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Study on the Variation of Candlenut Shells, Corn Cobs, and Rice Straw as Alternative Materials for Briquette Production

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The increasing demand for alternative energy sources is driven by the declining availability of fossil fuels and growing awareness of environmental impacts. Agricultural wastes such as candlenut shells, corn cobs, and rice straw are abundant biomass resources with considerable potential for use as raw materials in briquette production. This study aims to analyze the physical properties of briquettes produced from variations in the composition of these three types of agricultural waste. The evaluated parameters include moisture content, ash content, calorific value, and density. The briquettes were produced through carbonization, sieving to a particle size of 50 mesh, mixing with tapioca starch as a binder, manual molding using a cylindrical mold with a diameter of 5 cm and a height of 6 cm, and oven drying. The results indicate that variations in raw material composition significantly affect briquette quality. The optimal composition was obtained for sample S4, consisting of 25 g candlenut shells, 20 g corn cobs, and 5 g rice straw, yielding a moisture content of 5.1%, ash content of 7.4%, a calorific value of 5941 cal/g, and a density of 0.88 g/cm³. A higher proportion of candlenut shells contributed to an increase in the calorific value of the briquettes. These findings demonstrate that appropriate selection of raw material composition plays a crucial role in determining the quality and performance of biomass briquettes, indicating their potential development as an environmentally friendly alternative energy source derived from agricultural waste.

Keywords: Biomass briquette, candlenut shell, corncob, rice straw, physical properties.

INTRODUCTION

Fossil energy sources such as coal and petroleum remain among the most important energy resources worldwide, including in Indonesia, which is still highly dependent on fossil fuels. Consequently, fossil fuel reserves are gradually depleting, making the transition to renewable energy sources as alternatives increasingly necessary (Toruan et.al., 2024). The use of fossil-based energy has caused numerous environmental problems, including air pollution and global warming. To mitigate these impacts, a transition to renewable energy sources is required, one of which is biomass energy that can be converted into briquettes (Fitriana & Febrina, 2021).

Biomass briquettes are an alternative energy source that can be produced and developed; they are not only environmentally friendly but also help reduce dependence on fossil fuels. (Rifdah et.al., 2018). Candlenut shells are an abundant waste product from the candlenut processing industry. This waste is often discarded without further treatment, even though its high carbon content makes it a potential raw material for briquette production (Botahala et.al., 2021). Candlenut shells are an abundant waste product from the candlenut processing industry. This waste is often discarded without further treatment, even though its high carbon content makes it a potential raw material for briquette production (Rahmawati & Setiawan, 2021).

Rice straw, a by-product of rice harvesting, is a biomass feedstock that is often underutilized. Due to its high cellulose content, rice straw can be used as a raw material for briquette production. It can be processed into briquettes with physical and thermal characteristics that meet international standards. Converting rice straw into briquettes not only increases its economic value but also mitigates the environmental issues associated with open-field burning, which is common in rural areas (Firmansyah et.al., 2022). Corn cobs, an abundant agricultural residue, have significant potential as raw material for briquette production due to their high density and primary constituents—cellulose, hemicellulose, and lignin—making them a valuable biomass source (Arellano et.al., 2015). The quality of briquettes can be influenced by the type of binder used, one of which is tapioca starch. Tapioca starch is an ideal choice due to its natural properties, environmental friendliness, and wide availability. Its use as a binder can enhance the compressive strength and durability of briquettes, making them more efficient for daily use (Nuwa & Prihanika, 2018).

Chukwuneke et.al., (2020) highlighted the importance of natural innovations by blending different types of biomass to produce high-quality briquettes. Biomass mixtures, such as rice straw combined with corn cobs, can enhance combustion efficiency and generate lower emissions compared to the use of a single type of biomass.

