, experimenting with varying adhesive compositions—5%, 10%, and 15%—across two different briquette geometries: cylindrical and square-shaped briquettes. The results indicated that square briquettes with a 15% adhesive concentration exhibited the highest combustion rate. The combustion rate was found to increase as the adhesive concentration increased, with a significant rise in calorific value from 22.68 kJ at 10% adhesive to 31.08 kJ at 15%. These findings suggest that the higher adhesive concentration enhances the overall performance of the briquettes. Additionally, Nasruddin and Affandy (2011) highlighted the economic benefits of using biomass briquettes, estimating that they are 65% cheaper compared to traditional fuel sources such as kerosene, gas, and wood. Biomass briquettes are also renewable and can be produced sustainably, making them an attractive alternative to conventional energy sources.

Researchers have also investigated various raw materials for briquette production. For instance, Pratama (2020) explored the use of water hyacinth waste, while Aljarwi (2020) examined the effects of varying pressure levels on the quality of rice husk wafer briquettes. In both cases, the researchers sought to determine how different factors, such as raw material type and briquette shape, influenced the performance of the resulting briquettes. Stiawan (2022) conducted a study using peanut shells as the primary raw material, employing tapioca and rice flour adhesives to examine the calorific value and combustion rate of the briquettes. These studies indicate that various types of biomass waste, combined with different adhesives, can result in briquettes with diverse performance characteristics.

In addition to studies focusing on corncobs and other plant residues, coconut shells have also gained significant attention as a raw material for biobriquette production. Sukarti et al. (2023) conducted experiments using coconut shells as the primary raw material, investigating the impact of different adhesive concentrations—5%, 10%, and 15%—on the briquette properties. Similar to the findings of Pangga et al. (2022), Sukarti's study demonstrated that increasing the adhesive concentration resulted in higher calorific values. Moreover, the thermal properties of the briquettes were influenced by the proportion of coconut shell in the mixture. These findings highlight the potential of coconut shells as a high-quality biomass source for biobriquette production, particularly when combined with the right adhesive ratios.

Corncobs and coconut shells are two types of biomass waste that are abundantly available in many regions, yet they remain underutilized as energy sources. The large quantities of corncobs and coconut shells generated as agricultural waste represent a significant opportunity for the production of biobriquettes. However, few studies have explored the combination of these two biomass sources to optimize the characteristics of the briquettes. Most previous studies have focused on the use of either coconut shells or corncobs individually, without examining the potential synergies that may arise from combining them. It is crucial to investigate how the combination of these two materials, along with varying adhesive concentrations, affects the combustion properties and energy efficiency of the resulting biobriquettes.

Several factors influence the quality and performance of biobriquettes, including the type of biomass used, the particle size of the biomass, the density of the briquettes during molding, the type of adhesive, and the carbonization temperature during combustion. Manisi and Kadir (2019) emphasized that the quality of biobriquettes is closely linked to these variables. For instance, the finer the biomass particles, the denser the briquettes will be, resulting in improved combustion properties. Similarly, the type of adhesive used can significantly affect the bonding strength and thermal performance of the briquettes. These factors must be carefully considered when developing biobriquettes from a mixture of coconut shell charcoal and corncob charcoal.

Given the abundance of coconut shells and corncobs as agricultural waste, it is essential to explore their potential for producing high-quality biobriquettes that can serve as an alternative energy source. Previous studies have demonstrated that both coconut shells and corncobs have excellent potential as raw materials for biobriquette production. However, there is a lack of research on the combined use of these two materials. The present study seeks to fill this gap by investigating how varying the proportions of coconut shell charcoal and corncob charcoal in the briquette mixture affects the briquette's characteristics, including its calorific value, combustion rate, and overall energy efficiency.

The current research aims to contribute to the growing body of knowledge on biomass energy by providing new insights into the optimal combinations of coconut shell charcoal and corncob charcoal for biobriquette production. This study will not only assess the energy performance of these biobriquettes but also evaluate their economic feasibility and sustainability as a renewable energy source. By doing so, it hopes to offer practical solutions for reducing reliance on fossil fuels and promoting the use of renewable biomass energy in regions where these agricultural wastes are abundant.

The research also seeks to address a key gap in the existing literature by exploring the potential synergies between coconut shell charcoal and corncob charcoal. Most previous studies have focused on single biomass sources, but the combination of different biomass materials may lead to improved briquette properties, particularly in terms of calorific value and combustion efficiency. The findings of this study could have significant implications for the development of more efficient and cost-effective biobriquettes, contributing to the broader goal of enhancing energy security and reducing carbon emissions through the use of renewable energy sources.

Study objectives, hypothesis, and novelty

The objective of this research is to determine the effects of varying base materials, specifically coconut shell charcoal and corncob charcoal, on the characteristics of biobriquettes. Previous studies have established that both coconut shells and corncobs serve as excellent sources of biomass for renewable energy, yet the combination of these two materials remains largely unexplored. By investigating this combination, the study aims to identify how the proportion of these materials in the mixture influences key briquette properties such as calorific value, combustion rate, and overall energy performance.

The novelty of this research lies in the exploration of mixed biomass sources, particularly coconut shell charcoal and corncob charcoal, to optimize biobriquette production. Previous studies have often focused on individual materials, but there has been little emphasis on combining them to enhance briquette quality. This study seeks to fill that gap by assessing the synergies that may arise from using both types of charcoal together, along with varying adhesive concentrations, to improve the briquettes' thermal and combustion properties.

The specific objectives of the research are:

1. To analyze the effect of different proportions of coconut shell charcoal and corncob charcoal on the calorific value of the resulting biobriquettes.
2. To determine the optimal adhesive concentration that maximizes the combustion efficiency of the biobriquettes.
3. To evaluate the economic and environmental sustainability of biobriquettes produced from these mixed biomass sources.

