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Effect of Compaction Pressure and Drying Duration on the Characteristics of Biochar Briquettes from Coconut Shell and Sugarcane Bagasse

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ABSTRACT

The combination of coconut shell and sugarcane bagasse in biochar briquettes is of significant interest due to the potential for enhancing the sustainability and energy efficiency of biomass-based fuels. This study explores the unique synergy between these two widely available agricultural residues, aiming to optimize their properties for higher-quality biochar briquettes. Understanding the impact of varying drying times and pressing pressures on the physicochemical characteristics of the briquettes is essential for improving their performance as an eco-friendly energy source. The moisture content ranged from 2.21% to 15.59%, with the lowest value meeting the Indonesian National Standard (SNI ≤ 5%). Ash content exceeded the SNI limit (≤ 8%) at 9.66% after 24 hours of drying at 50 kg/cm² pressure. Volatile matter varied between 12.03% and 15.00%, with the lowest value aligning with SNI standards (10–15%). Fixed carbon content reached a maximum of 72.73%, indicating optimal carbon retention. Calorific values ranged from 4552.67 to 5941.91 cal/g, falling short of the SNI minimum (6814.11 cal/g) due to the inclusion of low-energy bagasse. The shatter index peaked at 31.00% at the lowest pressure and shortest drying time, indicating poor mechanical durability. In conclusion, briquettes processed with at least 24 h drying and 100 kg/cm² pressure yielded the best performance, meeting multiple SNI quality criteria, especially for moisture, volatile matter, and fixed carbon.

1. INTRODUCTION

Biomass is a promising form of renewable energy with significant potential as an alternative to fossil fuels. One such form, biomass briquettes, is produced through the carbonization of organic waste rich in carbon content. Biomass waste, such as coconut shells and sugarcane bagasse, holds substantial potential as an alternative energy source, contributing to sustainable development. Through the briquetting process, waste that previously had no added value can be converted into useful renewable energy (Ramadhana *et al.,* 2025).

West Kalimantan, particularly Kubu Raya Regency, holds considerable potential in terms of coconut shell waste availability, with production reaching 36.72 thousand tons in 2022 (BPS, 2022). Meanwhile, sugarcane bagasse, a by-product of the sugar industry, is also available in limited quantities in regions such as Sambas Regency, though it has yet to be optimally utilized. Both types of waste have the potential to be processed into high-value charcoal briquettes, while simultaneously supporting agricultural waste reduction efforts.

Despite the abundant availability of coconut shells and bagasse, there is limited research on how the combination of pressing pressure and drying duration affects the properties of mixed charcoal briquettes. Briquettes can be produced from a single material or a mixture, and theoretically, the combination of coconut shells and sugarcane bagasse can produce briquettes with optimal combustion properties and calorific value. However, several technical challenges remain in the production process, such as the mechanical strength of briquettes, which is influenced by pressing pressure, as well as the moisture content determined by drying duration. Insufficient pressing pressure results in fragile briquettes, while excessive pressure produces overly dense briquettes that are difficult to ignite. On the other hand, improper drying times lead to high moisture content, which diminishes combustion efficiency.

This study aims to evaluate the physicochemical quality of briquettes made from a combination of coconut shells and sugarcane bagasse, investigating the effects of different pressing pressures and drying durations. Additionally, the study will compare the results with the relevant Indonesian National Standards (SNI). The findings of this research are expected to contribute significantly to the scientific body of knowledge and support the development of sustainable, applicable biomass-based alternative energy solutions, particularly in the West Kalimantan region.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in the production of briquettes consisted of coconut shells (Figure 1a, initial moisture content 40%-60%) obtained from coconut farmers in West Kalimantan. Sugarcane bagasse (Figure 1b) was sourced from sugarcane juice vendors in Pontianak, West Kalimantan, with an initial moisture content of 40%-50% before carbonization. Tapioca starch (used as a binder) was purchased from the Puring Siantan market at a concentration of 5%, and water was used as a diluent. The briquettes were produced using an Enerpac hydraulic press (Figure 1c) and a Cabinet Dryer Type CD5A.

2.2. Experimental Design

The experimental design used was a Randomized Split-Plot Design (RPT), where the main plot was allocated to the pressing pressure (Factor A), and the subplot was assigned to the drying duration (Factor B). Factor A (pressing pressure) included three levels: A_1 (50 kg/cm²), A_2 (100 kg/cm²), and A_3 (150 kg/cm²). Factor B (drying duration) consisted of three levels: B1 (12 h), B2 (24 h), and B3 (36 h). Each treatment combination was replicated twice within each block, resulting in a total of 18 experimental units. The Randomized Split-Plot Design was chosen due to its ability to handle treatments with both fixed and random factors, providing efficient control over variability within the experimental units. The drying process was carried out using a mechanical dryer at a temperature of [insert temperature here] to ensure consistent drying conditions. Observational data were analyzed using Analysis of Variance (ANOVA). If significant differences were observed among treatments, Duncan's Multiple Range Test (DMRT) at a 5% significance level was employed for further comparisons (Rahmawati & Erina, 2020).

2.2.1. Research Implementation

The experimental procedures followed sequential steps: preparation of raw materials, carbonization, preparation of binder solution, mixing, pressing, and drying.

