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CHARACTERISTICS OF KLUWEK (PANGIUM EDULE) SHELL CHARCOAL BRIQUETTES ACTIVATED WITH NAOH

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ABSTRACT

Characteristics of Kluwek (Pangium edule) Shell Charcoal Briquettes Activated with NaOH. *Indonesia, as one of the countries with a high population, continues to face significant challenges in energy conservation. The development of alternative fuel sources is urgently required to address energy shortages, such as biocharcoal briquettes derived from biomass. Kluwek shells (Pangium edule) have potential as briquette material due to their high cellulose content, reaching 70.52%. This study aimed to evaluate the characteristics of briquettes, including moisture content, ash content, calorific value, combustion rate, and compressive strength, in accordance with the SNI 01-6235-2000 quality standards. The experimental variations included adhesive concentrations of 10%, 15%, and 20%, and mesh sizes of 30, 60, and 90. Overall, the results met the required standards. The optimal briquette characteristics were obtained from 10% NaOH-activated kluwek shell briquettes with 10% adhesive and a 30 mesh size, resulting in a moisture content of 1.65%, ash content of 3.30%, calorific value of 6191.17 Cal/g, and combustion rate of 1.13 g/min.*

INTRODUCTION

Indonesia still faces challenges in meeting its energy needs due to its large population. This has led to concerns about the possibility of a fuel crisis and dependence on non-renewable energy (fossil fuels), which is becoming increasingly limited(1). Alternative fuels are needed to address energy scarcity, such as charcoal briquettes produced from biomass(2). The raw materials for briquettes can come from a variety of organic materials. However, the main content required in making briquettes is high cellulose and carbon content(3).

Kluwak (Pangium edule) shells have potential as briquettes because they contain 70.52% cellulose and 92.04% carbon(4,5). Tapioca starch is usually used as an adhesive. The use of tapioca adhesive is decreasing because tapioca starch is considered a food ingredient. Previous research chose rubber latex as the adhesive solution because it has a calorific value of 6807.34 Cal/g, which is higher than tapioca starch with a calorific value of 6332.654 Cal/g(6).

The particle size of the feedstock affects the characteristics and performance of biomass briquettes. The smaller the particle size, the better, because density increases with finer particle size(7). However, the particle size of biomass briquettes should not be too large because it can create voids in the porosity of the briquette. If there are too many voids, the briquettes may crack easily(8). Therefore, it is necessary to conduct research to determine the particle size of biomass briquettes. If the pores in the briquettes are too large, it results in briquettes that crack easily. The research conducted in this study used 30, 60, and 80 mesh sieves and 10%, 15%, and 20% adhesive sizes to produce briquettes that have optimal quality.

The surface quality of kluwek (Pangium edule) shell charcoal briquettes can also be optimized by the activation process. A chemical activator that stimulates the porosity and surface area of charcoal is NaOH, which is effective in creating micropores[9]. Based on the above description, research was conducted on the impact of the type of adhesive and the appropriate particle size of NaOH-activated kluwek shell charcoal on the quality of the briquettes produced.

Moreover, biomass briquettes are recognized as a renewable and environmentally sustainable energy source. Briquettes made from agricultural residues or organic waste contribute to the conservation of natural resources and help lower net greenhouse gas emissions because the CO_2 released during combustion is approximately balanced by the CO_2 absorbed during plant growth, thereby supporting a carbon-neutral energy cycle[23,24]. Compared with conventional fossil fuels, biomass briquettes produce lower emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter, which improves air quality and reduces negative impacts on human health and the environment[25].

In addition to environmental advantages, the use of biomass briquettes can enhance local energy security and socio-economic development. The production of briquettes from locally available biomass waste supports a decentralized energy supply, reduces reliance on imported fuels, and generates economic opportunities for rural communities through jobs in biomass collection, processing, and briquette manufacturing[26]. These characteristics make biomass briquettes a promising renewable energy solution as well as a practical approach to waste valorization and community-level economic empowerment.

MATERIALS AND RESEARCH METHODS

This study employed a laboratory experimental design. The briquette production process began with the preparation of kluwek shell biomass. The biomass was first cleaned to remove contaminants, then cut into small pieces and dried. Subsequently, the kluwek shells were carbonized in a furnace at 700°C for 1 hour[10]. Thereafter, the charcoal activation process was performed chemically using a 10% NaOH solution, with a mass ratio of charcoal to solution of 1:2, for 24 hours[11]. The activated charcoal was then filtered and neutralized by washing with distilled water, followed by drying in an oven at 105°C for 2 hours. Finally, the briquettes were formed into 4 cm × 4 cm molds, which were subsequently dried in an oven at 105°C for 2 hours.

RESEARCH RESULTS AND DISCUSSION

The results of measuring the characteristics of kluwek shell briquettes show quality including moisture content, ash content, calorific value, combustion rate, and compressive strength. This can be seen in Table 1 below.

Tabel 1 Characterization Results of Kluwek (Pangium edule) Shell Briquettes

Adhesive	Size (mesh)	Moist Content (%)	Ash Content (%)	Calorific Value (Kal/gr)	Burning Rate (gr/menit)	Compressive Strength (kg/cm2)
10%	30	1,65	3,30	6191,17	1,13	5,42
	60	1,80	3,45	6080,55	1,28	5,65
	100	2,10	3,60	5642,47	1,38	5,84
15%	30	1,73	3,44	6093,48	1,21	6,91
	60	2,30	3,65	5786,52	1,35	7,30
	100	2,54	3,90	5782,91	1,48	7,90
20%	30	2,30	3,76	5742,12	1,55	8,57
	60	2,42	3,69	5685,41	1,60	9,70
	100	3,03	4,18	5492,42	1,78	10,41

Briquette Moisture Content Analysis

Briquettes exhibit a high degree of hygroscopicity, defined as the ability to absorb moisture from the surrounding environment. The moisture content was measured to evaluate the hygroscopic properties of the charcoal briquettes produced in this study(12).