This study hypothesizes that biobriquettes made from a combination of coconut shell charcoal and corncob charcoal will exhibit enhanced combustion properties compared to briquettes made from either material alone. Additionally, it is expected that a higher adhesive concentration will improve both the calorific value and combustion rate of the briquettes, contributing to better energy performance.

By testing these hypotheses, the research aims to provide valuable insights into the production of more efficient and sustainable biobriquettes, offering a potential alternative energy source that could help reduce dependence on fossil fuels. This aligns with broader global efforts to promote renewable energy solutions and reduce carbon emissions.

LITERATURE REVIEW

Biomass, as an organic material created through the process of photosynthesis, holds significant potential as a renewable energy source. Biomass includes both products and waste materials from various plant sources, which, after serving their primary purposes, are often considered economically non-viable and classified as waste. Common examples of biomass include peanut shells, rice husks, corncobs, and coconut shells (Martynis et al., 2012). These materials can be repurposed into biofuels, offering a sustainable alternative to traditional fossil fuels. In the context of briquette production, the utilization of biomass not only addresses energy scarcity but also provides an environmentally friendly solution by reducing agricultural waste (Sarwono et al., 2018).

Briquettes are solid fuel blocks made by compressing biomass, which can be used as an alternative to fossil fuels such as coal and natural wood. Briquettes are widely employed for both household cooking and industrial heating purposes (Wicaksono & Nurhatika, 2019). The process of briquette formation is influenced by several factors, including the density of the raw material, charcoal particle size, carbonization temperature, and applied pressure. Various types of biomass, such as rice husks, corncobs, sugarcane bagasse, cassava husks, and coconut shells, can be utilized to create briquettes (Rumiyanti et al., 2018). The quality of these briquettes is determined by their physical and chemical characteristics, such as moisture content, ash content, volatile matter, fixed carbon, density, hardness, and calorific value (Wicaksono & Nurhatika, 2019).

The diversity of briquette types, based on raw materials and geometric shapes, allows for a wide range of applications. The most commonly used briquettes are coal, charcoal, peat, and biomass briquettes, each with its own unique characteristics. Briquette shapes also vary, with common forms including cubes, cylinders, and hexagons, which can be produced in different sizes to suit various needs (Sakdiah et al., 2023).

Corncobs, an agricultural byproduct, are often underutilized by farmers. Although some of this waste is used as animal feed, a large portion is simply burned, contributing to environmental pollution due to the uncontrolled release of gases like SOx and NOx. Given the physical and chemical properties of corncobs, which include a high lignin content (33.3%) and the ability to reach combustion temperatures of up to 205°C, they have significant potential as a renewable energy source (Hidayat, 2022). Repurposing corncobs for energy production, such as through the creation of biobriquettes, could alleviate some of the environmental concerns associated with agricultural waste disposal while providing a viable source of renewable energy.

Coconut shells, another abundant waste product, are similarly valuable as a biomass resource. Comprising approximately 15% of the total mass of a coconut, the shell is the hardest part, protecting the fruit's interior with a thickness of 3-5 mm (Awang, 1991). Like wood, coconut shells contain high amounts of lignin and cellulose, with moisture content varying based on environmental factors and the maturity of the fruit. Once dried, mature coconut shells can have a moisture content between 6-9%, making them suitable for conversion into charcoal (Sukartono & Utomo, 2012). Given their high energy potential, coconut shells are commonly used in briquette production, particularly as a renewable and sustainable source of bioenergy.

In addition to raw materials, adhesives play a crucial role in the briquette manufacturing process. Adhesives bind the biomass particles together, enhancing the stability and calorific value of the resulting briquettes. Organic adhesives, such as tapioca starch, are frequently used due to their effectiveness and affordability. Tapioca starch, derived from cassava, contains starch (73-84.9%), fat (0.08%-1.54%), protein (0.03%-0.60%), and ash (0.02%-0.33%), making it an ideal binding agent for briquettes (Hidayat et al., 2022). The adhesive's role is not only to bind the particles but also to influence the overall performance of the briquettes. Excessive adhesive use, however, can reduce the calorific value and produce more smoke during combustion. Therefore, careful consideration of adhesive concentration is essential to ensure optimal briquette quality.

Adhesives can be classified into two types: organic and inorganic. Organic adhesives, such as tapioca, starch, tar, paraffin, and molasses, are known for their lower ash production during combustion. Inorganic adhesives, such as clay, cement, and sodium silicate, are stronger and more durable but produce more ash, making them less suitable for high-performance briquettes (Hidayat et al., 2022). In this study, tapioca starch was chosen as the adhesive due to its affordability and availability, as well as its lower impact on briquette performance in terms of ash content and smoke production.

The performance of briquettes is typically evaluated based on specific parameters, such as density, moisture content, ash content, calorific value, and combustion rate. These parameters are detailed in Indonesia's national standard for briquette quality, SNI No. 1/6235/2000. According to this standard, the moisture content of briquettes should not exceed 8%, as excessive moisture lowers the calorific value and prolongs ignition time. Similarly, the ash content should be no more than 8%, as higher ash content indicates the presence of silica, which degrades the quality of the briquettes. The calorific value, or the amount of heat produced during combustion, is another critical factor, with a minimum requirement of 5000 kcal/g (SNI No. 1/6235/2000).

Several studies have investigated the factors that influence briquette performance. For example, Stiawan (2022) demonstrated that the density of briquettes, calculated as the ratio of mass to volume, is directly affected by the pressure applied during molding. Higher pressure results in denser briquettes, which generally have better combustion properties. The moisture content of briquettes is also a crucial factor, as higher moisture levels reduce calorific value. Stiawan et al. (2023) found that increasing adhesive concentrations led to higher moisture content but lower calorific values, underscoring the need for careful control of adhesive use in the briquette-making process.