2.2.2. Preparation of Raw Materials and Carbonization Process

For coconut shell charcoal production, dried shells were placed into a drum kiln and ignited from the bottom. Once combustion stabilized, the drum was tightly sealed, and airflow was controlled through the opening and closing of ventilation holes on the drum's sides. The thermal oxidation stage continued until the intensity of emitted smoke gradually decreased. The resulting charcoal was then ground and sieved using a 70-mesh screen.

Figure 1. (a) Sun-dry coconut shells, (b) Sun-dry sugarcane bagasse, (c) Briquette compaction process

The sugarcane bagasse was first sun-dried for one day to reduce its high moisture content, which ranged between 40% and 50%. After drying, the bagasse underwent carbonization in a drum kiln, followed by grinding and sieving through a 70-mesh screen. For the experimental procedure, charcoals of coconut shell and sugarcane bagasse were mixed at a 1:1 ratio. This ratio was chosen to balance the properties of both materials, ensuring optimal combustion and mechanical durability of the briquettes, as both materials contribute distinct characteristics to the final product.

2.2.3. Preparation of Binder Solution

A total of 200 g of tapioca starch was weighed and mixed with 1 liter of water for each treatment. The moisture content of the tapioca starch was 10%. The ratio of tapioca starch to water was 1:4. It is important to note that mixing tapioca starch with cold water may not immediately function as an effective binder; heating or further processing may be required to activate its binding properties. The mixture was heated on a stove with constant stirring until it formed a viscous adhesive solution (Deglas & Fransiska, 2020).

2.2.4. Carbonization Process

Coconut shells and sugarcane bagasse were first sun-dried to facilitate the combustion process. After drying, the materials were weighed and then carbonized using a sealed kiln drum to limit air flow. The carbonization process lasted for 15 h for coconut shells and 5 h for sugarcane bagasse, at temperatures ranging from 25% to 49°C during the daytime in Pontianak, West Kalimantan. This temperature range is critical as it influences the volatile matter and fixed carbon content in the resulting charcoal. After cooling, the produced charcoal was ground and sieved through a 70-mesh filter to obtain uniform particle sizes.

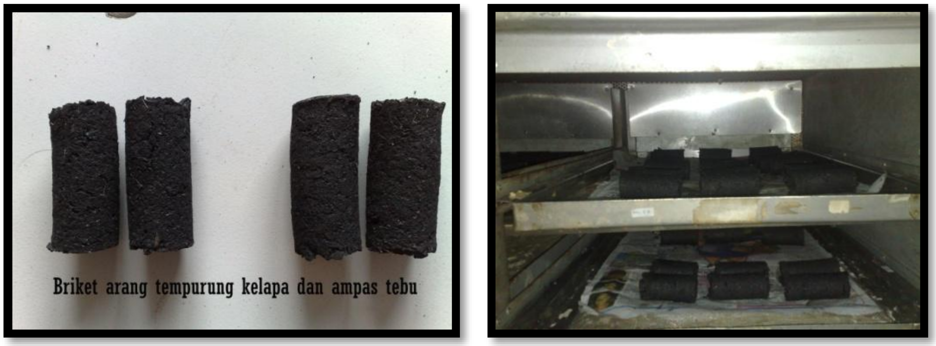

Figure 3. (a) Briquettes made of coconut shell and sugarcane bagasse, (b) Briquette drying

2.2.5. Briquette Production

Briquette production was carried out according to treatment, which involved variation in compaction pressures and a drying duration. Finely ground coconut shell and sugarcane bagasse charcoal were mixed in a 1:1 ratio, with 5% binder added. The mixture was homogenized and molded using a hydraulic press in wet condition, and then dried in a cabinet dryer at 80 °C (Figure 3). Other treatments were conducted according to their respective experimental combinations (Deglas & Fransiska, 2020).

2.2.6. Measurement Method

Moisture Content: Moisture content was determined using the thermogravimetric method based on the evaporation of water contained in the sample. Approximately 1–2 g of powdered or finely ground sample was weighed into a pre-weighed weighing bottle. The sample was then dried in an oven at a temperature of 100–105 °C for 3–5 hours. After drying, the sample was cooled in a desiccator and weighed. The moisture content was calculated on both a wet basis (wb) and a dry basis (db) using the following equation:

$$\text{Moisture content (wb)} = \frac{\text{Weight of evaporated water (g)}}{\text{Initial sample weight (g)}} \times 100\% \tag{1}$$

Ash Content: Ash content was determined using the thermogravimetric method by oxidizing all organic matter at high temperatures (750–950 °C). Approximately 2 g of briquette charcoal powder was weighed and placed into a pre-weighed porcelain crucible. The crucible containing the sample was then inserted into a muffle furnace at 525 °C for 4 hours. After ashing, the furnace temperature was gradually reduced to 100 °C, and the crucible was transferred to an oven maintained at 100 °C for 15 minutes. Prior to weighing, the crucible and ash were placed in a desiccator for 15 minutes to cool and equilibrate. The weighing process was repeated until a constant weight was obtained. The ash content on a dry basis (db) was calculated using the following equation:

$$\text{Ash content (db)} = \frac{Weight\ of\ ash\ (g)}{\text{Weight of Sample (g)}} \times 100\% \tag{2}$$