The composition of candlenut shells, corn cobs, and rice straw is believed to significantly influence the characteristics of briquettes, including moisture content, ash content, density, and calorific value. High moisture content reduces combustion efficiency, while high ash content affects residue and combustion behavior. Density determines the energy content per unit volume, whereas calorific value indicates the energy released during combustion. Therefore, studying the variation in the composition of these three materials is crucial for determining an optimal briquette formulation that is efficient and environmentally friendly. This approach also enhances the utilization of underexploited agricultural residues, providing added economic value while supporting the development of renewable energy.

MATERIALS AND METHOD

The composition of candlenut shells, corn cobs, and rice straw is believed to significantly influence the characteristics of briquettes, including moisture content, ash content, density, and calorific value. High moisture content reduces combustion efficiency, while high ash content affects residue and combustion behavior. Density determines the energy content per unit volume, whereas calorific value indicates the energy released during combustion. Therefore, studying the variation in the composition of these three materials is crucial for determining an optimal briquette formulation that is efficient and environmentally friendly. This approach also enhances the utilization of underexploited agricultural residues, providing added economic value while supporting the development of renewable energy.

The research process began with the collection of samples, including candlenut shells, rice straw, and corn cobs, obtained from Tanjung Raya Village, Buay Sandang Aji, South OKU. All materials were sun-dried for 2–3 days until reaching a dry condition. The next stage involved carbonization, during which the materials were gradually placed into a carbonization drum in a controlled manner. This step aimed to ensure that each type of material underwent optimal carbonization without interference from other materials, resulting in charcoal of uniform quality,

- S1 = 25g : 5g : 20g
- S2 = 25g : 12,5g : 12,5g
- S3 = 25g : 15g : 10g
- S4 = 25g : 20g : 5g

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RESULT AND DISCUSSION

This study was conducted using variations in the composition of natural materials to analyze the physical properties of the briquettes, including ash content, moisture content, calorific value, and density, with candlenut shells as the primary material combined with corn cobs and rice straw (25:5:20, 25:12.5:12.5, 25:15:10, 25:20:5). These combinations were based on differences in the inorganic content of each material, which potentially influence the amount of solid residue after combustion. The results of the tests for each parameter are presented in Table 4.1.

Table 4.1. Test Results of Ash Content, Moisture Content, Calorific Value, and Density

SampLE	Test Results			
	Ash Content (%)	Water Content (%)	Calorific Value (kal/gr)	Density (g/cm^3)
S1	8,4	4	5532	0,88
S2	7,8	4,2	5639	0,91
S3	7,6	4,5	5521	0,75
S4	7,4	5,1	5941	0,88

- **Ash Content**

The physical property results include ash content, determined based on the composition ratios of the materials and measured by comparing the mass before and after combustion for each sample.

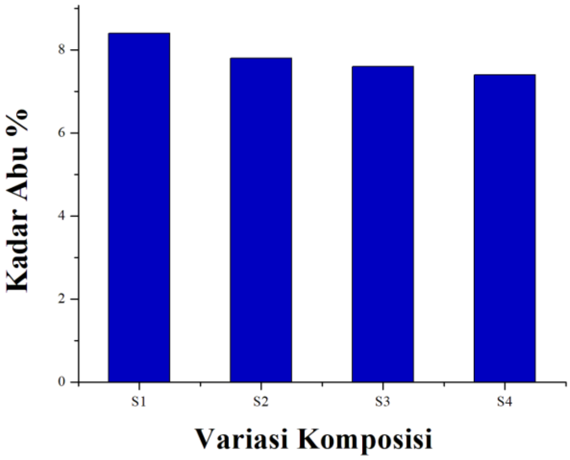

Figure 4.1. Relationship Between Composition Variations and Ash Content

Figure 4.1 shows that the ash content of the four briquette samples with different material compositions decreases across the compositions. The highest ash content was observed in sample 1 at 8.4%, followed by sample 2 at 7.8%, and sample 3 at 7.6%, while the lowest ash content was recorded in sample 4 at 7.4%. All briquette samples still meet the Indonesian National Standard (SNI), as the highest ash content (8.4%) remains below the maximum limit of 10%. According to SNI 01-6237-2000 for biomass briquettes, the allowable maximum ash content is approximately 10%.