Other relevant studies include research by Sulistyaningkarti and Utami (2017), which focused on the production of corncob briquettes using varying types and concentrations of adhesives. Their results indicated that briquettes made from corncobs with tapioca starch adhesive had superior quality compared to those made with wheat flour adhesive. The best-performing corncob briquettes had a moisture content of 3.665%, an ash content of 11.005%, and a calorific value of 5661.071 kcal/g. Similarly, Arbi et al. (2018) analyzed the calorific value of coconut shell-based briquettes and found that they produced 7486 kcal/g, exceeding the minimum standard set by SNI No. 1/6235/2000. Qistina et al. (2016) compared the performance of rice husk and coconut shell briquettes, observing a 9.72% decrease in calorific value for rice husk briquettes and a 7.21% decrease for coconut shell briquettes compared to their raw biomass. However, the thermal efficiency of rice husk briquettes was higher (31.13%) than that of coconut shell briquettes (22.28%).

The use of corncobs and coconut shells as raw materials for biobriquette production aligns with broader efforts to repurpose agricultural waste for renewable energy. In Indonesia, where corn and coconut are abundant, there is significant potential for converting these waste products into energy sources. The large-scale cultivation of corn results in considerable amounts of corncob waste, while coconut production generates vast quantities of discarded shells. Rather than burning or discarding these materials, they can be transformed into high-quality briquettes, offering a sustainable solution to energy needs.

In summary, this research aims to explore the optimal combination of corncob and coconut shell charcoal for biobriquette production. By investigating the effects of varying raw material proportions and adhesive concentrations on briquette quality, this study seeks to contribute to the development of more efficient, sustainable, and environmentally friendly biofuels. Through the utilization of agricultural waste, the study also addresses pressing environmental concerns related to waste disposal and pollution, providing a practical approach to promoting renewable energy in regions rich in biomass resources.

METHOD

Type of research

This study employed an experimental research design conducted in the physics laboratory of Undikma University. Experimental research, as defined by Sugiyono (2014), is designed to investigate the effect of a specific treatment or condition on an object under controlled circumstances. In this context, the research aimed to determine how the variation of base materials, namely coconut shell charcoal (ATK) and corncob charcoal (ABJ), impacted the characteristics of biobriquettes, including their calorific value and combustion rate.

Research design

The research was designed as an experimental study to investigate the effects of varying proportions of coconut shell charcoal (ATK) and corncob charcoal (ABJ) on the characteristics of biobriquettes. Conducted in the physics laboratory of Undikma University, the study followed a systematic, stage-based approach, ensuring that all experimental variables were controlled and monitored in a laboratory environment. This experimental research, as described by Sugiyono (2014), aimed to determine how specific treatments—in this case, varying the composition of biomass materials—affect the outcome, which was measured through parameters such as calorific value and combustion rate.

The research unfolded in four key stages. First, the preparation stage involved the collection and drying of coconut shells and corncobs, which were sourced from local agricultural waste. The materials were subjected to sun drying for five days to reduce moisture content, a critical step to ensure proper carbonization. After drying, the second stage, carbonization, was carried out. Both coconut shells and corncobs were carbonized through open-air burning, transforming the raw biomass into charcoal. This process was carefully monitored to produce a consistent quality of charcoal from both materials.

Following carbonization, the third stage focused on the production of biobriquettes. A mixture of coconut shell and corncob charcoal was combined with a 10% tapioca starch adhesive. The briquettes were then formed into rectangular shapes using a manual briquette press, with dimensions set at 4.5 cm x 3.2 cm x 3.2 cm to standardize the volume. After molding, the biobriquettes were left to dry in sunlight for six days, ensuring sufficient hardening and moisture reduction before testing.

In the final stage, the produced biobriquettes were subjected to a series of tests to evaluate their calorific value and combustion rate. The calorific value test was conducted using a calorimeter, which measured the amount of heat released during combustion. The combustion rate test involved igniting the briquettes and timing how long it took for each briquette to burn completely, allowing for a comparison of energy efficiency across different biomass mixtures.

By integrating these stages, the research aimed to explore the optimal combination of coconut shell and corncob charcoals to produce high-efficiency biobriquettes. This design provided a structured and replicable approach to analyzing how varying raw material compositions affected the energy output and burning characteristics of the biobriquettes, with the goal of identifying the most effective mixture for renewable fuel production.

Research location and duration

The research took place at the physics laboratory of the Faculty of Science and Technology (FSTT) at Undikma University from October 2023 to March 2024.

Research instruments

The instruments used in this study were essential for ensuring accurate and consistent measurements throughout the experimental process. The tools included both physical instruments and materials necessary for the collection, preparation, and testing of biobriquettes made from coconut shell charcoal (ATK) and corncob charcoal (ABJ). Each instrument played a crucial role in facilitating the various stages of the research, from material preparation to the evaluation of the final product's performance.

A measuring cylinder was employed to accurately measure the volume of liquids used during the briquette-making process, such as the water mixed with the tapioca starch adhesive. The manual briquette press was used to mold the charcoal and adhesive mixture into uniform rectangular blocks. This press ensured that the briquettes were formed under consistent pressure, which is vital for maintaining uniform density and size, both of which influence the briquette's performance during combustion. An (shieve shaker) was used to sieve the crushed charcoal to obtain fine particles, ensuring even distribution of material in the briquette mix.

For the evaluation of the calorific value, a calorimeter was the primary instrument. It measured the heat energy released by the biobriquettes during combustion, which is critical for assessing the energy efficiency of the different biomass compositions. Alongside this, a thermometer was used to record temperature changes in the calorimeter, while a stopwatch was employed to measure the time taken for each briquette to completely burn during the combustion rate test.