Volatile Matter Content: The volatile matter content was determined using the thermogravimetric method according to ASTM D1762-84 (2021). Approximately 2 g of powdered charcoal briquette sample was weighed into a porcelain crucible with a known weight. The sample was then placed in an oven at 100 °C for 3 h. After drying, the crucible was cooled in a desiccator for 15 min before weighing. Subsequently, the sample (W_i) was transferred to a muffle furnace and heated at 900 °C for 5 to 6 min. After combustion, the crucible was again cooled in a desiccator for 15 min and then weighed (W_f). The volatile matter content was calculated using the following equation:

$$\text{Volatile Matter Content (\%)} = \frac{W_i - W_f}{W_i} \text{ x } 100\% \tag{3}$$

Calorific Value: The calorific value of the briquette was determined using a bomb calorimeter and expressed in cal/g. The bomb calorimeter chamber was cleaned thoroughly. A fuel sample weighing 0.15 g was placed in a platinum crucible. The ignition wire was attached to the ignition terminals, and the bomb was tightly sealed. Oxygen was introduced into the bomb at a pressure of 30 bar. The bomb was placed inside the calorimeter vessel and properly closed. The cooling water stirrer was operated for 5 minutes, and the initial temperature was recorded. The sample was ignited and allowed to react for 5 minutes, after which the temperature increase was recorded. The calorific value was calculated using the following equation:

$$Calorific\ Value\ (HHV) = \frac{C}{Sample\ weight} \tag{4}$$

where HHV is higer heating value (cal/kg), *C* is net heat (cal) released from the sample (equal to heat absorbed by the calorimeter substracted by heat from ignition materials)

Fixed Carbon Content: Fixed carbon is the fraction of carbon (C) present in briquettes, excluding moisture, volatile matter, and ash. The fixed carbon content was calculated using the following equation:

$$\text{Fixed Carbon} = 100 - (M + V + A)\% \tag{5}$$

where M is moisture content (%), V is volatile matter content (%), and A is ash content (%)

3. RESULTS AND DISCUSSION

3.1. Moisture Content

Table 1 presents a summary of the ANOVA results, including the corresponding p-values, which show that the highest moisture content was observed in the treatment with a pressing pressure of 50 kg/cm² and a drying duration of 12 hours. The highest moisture content was observed in the treatment with a pressing pressure of 50 kg/cm² and a drying duration of 12 hours. This result can be attributed to the combination of the shortest drying time and the lowest pressing pressure compared to other treatments, which resulted in a higher retained moisture content. A shorter drying duration allows for less water evaporation from the briquette, while lower pressing pressure reduces the expulsion of water, thereby maintaining higher moisture levels. On the other hand, longer drying durations (24 and 36 hours) lead to very low moisture content, which might be considered ideal for certain applications. However, from a technical and practical standpoint, excessively low moisture levels could impact the hygroscopicity of the briquettes and their storage properties. Extremely low moisture content may cause the briquettes to become brittle, affecting their durability and handling. A balance should be maintained to ensure optimal moisture content that supports both the structural integrity of the briquettes and their ease of storage, with standard acceptable moisture content typically ranging between 8-12%.

Table 1. Average of experimental data moisture content (%)

Drying Time	**Compaction Pressure**			**Average**
	A_1 Pressure (50 kg/cm²)	**A_2 Pressure (100 kg/cm²)**	**A_3 Pressure (150 kg/cm²)**	
B_1 (12 hours)	15.59^{a}	8.36^{c}	11.41^{b}	11.79^{s}
B_2 (24 hours)	3.44^{d}	2.66^{e}	2.91^{de}	3.00^{t}
B_3 (36 hours)	2.75^{e}	2.21^{f}	2.75^{e}	2.57^{u}
Average	7.265^{p}	4.41^{q}	5.69^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

Findings reported by Setyono & Purnomo (2022) indicate that the moisture content of briquettes is significantly influenced by both pressing duration and drying time. The longer these processes are carried out, the more water is released. This occurs because, during pressing and drying, most of the water within the raw material is forced out of the briquette structure. Similarly, Syukri *et al.* (2024) confirmed that briquette moisture content is affected by pressing and drying duration, with prolonged drying resulting in greater moisture loss.

The minimum pressure of 100 kg/cm² is typically used to ensure optimal compaction of the briquettes, enhancing their density and mechanical strength. However, as shown in Table 1, a pressure of 50 kg/cm² also results in a moisture content of less than 5%, indicating that lower pressures can still produce briquettes with acceptable moisture levels. This finding suggests that the pressure used in briquette production may not need to be as high as 100 kg/cm² to achieve the desired moisture content. Further comparison with literature on the moisture characteristics of coconut shell and bagasse briquettes is needed to better understand the optimal pressure and moisture content for these materials. An increase in moisture content in briquettes can reduce their durability and mechanical strength, as well as cause surface cracking when the moisture level is too high (Abdel Aal *et al.,* 2023).