The highest ash content observed in sample 1 is attributed to the high proportion of rice straw in the raw material mixture. Rice straw is known to contain a considerable amount of inorganic compounds, primarily in the form of silica, calcium, and potassium. These compounds are resistant to combustion and remain as residue in the form of ash after the burning process. Additionally, the fibrous and lightweight structure of rice straw tends to produce a greater amount of ash compared to other raw materials, such as corn cobs or candlenut shells (Rianawati et.al., 2021).

Meanwhile, the decrease in ash content from Sample 2 to Sample 4 is attributed to the gradual reduction of rice straw, which is compensated by an increase in the proportion of corn cobs and candlenut shells. As the amount of rice straw in the mixture decreases, the total content of inorganic compounds is reduced, resulting in lower ash residue after combustion (Dizaji et.al., 2019).

This study is consistent with the findings of (Mahendry et.al., 2023), regarding the influence of material composition on the ash content of biomass briquettes. In their study, the lowest ash content of 1.6% was observed in briquettes composed of 65% candlenut shells, 25% corn cobs, and 10% binder, whereas the highest ash content of 4.84% was found in briquettes dominated by 90% corn cobs. These results indicate that both the type and proportion of raw materials significantly affect the amount of combustion residue. The high ash content in corn cob-based briquettes is attributed to their high silica content, while candlenut shells tend to produce lower ash due to a lower proportion of non-combustible inorganic compounds.

- **Water Content**

Moisture content is a critical parameter in evaluating briquette quality, as it directly affects combustion characteristics, storage stability, and calorific value. High moisture content can reduce combustion efficiency because part of the energy is consumed in evaporating water, whereas excessively low moisture content may cause the briquettes to become brittle and prone to breakage (Tumuluru et.al., 2015). The measurement results are presented in Figure 4.2.

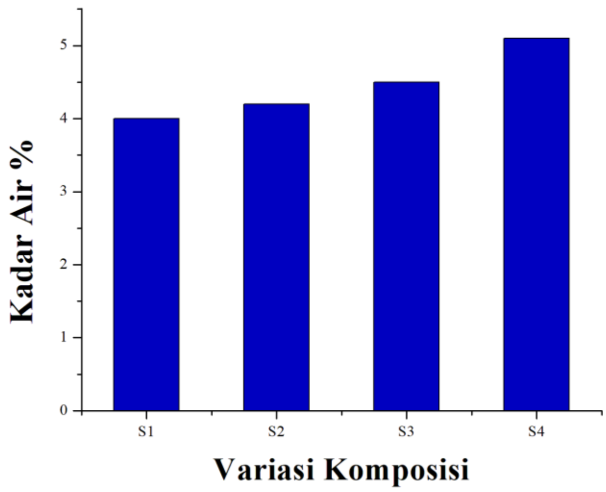

Figure 4.2. Relationship Between Composition Variations and Moisture Content.

Figure 4.2 shows that the lowest moisture content was recorded in sample 1 at 4.0%, followed by sample 2 at 4.2%, sample 3 at 4.5%, and the highest moisture content in sample 4 at 5.1%. The increase in moisture content in the briquettes indicates that variations in raw material composition affect the material's ability to absorb and retain moisture. High moisture content is generally associated with rice straw, which has a high porosity and strong hygroscopic properties, allowing water to be easily absorbed and retained within the briquette structure. Rice straw also contains high levels of cellulose and hemicellulose, which are hydrophilic and contribute to water absorption. Additionally, corn cobs influence the high moisture content due to their high water absorption capacity and more open fibrous structure, which makes it difficult to remove water during drying. (Potip & Wongwuttanasatian,2018).