Additional instruments included molds, specifically cubic molds, that shaped the briquettes into blocks with precise dimensions of 4.5 cm x 3.2 cm x 3.2 cm. This standardization allowed for consistent comparisons between different briquette samples. A balance scale was used to weigh the briquettes both before and after combustion to determine mass loss, which is crucial for calculating the combustion rate. A gas lighter was used to ignite the briquettes for the combustion tests, while mortar and pestle were utilized to crush the charcoal into fine powder before mixing.

In terms of materials, the study used coconut shell and corncob charcoal as the primary biomass materials, tapioca starch as the adhesive, and water to bind the mixture. These raw materials were combined in precise ratios to form the biobriquettes, and their physical and chemical properties were critical in determining the overall efficiency and performance of the briquettes.

Together, these instruments and materials were integral to conducting the research, ensuring that the biobriquettes were produced and tested under controlled and replicable conditions. Each tool contributed to gathering the necessary data to evaluate the effects of the varying proportions of coconut shell and corncob charcoal on the calorific value and combustion rate of the biobriquettes.

Data collection techniques

Data collection in this study involved systematic methods to gather quantitative data on the physical and combustion properties of the biobriquettes produced from varying proportions of coconut shell charcoal (ATK) and corncob charcoal (ABJ). The primary data collected included mass density, moisture content, ash content, calorific value, and combustion rate. The process began by weighing the biobriquettes before and after combustion using a digital balance scale to determine their mass, which was critical for calculating both density and combustion rate. For moisture content, the biobriquettes were dried under sunlight, and their weight was recorded before and after drying to assess the percentage of water lost.

Ash content was measured by burning the biobriquettes completely and weighing the residual ash to evaluate how much non-combustible material remained after combustion. This was essential for determining the efficiency of the briquettes, as higher ash content typically reduces calorific value. The calorific value was measured using a calorimeter, which provided data on the heat energy released during combustion. Temperature changes were monitored with a thermometer, and the calorimeter readings were used to calculate the total heat generated by each biobriquette sample. Finally, the combustion rate was assessed by igniting the briquettes and recording the time taken for them to burn completely using a stopwatch. This measurement provided insights into the efficiency and burn duration of the different biomass mixtures. All data were carefully recorded in tables for further analysis.

Data analysis techniques

Data analysis in this study involved processing the collected data to draw meaningful conclusions regarding the effects of varying the proportions of coconut shell charcoal (ATK) and corncob charcoal (ABJ) on biobriquette performance. First, the mass density of each briquette was calculated using the formula for density, where the mass of the briquette was divided by its volume. This value was used to compare the compactness of briquettes across different biomass compositions, which directly impacts combustion efficiency.

Moisture content was analyzed by calculating the percentage of water lost during drying, which was crucial for understanding how the moisture levels in the briquettes affected their calorific value. Similarly, ash content was analyzed by comparing the mass of the briquette before and after combustion to determine the percentage of non-combustible material. High ash content was correlated with lower calorific values, as confirmed by previous studies.

Calorific value was calculated using the formula for heat energy, factoring in the mass of the water in the calorimeter, the specific heat capacity of water, and the temperature change observed during combustion. This allowed for a comparison of the energy efficiency of each briquette mixture. Lastly, the combustion rate was determined by calculating the mass loss over time, providing insights into how quickly each briquette burned and its suitability as a sustainable fuel source. These analyses provided a comprehensive understanding of how the different biomass compositions affected the overall performance of the biobriquettes.

RESULTS AND DISCUSSION

Coconut shells and corncobs are among the most commonly found agricultural and household waste materials in the surrounding environment. These waste products can serve as raw materials for the production of biobriquettes. The process of making biobriquettes from coconut shells and corncobs begins with material preparation. Once the coconut shells and corncobs are dried, they are carbonized and ground into fine powder. The coconut shell and corncob charcoal are then sieved to obtain finer charcoal particles before being mixed with an adhesive. Before molding, the finely ground charcoal is first mixed with the adhesive. In this process, 10% tapioca starch is used as the adhesive, which is added to a container, mixed with water, and heated until it thickens. The prepared adhesive is then combined with the coconut shell and corncob charcoal. The proportions of corncob charcoal used are 0%, 15%, 30%, 45%, 60%, 75%, and 90%, while the proportions of coconut shell charcoal are 90%, 75%, 60%, 45%, 30%, 15%, and 0%. The mixture of charcoal and adhesive is then combined to form a dough. This dough is placed into cube-shaped molds, compressed using a manual press, and dried under the sun for approximately three days, depending on the weather. An example of the process for making biobriquettes from corncob charcoal (ABJ) and coconut shell charcoal (ATK) can be seen in Figure 1.