3.2. Ash Content

Table 2 presents a summary of the ANOVA results, including the corresponding p-values, which show that the highest ash content was obtained in charcoal briquettes subjected to a pressure of 50 kg/cm² with a drying duration of 24 hours, reaching 9.66%. This occurred because the applied pressure was relatively low, resulting in a more porous structure (less compact) that allowed greater mineral deposition, thereby increasing the ash content. In the briquetting process, compaction pressure plays a crucial role in determining briquette quality, influencing parameters such as moisture content, ash content, density, and calorific characteristics Muazu & Stegemann (2020). Compared with the Indonesian National Standard (SNI), this briquette already meets the requirement for ash content. According to SNI, the maximum allowable ash content for charcoal briquettes is 8%. Amrullah *et al.* (2020) reported that ash content decreased at a compaction pressure of 2000 psi compared to 1500 psi, which was attributed to the higher density of briquettes that led to reduced ash levels.

The ash content in briquettes is the inorganic residue remaining after the combustion or oxidation of raw materials, influenced by several key factors. One of the most determining factors is the ash content of the raw materials. Research by Sitogasa *et al.* (2022) on biomass briquettes made from durian waste and sawdust indicates that the ash content is affected by the type of raw material used in the briquette production. Raw materials with higher mineral content, such as sawdust or other types of biomass, tend to result in higher ash content after the carbonization process. The use of binders in briquette production also contributes to the increase in ash content. Binders that contain inorganic materials, while serving to bind raw material particles, can add to the amount of ash formed in the briquettes. The amount and type of binder used in briquette production can affect the ash content of the resulting briquettes. Higher binder concentrations may lead to increased ash content, as certain binder components contribute inorganic residues that remain after combustion, thereby increasing the amount of ash produced (Napitupulu *et al.,* 2025). The compaction process also affects the ash content, where increasing briquette density, caused by higher compaction pressure and longer drying duration, can reduce pore space within the briquette, thereby decreasing ash formation. Although increasing briquette density can help reduce ash content, factors such as the ash content of raw materials and the contribution of binders remain crucial elements to consider in the briquette production process.

Table 2. Average of experimental data ash content (%)

Drying Time	**Compaction Pressure**			**Average**
	A_1 Pressure (50 kg/cm²)	**A_2 Pressure (100 kg/cm²)**	**A_3 Pressure (150 kg/cm²)**	
B_1 (12 hours)	5.02^{h}	7.51^{c}	7.76^{b}	6.76^{s}
B_2 (24 hours)	9.66^{a}	5.15^{g}	8.95^{a}	7.92^{t}
B_3 (36 hours)	6.55^{f}	6.65^{e}	7.03^{d}	6.74^{u}
Average	7.08^{p}	6.44^{q}	7.91^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

3.3. Volatile Matter

Table 3 presents a summary of the ANOVA results, including the corresponding p-values, where the lowest volatile matter content of 12.03% was obtained in charcoal briquettes produced under a compaction pressure of 100 kg/cm² with a drying time of 36 hours. This result is attributed to the extended drying duration, which allows more volatile compounds to evaporate. Pressure also influences the release of volatile matter; as the compaction pressure increases, the briquette structure becomes denser and more compact, leading to reduced pore size, which restricts the escape of volatile compounds from the material. Research by Biantoro & Widayat (2021) indicates that compaction pressure affects the physical characteristics of briquettes, including volatile matter, density, and combustion properties. As pressure increases, the briquette structure becomes more compact, affecting parameters such as volatile matter. Drying time and conditions also influence the volatile content: a longer drying time and appropriate drying conditions can facilitate the evaporation of more volatile compounds before final compaction (Fadhian *et al.,* 2025).

The research findings further indicate that treatments with 12- and 24-hour drying times at pressures of 50–150 kg/cm² produced volatile matter contents exceeding the SNI reference limit of 10–15%. However, when the drying time was extended to 36 hours, the volatile matter content across all pressure variations complied with the established standard. According to SNI, the volatile matter content of briquettes should fall within the range of 10–15%.

Table 3. Average of experimental data value of volatile matter content (%)

Drying Time	**Compaction Pressure**			**Average**
	A_1 Pressure (50 kg/cm²)	**A_2 Pressure (100 kg/cm²)**	**A_3 Pressure (150 kg/cm²)**	
B_1 (12 hours)	21.14^{b}	21.81^{a}	21.42^{ab}	21.45^{s}
B_2 (24 hours)	18.67^{d}	19.44^{c}	21.00^{b}	19.70^{t}
B_3 (36 hours)	13.06^{f}	12.03^{g}	14.33^{c}	13.14^{u}
Average	17.62^{p}	17.76^{q}	18.91^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

3.4. Fixed Carbon Content

Table 4 presents a summary of the ANOVA results, including the corresponding p-values, showing that the lowest fixed carbon content was 66.16% at a compaction pressure of 150 kg/cm² with a drying duration of 12 hours, while the highest fixed carbon content was 72.73% at a compaction pressure of 100 kg/cm² with a drying duration of 24 hours. These findings indicate that drying time has a significant effect on fixed carbon content. Volatile matter, and moisture content, which in turn increases fixed carbon levels. Compaction pressure during the pressing process also plays a crucial role in determining the fixed carbon content of charcoal briquettes. Higher pressure results in denser briquette structures, thereby increasing bulk density. This higher density condition is directly correlated with higher fixed carbon content. In addition, variations in fixed carbon levels are influenced by the bulk density characteristics of the raw material used and the extent to which the carbonization process proceeds optimally. According to Rindayatno & Lewar (2017), fixed carbon is affected by raw material density, carbonization stages, and volatile compound content. Higher raw material density produces greater fixed carbon formation, whereas a reduction in volatile matter enhances the development of fixed carbon.