This study is consistent with the findings of (Mahendry et.al., 2023), which showed that the lowest moisture content was found in sample 1, composed of 90% candlenut shells and 10% binder, at 4.59%, while the highest moisture content was observed in sample 2, composed of 90% corn cobs and 10% binder, reaching 14.94%. These results indicate that both the type and proportion of raw materials significantly affect the moisture content of briquettes. Candlenut shells tend to have low natural moisture content and a dense structure, producing briquettes that dry quickly and achieve lower final moisture levels. In contrast, corn cobs have a higher water absorption capacity and a more open fibrous structure, making it more difficult to remove water during the drying process. This is the primary reason why briquettes dominated by corn cobs exhibit higher moisture content.

- **Density**

Density is a critical parameter in evaluating briquette quality, as it is directly related to durability, combustion efficiency, and ease of storage.

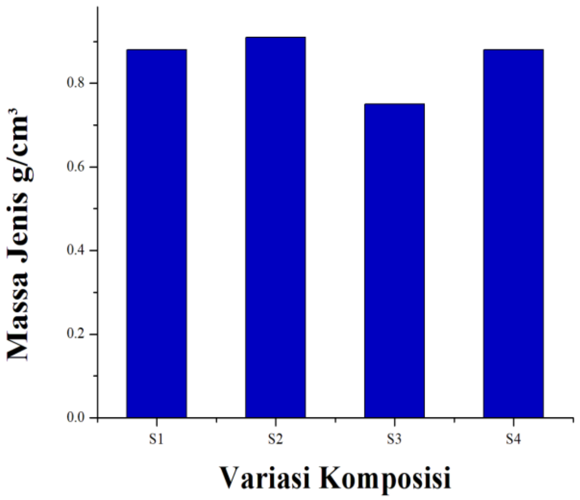

Figure 4.3. Relationship Between Composition Variations and Density

Figure 4.3 shows the density values among the samples, indicating that variations in the proportion of corn cobs and rice straw affect briquette compaction. Sample 2 exhibited the highest density at 0.91 g/cm³, influenced by the higher proportion of corn cobs and lower amount of rice straw. The denser structure of corn cobs supports particle compaction during molding, whereas the lightweight and porous nature of rice straw tends to reduce density, as seen in sample 3, which had the lowest value of 0.75 g/cm³. Samples 1 and 4 exhibited identical densities of 0.88 g/cm³, suggesting that a relatively balanced combination of corn cobs and rice straw results in similar compaction levels. According to SNI 01-6235-2000, samples 1, 2, and 4 meet the standard density requirements for briquettes, whereas sample 3 does not. The low density in sample 3 is attributed to the high proportion of rice straw, which is lightweight, fibrous, and highly porous. (Osarenmwinda & Nwachukwu, 2010). In sample 3, the less dense structure of rice straw resulted in a looser briquette with numerous air voids, reducing both density and physical stability. Additionally, variations in density values among the samples were influenced by the manual pressing method, which did not employ hydraulic or mechanical equipment. Manual pressing produces uneven and suboptimal pressure, preventing the particles within the briquettes from being fully compacted and leaving air gaps within the structure, ultimately leading to lower overall density values. (Lisowski et.al., 2020).

This study aligns with the findings of (Cabrales et.al., 2020), which demonstrated that briquette density can increase or decrease significantly depending on compaction conditions and the characteristics of the raw materials. Density increased substantially when the molding pressure was raised from 7.0 MPa to 14.0 MPa, resulting in a 50%

increase in density from 310 kg/m³ to 460 kg/m³. This improvement was attributed to the higher particle packing, producing a more compact and stable briquette structure. Conversely, increasing the moisture content of the raw material from 8.3% to 54.5% led to a 45% decrease in dry density, from 380 kg/m³ to 210 kg/m³. This reduction occurred because high moisture caused briquettes to expand after molding, lowering particle packing and resulting in less dense briquettes.

- **Calorific Value**

Calorific value is a crucial parameter in evaluating the quality of solid fuels, such as briquettes. It indicates the amount of heat energy released when the material is completely combusted. (Setialana, 2014).