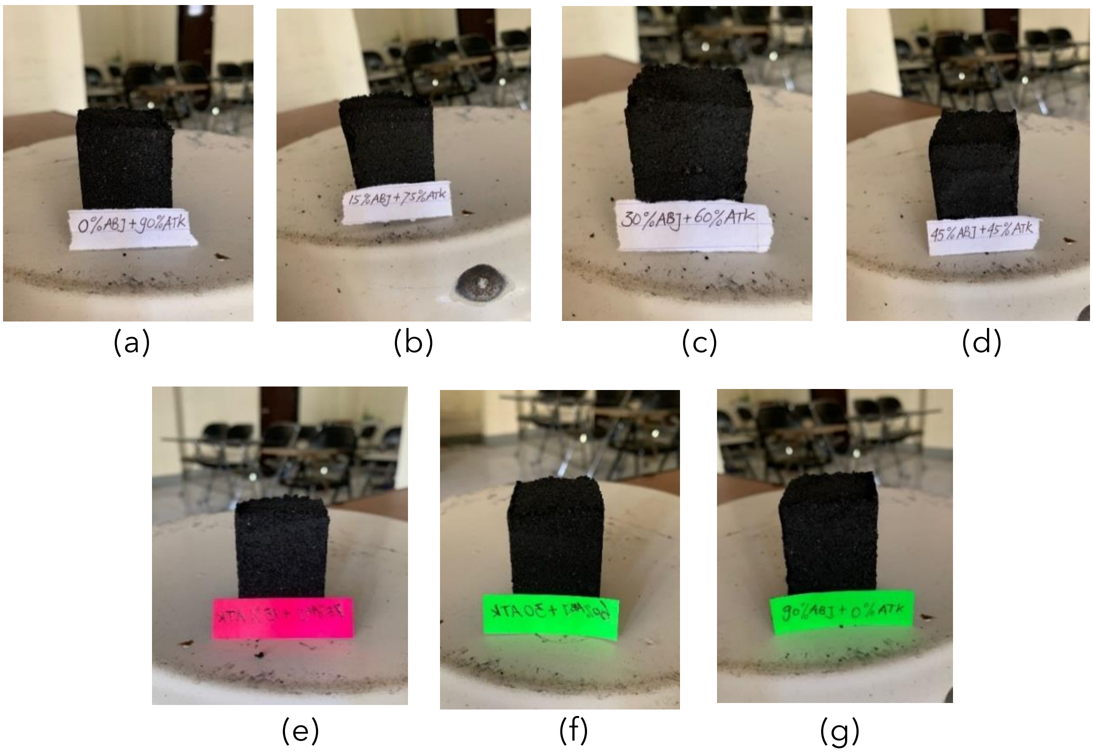

Figure 1. Briquettes made from corncob charcoal and coconut shell charcoal with the following compositions: a) 0% ABJ + 90% ATK, b) 15% ABJ + 75% ATK, c) 30% ABJ + 60% ATK, d) 45% ABJ + 45% ATK, e) 60% ABJ + 30% ATK, f) 75% ABJ + 15% ATK, g) 90% ABJ + 0% ATK.

Briquette Density Analysis

The pressure applied to the briquette affects its density (Khusaini & Rahman, 2024).

Table 1. Determination of briquette density

Sample	Composition of Base Materials with 10% Adhesive	Density (gr/cm³)
A	0%ABJ + 90%ATK	0,536
B	15%ABJ+75%ATK	0,459
C	30%ABJ+60%ATK	0,509
D	45%ABJ+45%ATK	0,488
E	60%ABJ+30%ATK	0,461
F	75%ABJ+15%ATK	0,416
G	90%ABJ+0%ATK	0,399

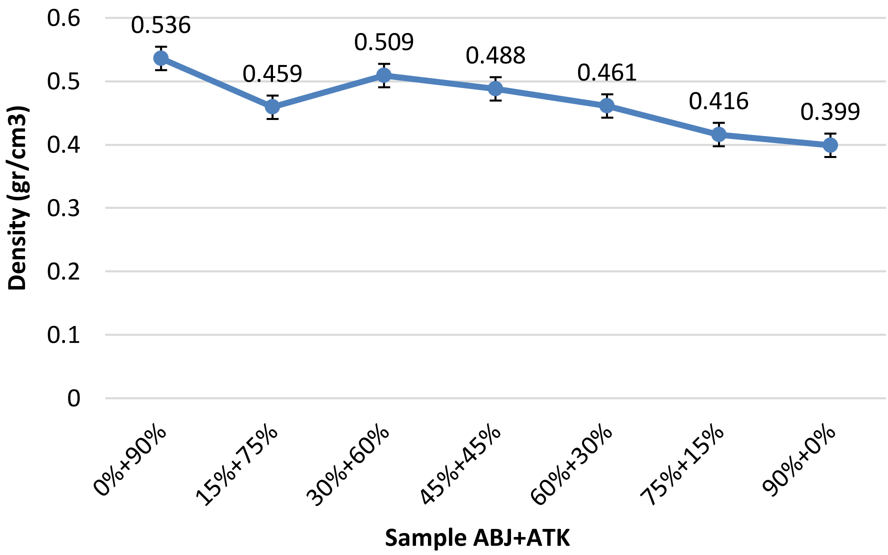

Figure 2. Graph of briquette density

The Table 1 and Figure 2 provided illustrate the density values of biobriquettes made from varying compositions of corncob charcoal (ABJ) and coconut shell charcoal (ATK), with a consistent 10% tapioca adhesive across all samples. The densities range from 0.399 g/cm³ to 0.536 g/cm³, with Sample A (0% ABJ + 90% ATK) demonstrating the highest density at 0.536 g/cm³, and Sample G (90% ABJ + 0% ATK) showing the lowest density at 0.399 g/cm³. The general trend indicates that as the proportion of ABJ increases and the ATK proportion decreases, the density tends to decline. This suggests that coconut shell charcoal (ATK) contributes more to the overall compactness and density of the briquettes compared to corncob charcoal (ABJ). Sample C (30% ABJ + 60% ATK) has a slightly higher density than samples with more balanced or higher ABJ content, reinforcing the idea that a higher percentage of ATK improves the density.

The graph further visualizes this trend, showing a peak at Sample C and a steady decline in density as the proportion of ABJ increases beyond 30%. This decrease in density with higher ABJ content may be attributed to the lighter, less compact nature of corncob charcoal compared to coconut shell charcoal, which has a denser structure. The results imply that briquettes with a higher percentage of ATK are more compact, which could positively influence their combustion properties, such as burn rate and energy efficiency. Therefore, the composition of coconut shell charcoal in the biobriquette mix plays a critical role in determining the overall density, which is an essential factor in the performance of the briquettes as a renewable energy source.