Table 4. Average of experimental data value of bound carbon content (%)

Drying Time	Compaction Pressure			Average
	A_1 Pressure (50 kg/cm^2)	**A_2 Pressure (100 kg/cm^2)**	**A_3 Pressure (150 kg/cm^2)**	
B_1 (12 hours)	66.31^{de}	71.93^{a}	66.16^{e}	68.14^{s}
B_2 (24 hours)	68.21^{c}	72.73^{a}	67.10^{d}	69.36^{t}
B_3 (36 hours)	69.54^{b}	69.36^{b}	68.80^{bc}	69.23^{u}
Average	68.02^{p}	71.34^{q}	67.35^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

Fixed carbon content and volatile matter contribute directly to the calorific capacity of charcoal briquettes, with fixed carbon serving as the primary energy source released during combustion. Fixed carbon reacts with oxygen (O_2) to produce heat. The fixed carbon content of the briquettes obtained in this study falls within the Indonesian National Standard (SNI) requirements, as the standard specifies a fixed carbon range of 60–80%.

3.5. Calorific Value

Table 5 presents a summary of the ANOVA results, including the corresponding p-values, showing that the lowest calorific value was obtained at a treatment of 50 kg/cm^2 compaction pressure with a drying time of 12 hours, yielding 4552.677 cal/g. This indicates that drying duration and pressure significantly influence the calorific value. Briquettes subjected to 50 kg/cm^2 pressure with 12 hours of drying retained a higher moisture content, which consequently reduced their calorific value. The elevated moisture content in the charcoal briquettes implies a reduction in the amount of heat energy produced, as a substantial portion of the energy is consumed for water evaporation. The density of the briquettes plays a crucial role in determining the calorific quality; higher briquette density results in greater calorific value. According to Aljarwi *et al.* (2020), increasing compaction pressure enhances briquette density and decreases moisture content, thereby accelerating heat transfer.

Table 5. Average of experimental data calorific value (%)

Drying Time	Compaction Pressure			Average
	A_1 (Pressure 50 kg/cm^2)	**A_2 (Pressure 100 kg/cm^2)**	**A_3 (Pressure 150 kg/cm^2)**	
B_1 (12 hours)	4552.67^{f}	5591.88^{d}	5426.11^{e}	5190.22^{s}
B_2 (24 hours)	5795.47^{ab}	5602.78^{d}	5941.91^{a}	5780.05^{t}
B_3 (36 hours)	5671.78^{d}	5685.47^{c}	5788.37^{b}	5715.21^{u}
Average	5339.97^{p}	5626.69^{q}	5718.80^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

High moisture content in briquettes results in a significant amount of heat energy being consumed for moisture evaporation during combustion, which consequently decreases the effective heating value and combustion efficiency (Mibulo *et al.,* 2023). In contrast, lower moisture content enhances the calorific value, promotes easier ignition, and improves the combustion performance of the briquettes Rusman *et al.* (2023) reported that during the compaction process, part of the moisture and binder content is expelled from the briquettes. The reduction of water and binder components decreases both moisture and ash derived from the binder, thereby increasing calorific value. Furthermore, the activation process in briquettes produces a more open pore configuration, which facilitates moisture reduction and decreases volatile matter. This phenomenon occurs because the thermal energy within the briquettes is initially absorbed for water evaporation before it can be optimally utilized as a combustion heat source. Each 1% increase in moisture content may result in a heat energy loss of approximately 9.6 kcal/kg. When compared with the Indonesian National Standard (SNI), the calorific value obtained in this study has not yet met the required standard. This is attributable to the use of an equal mixture of bagasse and coconut shell, in which bagasse possesses a lower calorific value than coconut shell. The SNI standard for charcoal briquette calorific value is 6814.11 cal/g.

Based on the comparison of five studies presented in Table 6, it is evident that the properties of biomass briquettes are strongly influenced by the type of raw material and its composition, particularly when comparing sugarcane bagasse and coconut shell. The ash content reported across the studies ranges from 3.21% to 8.52%. The lowest ash

Table 6. Characteristic of charcoal briquettes produced in this study compared to those reported in literatures

Study/Parameter	**Ash Content (%)**	**Volatile Matter (%)**	**Fixed Carbon (%)**	**Calorific Value (cal/g)**
This current work	5.15	21.81	72.73	5795
Sugarcane Bagasse and Coconut Shell Charcoal Briquette (Mustain *et al.,* 2021)	3.21	14.87	78.45	6.980
Briquettes made from rice husk and coconut shell (Qistina *et al.,* 2016)	8.52	16.34	70.26	5.210
Coconut shell briquettes (Barus *et al.,* 2024)	4.10	13.92	79.18	7.120
Coconut shell - sugarcane bagasse (Deglas & Fransiska, 2020)	6.89	10.54	73.40	5.687

content was reported by Qistina *et al.* (2016) at 3.21%, while the highest ash content was observed in briquettes produced solely from sugarcane bagasse. The relatively low ash content of coconut shell briquettes indicates a lower concentration of inorganic mineral constituents compared to sugarcane bagasse, resulting in reduced combustion residues and improved suitability for fuel applications.