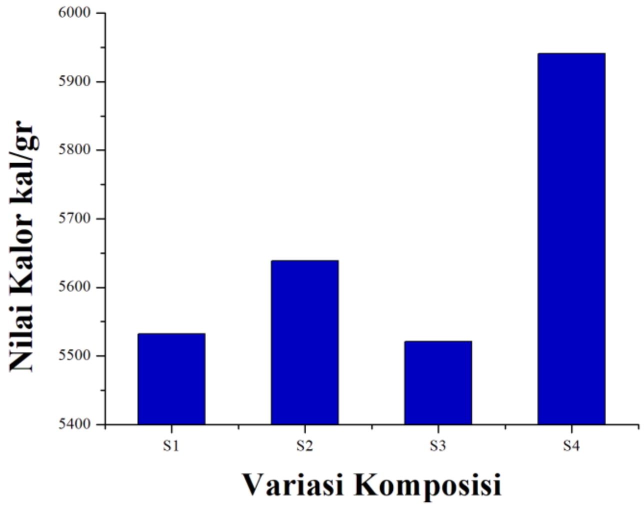

Figure 4.4. Relationship Between Composition Variations and Calorific Value

Figure 4.4 shows that the highest calorific value was obtained in sample 4 at 5,941 cal/g, followed by sample 2 at 5,639 cal/g, sample 1 at 5,532 cal/g, and the lowest value in sample 3 at 5,521 cal/g. The fluctuations in calorific value among the samples indicate that the raw material composition influences the energy released. Higher calorific values correspond to greater heat energy released during combustion, reflecting better briquette quality as an alternative fuel. The increase in calorific value in sample 4 is attributed to the high carbon content and energy density of candlenut shells. Conversely, the lower calorific value in sample 3 reflects the dominance of raw materials with volatile compounds or high moisture content, which reduce combustion efficiency. (Yang et.al., 2017). Figure 4.4 illustrates that the formulation of raw materials has a significant effect on the calorific value of briquettes. High calorific values indicate good energy efficiency, which is influenced by low moisture and ash content. High moisture content inhibits combustion as energy is consumed to evaporate water, while high ash content reduces calorific value because it represents non-combustible residue. Furthermore, decreases in calorific value can also be affected by the manual briquette molding process. Manual pressing may create air voids within the briquettes due to uneven pressure, reducing briquette density and leading to inefficient combustion. This can result in a substantial decrease in calorific value. (Inegbedion & Ikpoza, 2023).

Kpalo et al. (2020) characterized hybrid briquettes produced from corn cobs (CC) and oil palm trunk bark (OPTB) with various mixing ratios using a low-pressure densification technique. The results showed that the calorific values ranged from 16.54 MJ/kg to 17.78 MJ/kg, with briquettes made entirely from OPTB exhibiting the highest calorific value. Nevertheless, the mixed briquettes with a 25% corn cob and 75% OPTB ratio also demonstrated a relatively high calorific value of 16.91 MJ/kg, indicating that combining two biomasses with different thermal characteristics can produce briquettes with competitive energy content.

CONCLUSION

The variation in raw material composition significantly influenced the physical characteristics of the resulting briquettes. Sample S4, composed of 25 g candlenut shells, 20 g corn cobs, and 5 g rice straw, exhibited the most optimal performance, with a calorific value of 5,941 cal/g, density of 0.88 g/cm³, moisture content of 5.1%, and ash content of 7.4%. All these parameters meet the Indonesian National Standard (SNI 01-6235-2000) for briquette quality, which specifies a minimum calorific value of 5,000 cal/g, maximum moisture content of 15%, maximum ash content of 8%, and density range of 0.8–1.2 g/cm³. The low proportion of rice straw in this formulation contributed to reduced moisture and ash content, while the inclusion of corn cobs provided balance in density and supported stable combustion. This combination, together with candlenut shells, produced briquettes with high energy content and physical properties conforming to the standard. Overall, a formulation dominated by candlenut shells and corn cobs with minimal rice straw resulted in briquettes with excellent combustion performance and physical quality. These findings indicate that the proper selection and proportioning of biomass materials can effectively produce high-quality briquettes, providing a feasible alternative energy source and promoting sustainable utilization of agricultural waste.

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