Moisture content analysis

Moisture content refers to the amount of water contained in the biobriquettes (Aljarwi et al., 2020). The moisture content significantly affects the quality of the briquettes. Higher moisture content in a biobriquette results in a lower calorific value and a longer ignition time. Conversely, the lower the moisture content in the biobriquette, the higher the calorific value, and the easier it is to ignite the briquette. This is because a portion of the heat generated is used to evaporate the water within the biobriquette (Jannah et al., 2022). The results of the moisture content analysis of the briquettes produced in this study can be seen in Table 2 and Figure 3.

Table 2. Results of briquette moisture content test

Sample	Composition of Base Materials with 10% Adhesive	Moisture Content (%)
A	0%ABJ + 90%ATK	6,385
B	15%ABJ+75%ATK	8,563
C	30%ABJ+60%ATK	6,657
D	45%ABJ+45%ATK	6,219
E	60%ABJ+30%ATK	5,074
F	75%ABJ+15%ATK	4,972
G	90%ABJ+0%ATK	4,152

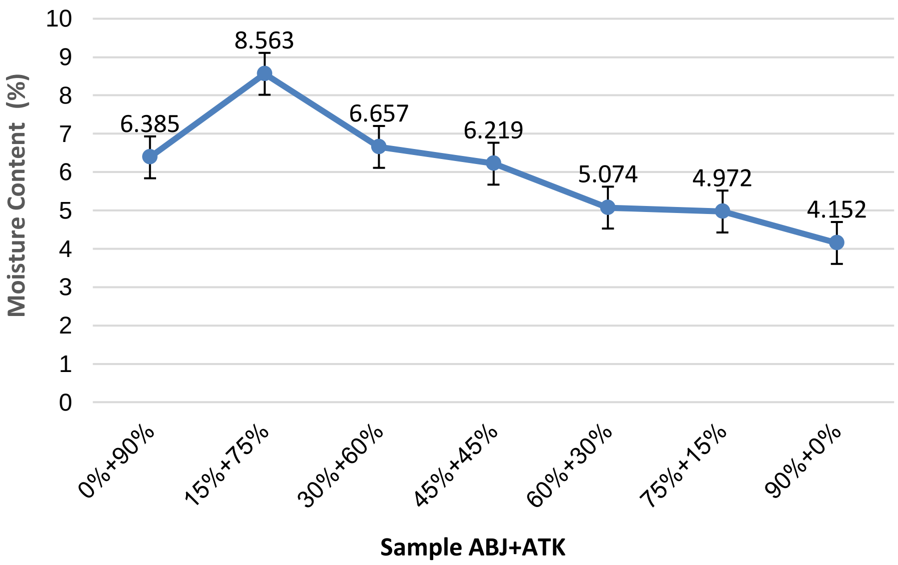

Figure 3. Moisture content graph of briquettes

Based on Table 2 and Figure 3, it can be observed that the percentage of materials used has a different impact on the moisture content of the biobriquettes. The moisture content of the biobriquettes ranges between 4% and 8%. The biobriquette with the lowest moisture content, at 4%, is the one using a composition of 90% ABJ (corncob charcoal) and 0% ATK (coconut shell charcoal). On the other hand, the highest moisture content, at 8%, is found in the biobriquette with a composition of 15% ABJ and 75% ATK. A moisture content of 4% is more stable and durable compared to 8%, as lower moisture content reduces the risk of mold formation and spoilage. Although the 8% moisture content is higher, it remains relatively low and is still within acceptable limits for good quality briquettes. This slightly higher moisture level may reduce the calorific value per gram of fuel, but it still falls within the acceptable range according to the SNI-01-6235-2000 standard, which stipulates that moisture content should not exceed 8%.

Research by Amin et al. (2017) showed that moisture content increases as the proportion of material or adhesive in the briquette increases. In this study, the moisture content is considered stable because, in addition to the influence of ABJ and ATK materials, the pressure applied during briquette production also plays a role. If the moisture content is unstable, it could be due to the materials used or the pressure applied. The data indicates that the higher the percentage of ABJ, the lower the moisture content, while the higher the percentage of ATK, the higher the resulting moisture content.

Ash Content Analysis

Table 3. Results of briquette ash content test

Sample	Composition of Base Materials with 10% Adhesive	Ash Content (%)
A	0%ABJ + 90%ATK	8,612
B	15%ABJ+75%ATK	9,589
C	30%ABJ+60%ATK	9,306
D	45%ABJ+45%ATK	10,128
E	60%ABJ+30%ATK	11,173
F	75%ABJ+15%ATK	11,455
G	90%ABJ+0%ATK	12,231