The volatile matter content among the five studies exhibits considerable variation, ranging from 10.54% to 21.81%. Lower volatile matter values, such as those reported by Deglas & Fransiska (2020), suggest a more effective carbonization process, in which a substantial portion of volatile compounds has been decomposed. In contrast, higher volatile matter contents indicate the presence of residual volatile compounds that may facilitate easier ignition but can also lead to increased smoke generation during combustion.

Fixed carbon content demonstrates a strong positive correlation with calorific value. The highest fixed carbon contents were reported by Barus *et al.* (2024) and Mustain *et al.* (2021), at 79.18% and 78.45%, respectively. These elevated values indicate that briquettes derived from coconut shell or mixtures with a higher proportion of coconut shell possess a greater concentration of carbonaceous material, which contributes to higher heat release and longer combustion duration.

The calorific values obtained from the five studies fall within the range of 5,210–7,120 cal/g. The highest calorific value was reported by Barus *et al.* (2024), while the lowest value was associated with briquettes made from sugarcane bagasse. Variations in calorific value are primarily governed by ash content, volatile matter, and fixed carbon, where higher fixed carbon and lower ash content result in enhanced energy output. These findings further confirm the superior potential of coconut shell as a primary raw material for biomass briquette production.

Overall, the comparative analysis of the five studies indicates that coconut shell–based briquettes or coconut shell–bagasse blends with a higher proportion of coconut shell exhibit superior fuel characteristics compared to briquettes produced solely from sugarcane bagasse. Through appropriate optimization of raw material composition and carbonization conditions, biomass wastes such as sugarcane bagasse and coconut shell demonstrate significant potential as sustainable and environmentally friendly alternative energy sources.

3.6. Shatter Index (%)

Table 7 presents a summary of the ANOVA results, including the corresponding *p*-values, showing that the highest shatter index of charcoal briquettes was observed in the treatment with a compaction pressure of 50 kg/cm² and a drying duration of 12 hours, reaching 31.00%. This occurred because the drying time was the shortest and the applied pressure was the lowest compared to other treatments, causing the briquettes to easily break when dropped from a height of 1.8 m. Pressure significantly affects the durability or compactness of briquettes; the higher the pressure, the stronger and more compact the briquettes become. Drying duration also influences the impact resistance of charcoal briquettes. Longer drying results in stronger briquettes, while shorter drying leaves the briquettes moist, thereby reducing their strength due to decreased compactness, making them more prone to breaking when dropped from height of 1.8 m. According to Suryaningsih & Azka (2020), the strength of briquettes increases with higher compaction loads, as briquettes with greater loading capacity can withstand higher mechanical forces. This is attributed to the higher density of briquettes formed under higher pressure, which strengthens inter-particle bonding.

Table 7. Average of experimental data on Shatter Index (%)

Drying Time	**Compaction Pressure**			**Average**
	A_1 (Pressure 50 kg/cm²)	**A_2 (Pressure 100 kg/cm²)**	**A_3 (Pressure 150 kg/cm²)**	
B_1 (12 hours)	31.00^{a}	11.84^{b}	6.46^{c}	16.43^{s}
B_2 (24 hours)	12.60^{b}	2.49^{e}	0.72^{f}	5.27^{t}
B_3 (36 hours)	3.80^{d}	0.90^{f}	0.68^{f}	1.79^{u}
Average	15.80^{p}	5.08^{q}	2.62^{r}	

Note: Numbers followed by the same letter are not significantly different at the 5% level according to DMRT.

The density of briquettes is closely related to the shatter index, which measures the briquettes' resistance to impact or pressure. As the density of the briquettes increases, their structure becomes more compact, making them stronger and more resistant to damage or breakage when dropped. In contrast, briquettes with lower density are more fragile and prone to breaking upon impact, thereby increasing the shatter index. Increasing the density of the briquettes through higher compaction pressure can reduce the shatter index, improving the briquettes' durability and impact resistance. Density is a key parameter that influences the physical resistance of briquettes to impact (shatter) due to the compact structure formed during the pressing process (Oriabure *et al.,* 2017).

Similarly, Setiowati & Tirono (2014) reported that the mechanical strength of a product is influenced by several factors, including the type of raw material, particle size, particle density, binder type, compaction pressure, and overall product density. The denser the product, the greater its mechanical strength. Compaction pressure during molding plays a crucial role in determining briquette density. Higher pressure causes the constituent particles to compress more tightly, closing inter-particle voids, and thus increasing density while reducing porosity (Pambudi *et al.,* 2018). Furthermore, density is closely related to the moisture content of biochar briquettes. Increased structural compactness leads to a significant reduction in the amount of water retained within the briquette (Hafiza *et al.,* 2024).

4. CONCLUSIONS

Based on the results of this study, several parameters of the charcoal briquettes meet the standards set by the Indonesian National Standard (SNI), while others do not comply with the criteria. The ash content in the tested briquettes exceeded the allowable limit of 8% set by SNI, with the highest ash content observed in briquettes subjected to a compaction pressure of 50 kg/cm² and a drying duration of 24 hours. However, the fixed carbon content of the briquettes met the standard range of 60-80%. The volatile matter content in some treatments also exceeded the SNI limit of 10-15%, but when the drying time was extended to 36 hours, the volatile matter content across all pressures met the established standard.

Several limitations in this study include the limited number of replications, which affects the generalization of the results, and the uncontrolled carbonization temperature, which may influence the final quality of the charcoal briquettes. The impact of a more controlled carbonization temperature in future studies could provide more consistent and accurate results. Future research should focus on the material ratio to determine the optimal proportion between materials coconut shell and bagasse, as well as optimizing the use of binders, which can affect the physical properties of the briquettes such as mechanical strength and ash content. Better control of the carbonization temperature could also enhance the quality of the briquettes and ensure that the production results meet the standards set by SNI.

AUTHOR CONTRIBUTION STATEMENT

Author	**C**	**M**	**So**	**Va**	**Fo**	**I**	**R**	**D**	**O**	**E**	**Vi**	**Su**	**P**	**Fu**
WD	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Fra		✓		✓		✓	✓	✓		✓				
MKE		✓	✓	✓		✓	✓	✓		✓	✓			

C: Conceptualization
M: Methodology
So: Software
Va: Validation
Fo: Formal Analysis
I: Investigation
D: Data Curation
R: Resources
O: Writing - Original Draft
E: Writing - Review & Editing
Vi: Visualization
Su: Supervision
Fu: Funding Acquisition
P: Project Administration

REFERENCES

Abdel Aal, A.M.K., Ibrahim, O.H.M., Al-Farga, A., & El Saeidy, E.A. (2023). Impact of biomass moisture content on the physical properties of briquettes produced from recycled *Ficus nitida* pruning residuals. *Sustainability*, ***15***(15), 11762. https://doi.org/10.3390/su151511762

Aljarwi, M.A., Pangga, D., & Ahzan, S. (2020). Uji laju pembakaran dan nilai kalor briket wafer sekam padi dengan variasi tekanan. *ORBITA: Jurnal Kajian, Inovasi dan Aplikasi Pendidikan Fisika*, ***6***(2), 200–206. https://doi.org/10.31764/orbita.v6i2.26455

Amrullah, A., Syarief, A., & Saifudin, M. (2020). Combustion behavior of fuel briquettes made from ulin wood and gelam wood residues. *International Journal of Engineering, Transactions B: Applications*, ***33***(11), 2365–2371. https://doi.org/10.5829/ije.2020.33.11b.27

ASTM International. (2021). *ASTM D1762-84(2021): Standard Test Method for Chemical Analysis of Wood Charcoal*. West Conshohocken, PA: ASTM International. https://doi.org/10.1520/D1762-84R21

BPS (Badan Pusat Statistik). (2022). *Produksi perkebunan menurut kabupaten/kota dan jenis tanaman di Provinsi Kalimantan Barat (ribu ton), 2022*. BPS Provinsi Kalimantan Barat. Accessed on June 07, 2026. https://kalbar.bps.go.id/id/statistics-table/3/ZWxKek1URkRaV0kwYlM5T2NHcHRNVkZXTkVkaGR6MDkjMw==/produksi-perkebunan-menurut-kabupaten-kota-dan-jenis-tanaman-di-provinsi-kalimantan-barat--2017.html?year=2022

Barus, I.Y., Masrullita, M., Nasrul, Z.A., Sulhatun, S., Sylvia, N., & Hasfita, F. (2024). Pemanfaatan ampas tebu (*Saccharum officinarum* L.) dan tempurung kelapa sebagai bahan baku pembuatan briket. *Chemical Engineering Journal Storage*, ***4***(4), 522–531. https://doi.org/10.29103/cejs.v4i4.16699

Biantoro, A.B., & Widayat, W. (2021). Pengaruh tekanan kompaksi dan perekat terhadap karakteristik briket limbah daun cengkeh. *Jurnal Inovasi Mesin*, ***3***(2), 18-28. https://doi.org/10.15294/jim.v3i2.52796

Deglas, W., & Fransiska, F. (2020). Analisis perbandingan bahan dan jumlah perekat terhadap briket tempurung kelapa dan ampas tebu. *Teknologi Pangan: Media Informasi dan Komunikasi Ilmiah Teknologi Pertanian*, ***11***(1), 72–78. https://doi.org/10.35891/tp.v11i1.1899

Fadhian, M. F., Wahyudie, I. A., & Yuliyanto, Y. (2025). Pengaruh proses dan variasi fraksi perekat briket antrasit terhadap nilai kuat tekan. *Jurnal Inovasi Teknologi Terapan*, ***3***(2), 411–417. https://doi.org/10.33504/jitt.v3i2.272

Hafiza, H.N., Masthura, M., & Jumiati, E. (2024). Pengaruh densitas terhadap kadar air pembuatan briket bioarang kulit dan tongkol jagung. *Buletin Fisika*, ***25***(1), 130–134. https://doi.org/10.24843/bf.2024.v25.i01.p17

Mibulo, T., Nsubuga, D., Kabenge, I., & Wydra, K. D. (2023). Characterization of briquettes developed from banana peels, pineapple peels and water hyacinth. *Energy, Sustainability and Society*, ***13***(36), 1–14. https://doi.org/10.1186/s13705-023-00414-3