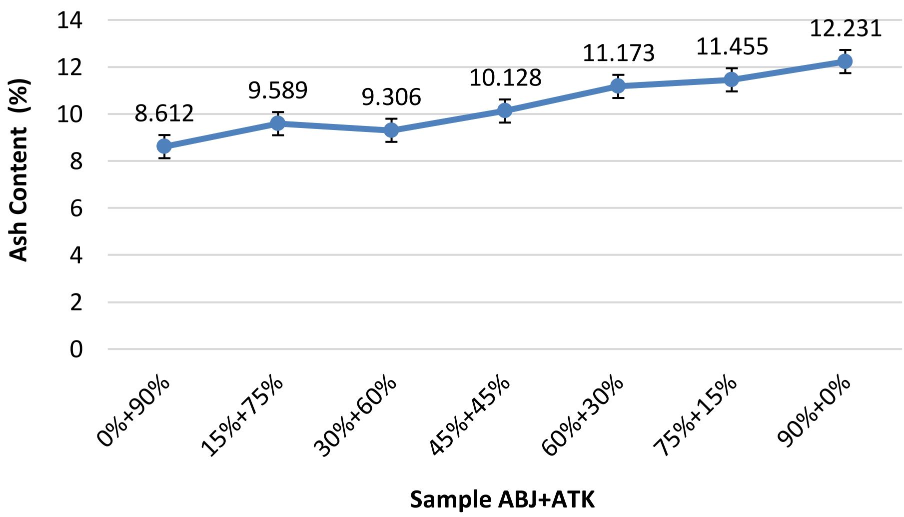

Figure 4. Ash content graph of briquettes

Based on Table 3 and Figure 4, it can be observed that the ash content of the briquettes made from a mixture of corncob charcoal (ABJ) and coconut shell charcoal (ATK) ranges between 8% and 12%. The lowest ash content is found in the sample with 0% ABJ + 90% ATK, which is 8.612%, while the highest ash content is in the sample with 90% ABJ + 0% ATK, reaching 12.231%. The more charcoal present in the briquette, the higher the ash content. An ash content of 8% is considered low, meaning that most of the material can burn completely. This results in high combustion efficiency, allowing more energy to be generated from each gram of briquette. On the other hand, an ash content of 12% is categorized as high, indicating that there is more non-combustible material in the briquette, which reduces combustion efficiency because part of the material does not burn. From this study, it is evident that the composition of the raw materials plays a crucial role in determining the ash content of the briquettes, although the results remain fairly consistent. When compared to the Indonesian National Standard (SNI 01-6253-2000) for charcoal briquettes, the maximum allowable ash content is 8%. This indicates that briquettes made with 90% coconut shell waste have good quality, particularly in terms of ash content, as they meet the established standard.

Calorific value

The calorific value of a fuel is the maximum amount of heat energy released by the fuel through complete combustion per unit mass or volume. After the briquettes are dried, the next step is to test their calorific value. The analysis of the calorific value of the briquettes produced in this study can be seen in Table 4 and Figure 5.

Table 4. Results of briquette calorific value test

Sample	Composition of Base Materials with 10% Adhesive	Calorific Value (calories)
A	0%ABJ + 90%ATK	10.640
B	15%ABJ+75%ATK	10.439
C	30%ABJ+60%ATK	10.841
D	45%ABJ+45%ATK	9.837
E	60%ABJ+30%ATK	8.030
F	75%ABJ+15%ATK	7.628
G	90%ABJ+0%ATK	6.424

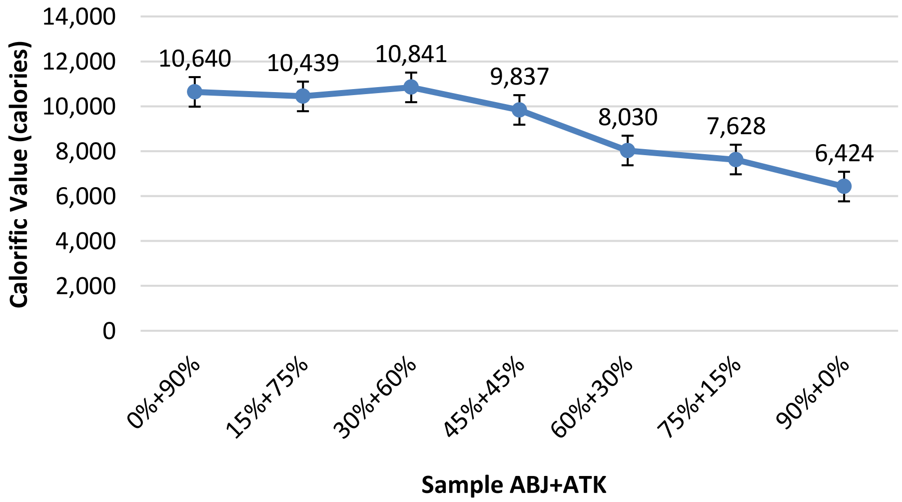

Figure 5. Graph of the calorific value of briquettes

From this study, the calorific value of the briquettes ranged between 6,424 calories and 10,640 calories. The analysis of the calorific value across different composition variations showed that a higher percentage of coconut shell charcoal (ATK) in the mixture resulted in an increased calorific value. The briquette with the lowest calorific value, 6,424 calories, was produced using 90% corncob charcoal (ABJ) and 0% coconut shell charcoal (ATK). In contrast, the briquette with the highest calorific value, 10,640 calories, was made with 30% ABJ and 60% ATK. The findings suggest that the calorific value is primarily influenced by the material used; the higher the ATK content, the greater the calorific value, although the values showed some instability. In comparison to Roni Setiawan's (2022) research, which indicated that calorific values remained stable depending on the adhesive used, this study used only one type of adhesive, making the ABJ and ATK content crucial in determining the calorific value.

High ABJ content produced lower calorific values, while high ATK content resulted in higher values. Therefore, when comparing briquettes made solely from coconut shell charcoal to those made from corncob charcoal, there is a significant difference in calorific value. Briquettes made entirely from ATK had a very high calorific value of 10,640 calories, while those made solely from ABJ saw a considerable drop to 6,424 calories. However, both values still meet the Indonesian National Standard (SNI), which requires a minimum of 5,000 calories per gram. When these two materials were mixed, the results varied: briquettes with a higher ATK content had a higher calorific value, while those with more ABJ had a lower calorific value, as shown in Table 4.4 and Figure 4.5. Therefore, briquettes made from a mix of coconut shell charcoal and corncob charcoal are suitable as biofuel. However, the best-performing briquette in terms of calorific value was Sample A, with 90% coconut shell charcoal.

Combustion rate

The combustion rate refers to the speed at which a briquette is consumed during burning. A higher combustion rate means the briquette burns faster. The speed and duration of combustion are influenced by the material structure and its density. This aligns with research by Iriany et al. (2016), which indicated that biobriquettes with higher density are more compact, resulting in longer burn times compared to those with lower density. The results of the combustion rate tests are shown in the Table 5 and Figure 6.

Table 5. Briquette Combustion Rate Test Results

Sample	Composition of Base Material 10% Adhesive	Combustion Rate (g/min)
A	0%ABJ + 90%ATK	0,464
B	15%ABJ+75%ATK	0,478
C	30%ABJ+60%ATK	0,620
D	45%ABJ+45%ATK	0,576
E	60%ABJ+30%ATK	0,660
F	75%ABJ+15%ATK	0,681
G	90%ABJ+0%ATK	0,770

Based on Table 5 and Figure 6, it can be observed that the composition of materials has a significant effect on the combustion rate of the briquettes produced. The combustion rate of the corncob charcoal (ABJ) and coconut shell charcoal (ATK) briquettes ranges from 0.464 g/min to 0.770 g/min. The briquette with the lowest combustion rate, 0.464 g/min, is composed of 0% ABJ and 90% ATK. On the other hand, the briquette with the highest combustion rate, 0.770 g/min, is made from 90% ABJ and 0% ATK.

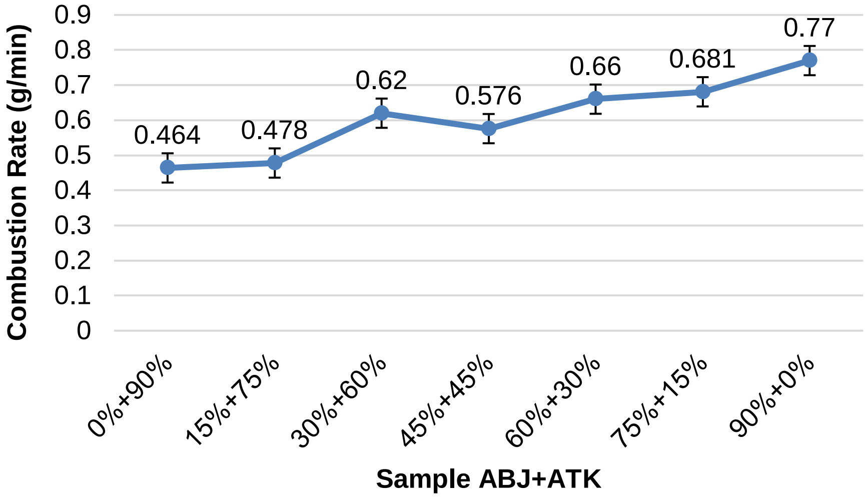

Figure 6. Graph of briquette combustion rate

The study reveals that the higher the ATK content and the lower the ABJ content, the slower the combustion rate. Conversely, a higher proportion of ABJ results in a faster combustion rate. The combustion rate is influenced by the adhesive and the raw material composition, with a trend showing that a higher proportion of corncob charcoal leads to a higher combustion rate. This is because briquettes with more coconut shell charcoal have a higher calorific value than those with more corncob charcoal. As the calorific value increases, the combustion rate improves, which aligns with the findings of Masthura (2019).

Analysis of the characteristics of corncob charcoal (ABJ) and coconut shell charcoal (ATK) briquettes

From the analysis, the characteristics of briquettes made from a mixture of coconut shell charcoal and corncob charcoal meet the required standards for moisture content (4.1526%-8.563%) and calorific value (6,424.32–10,841.04 calories). Both parameters meet the Indonesian National Standard (SNI) for briquette quality, which stipulates a maximum moisture content of ≤8% and a minimum calorific value of 5,000 cal/g. The ash content results were stable but not too high, with only one sample meeting the SNI ash content standard—0% ABJ and 90% ATK. As for density, the values tended to decrease. In comparison, the study by Jannah et al. (2022) found that density remained stable using durian skin as the base material and tapioca and rice flour as adhesives. The ash content remained stable in this study, with higher percentages of corncob charcoal resulting in higher ash content.

CONCLUSION

The results of this study indicate that the variation in base materials, specifically the proportions of coconut shell charcoal (ATK) and corncob charcoal (ABJ), significantly affects the characteristics of the produced biobriquettes. Briquettes with a higher percentage of ATK exhibited better overall quality in terms of calorific value and combustion efficiency. The highest calorific value of 10,640 calories was found in briquettes composed of 90% ATK, while briquettes with higher ABJ content showed lower calorific values, with the lowest being 6,424 calories for 90% ABJ. This highlights that coconut shell charcoal contributes more to the energy efficiency of the briquettes. Moreover, the study found that the ash content, although influenced by the composition, remained within acceptable ranges, and the briquettes met the Indonesian National Standard (SNI) in terms of moisture content and calorific value. Only one sample, 0% ABJ + 90% ATK, met the ash content requirement of SNI.

Additionally, the combustion rate analysis revealed that briquettes with higher ABJ content burned faster, with the fastest combustion rate being 0.770 g/min for 90% ABJ. In contrast, briquettes with higher ATK content had slower combustion rates, indicating longer burn durations, which is desirable for sustained heat production. Therefore, while both ATK and ABJ can be utilized in biobriquette production, coconut shell charcoal offers superior characteristics in terms of both calorific value and combustion stability. The optimal mix for high-performance briquettes was found to be 90% ATK and 10% adhesive, making it a promising alternative for biomass energy production.

RECOMMENDATION

Based on the findings of this study, it is recommended that future research explore the use of different adhesive types and concentrations to further enhance the quality of biobriquettes made from coconut shell charcoal and corncob charcoal. Additionally, optimizing the carbonization process, such as controlling temperature and duration, may yield more consistent results in terms of calorific value and combustion efficiency. Further studies could also investigate the long-term storage stability of these biobriquettes, particularly in varying environmental conditions. Implementing these improvements could make biobriquettes a more viable and efficient alternative to traditional fossil fuels for both industrial and household use.

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