Muazu, R.I., & Stegemann, J.A. (2020). A review of technical and economic aspects of biomass briquetting. *Sustainability,* ***12***(11), 4609. https://doi.org/10.3390/su12114609

Mustain, A., Sindhuwati, C., Wibowo, A.A., Estelita, A.S., & Rohmah, N.L. (2021). Pembuatan briket campuran arang ampas tebu dan tempurung kelapa sebagai bahan bakar alternatif. *Jurnal Teknik Kimia dan Lingkungan*, ***5***(2), 100–106. https://doi.org/10.33795/jtkl.v5i2.183

Napitupulu, R., Pratama, R.J., & Dharta, Y. (2025). Analisis pengaruh konsentrasi perekat tepung tapioka terhadap pengurangan kadar abu pada briket tempurung kelapa. *Jurnal Teknologi*, ***25***(1), 20-24. http://dx.doi.org/10.30811/teknologi.v25i1.6258

Oriabure, E.D., Terzungwue, T.E., & Emoh, O.F. (2017). Density, shatter index and heating value of briquettes produced from the leaves of *Terminalia mentalis* and sawdust of *Daniela oliveri*. *International Journal of Pure Agricultural Advances*, ***1***(1), 38–44. https://doi.org/10.20448/813.11.38.44

Pambudi, F.K., Nuriana, W., & Hantarum, H. (2018). Pengaruh tekanan terhadap kerapatan, kadar air dan laju pembakaran pada biobriket limbah kayu sengon. *Prosiding Seminar Nasional Sains dan Teknologi Terapan VI*, 547–553.

Qistina, I., Sukandar, D., & Trilaksono, T. (2016). Kajian kualitas briket biomassa dari sekam padi dan tempurung kelapa. *Jurnal Kimia VALENSI*, ***2***(2), 136–142. https://doi.org/10.15408/jkv.v2i2.4054

Rahmawati, A.S., & Erina, R. (2020). Rancangan acak lengkap (RAL) dengan uji ANOVA dua jalur. *OPTIKA: Jurnal Pendidikan Fisika*, ***4***(1), 54–62. https://doi.org/10.37478/optika.v4i1.333

Ramadhana, A.K., Hidayat, M.F., Muhaji, M., & Abdullah, M.Y. (2025). Production and characteristics test of bio-char briquettes from coconut shells and corncobs to optimize agricultural waste in Indonesia. *Journal of Mechanical Engineering, Science, and Innovation*, ***5***(1), 64–76. https://doi.org/10.31284/j.jmesi.2025.v5i1.7613

Rindayatno, R., & Lewar, D.O. (2017). Kualitas briket arang berdasarkan komposisi campuran arang kayu ulin (*Eusideroxylon zwageri* Teijsm & Binn) dan kayu sengon (*Paraserianthes falcataria*). *ULIN: Jurnal Hutan Tropis*, ***1***(1), 39–48. https://doi.org/10.32522/ujht.v1i1.792

Rusman, L.O., Lestari, L., Raharjo, S., Usman, I., & Chrismiwahdani, D. (2023). Pengaruh temperatur aktivasi terhadap kualitas briket arang aktif sekam padi. *Journal Online of Physics*, ***8***(3), 39–46. https://doi.org/10.22437/jop.v8i3.23846

Setiowati, R., & Tirono, M. (2014). Pengaruh variasi tekanan pengepresan dan komposisi bahan terhadap sifat fisis briket arang. *Jurnal Neutrino: Jurnal Fisika dan Aplikasinya*, ***7***(1), 23–31. https://doi.org/10.18860/neu.v7i1.2636

Setyono, M.Y.P., & Purnomo, Y.S. (2022). Analisis kadar air dan kadar abu briket lumpur IPAL dan fly ash dengan penambahan serbuk gergaji kayu. *INSOLOGI: Jurnal Sains dan Teknologi*, ***1***(6), 696–703. https://doi.org/10.55123/insologi.v1i6.1047

Sitogasa, P.S.A., Mirwan, M., Rosariawari, F., & Rizki, A.M. (2022). Analysis of water and ash content in biomass briquettes from durian fruit peel waste and sawdust. *Journal of Research and Technology*, ***8***(2), 279–288.

Suryaningsih, S., & Nurusysyifa, A.A. (2020). Pengaruh tekanan pembriketan terhadap karakteristik mekanik dan karakteristik pembakaran pada briket campuran sekam padi dan bonggol jagung. *JIIF* (*Jurnal Ilmu dan Inovasi Fisika*), ***4***(1), 23–28. https://doi.org/10.24198/jiif.v4i1.26140

Syukri, M., Maisarah, M., Rangkuti, U.I.P., Rahimah, R., Harahap, K.A.T., & Nurhidayat, T. (2024). Pengaruh variasi ukuran partikel pada pembuatan bio-briket dari pelepah dan tandan buah kosong kelapa sawit. *Jurnal Teknik Kimia USU*, ***13***(2), 146–153. https://doi.org/10.32734/jtk.v13i2.17081

Yang, H., Huang, L., Liu, S., Sun, K., & Sun, Y. (2016). Pyrolysis process and characteristics of products from sawdust briquettes. *BioResources*, ***11***(1), 2438–2456. https://doi.org/10.15376/biores.11.1.2438-2456