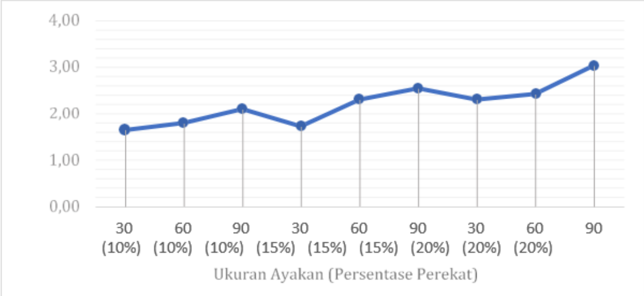

Figure 1. Moisture Content of Kluwek (Pangium edule) Shells

As shown in Table 1, briquettes with 20% adhesive and a 90-mesh particle size exhibited the highest moisture content at 3.03%, whereas briquettes with 10% adhesive and a 30-mesh particle size showed a lower moisture content of 1.65%. Figure 1 illustrates that the moisture content increases with both the percentage of adhesive and the particle size. The moisture content also tends to increase with smaller particle sizes of charcoal briquettes, as larger particle sizes contain larger pores between particles, resulting in lower density. This finding is consistent with the study by Masyamah (1993) cited in Widya & Jaswella (2022), which reported that the density of charcoal briquettes significantly affects water content: the higher the density, the greater the water content(13).

Moreover, the moisture content increases with higher adhesive percentages. Briquettes with 20% rubber gum adhesive exhibited higher moisture content compared to those using molasses adhesive at 10% and 15%. This observation aligns with Maryono (2013), who stated that increasing the adhesive composition enhances briquette density, thereby reducing pore size(14). Additionally, the pressing process during briquette formation affects the moisture content, as compressive forces reduce the volume of the pores, which can lead to a decrease in water content.

Briquette Ash Content Analysis

The analysis of ash content in briquettes aims to estimate the amount of residue remaining after complete combustion. Lower ash content indicates higher briquette quality.

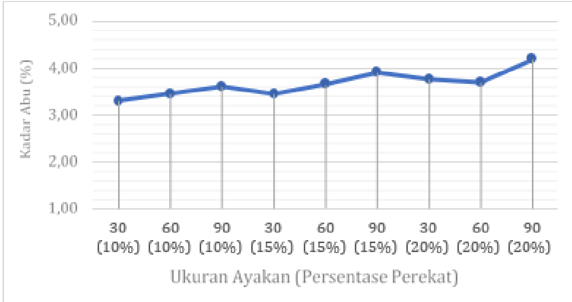

Figure 2 Results of Ash Content of Kluwek Shell (Pangium edule)

Based on the data presented in Table 1, the highest ash content was observed in briquettes with 20% adhesive and a 90-mesh particle size, at 4.18%, while the lowest ash content was found in briquettes with 10% adhesive and a 30-mesh particle size, at 3.30%. Figure 2 illustrates that ash content increases with both the adhesive percentage and particle size.

The results of ash content analysis in a study by Iriany (2016) indicated that variations in particle size can affect the ash content of briquettes. High and low ash content are also influenced by the carbonization process, as an optimal carbonization process produces purer charcoal with lower ash content. In the present study, ash content increased with decreasing particle size and increasing adhesive percentage[15]. Briquettes with larger particles tend to burn more efficiently, producing less ash compared to smaller particles. Similarly, Alfajriandi (2017) reported that smaller particle sizes correspond to higher ash content[16].

The addition of rubber gum adhesive also affects the ash content of briquettes; higher amounts of rubber gum result in increased ash content. Furthermore, the pressing process during molding influences the ash content, as higher pressing pressure reduces the ash content. This occurs because the pressing process removes a portion of the adhesive, resulting in lower ash content[17].

Briquette Calorific Value Analysis

Calorific value is a critical parameter in briquette production, as it determines the heat energy produced. The higher the calorific value, the better the quality of the briquette, as less fuel is required to achieve a given amount of combustion energy. Calorific value is influenced not only by intrinsic factors but also by proximate properties such as moisture and ash content. Lower moisture and ash content in charcoal briquettes result in higher calorific values.

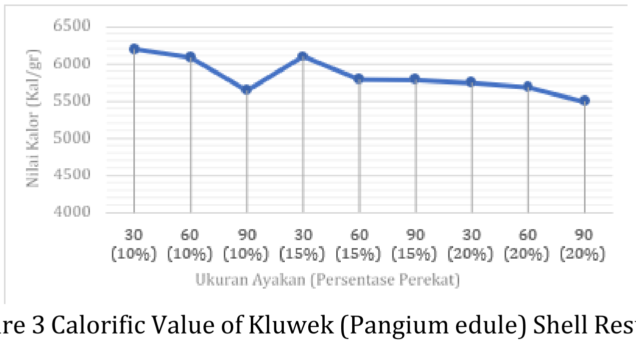

Figure 3 Calorific Value of Kluwek (Pangium edule) Shell Results

Based on the data presented in Table 1, the highest calorific value of 6191.17 cal/g was observed in briquettes with 10% adhesive and a 30-mesh particle size. In contrast, briquettes with the same 10% adhesive but a 30-mesh particle size exhibited the lowest calorific value of 5492.42 cal/g. These findings support the observations of Widya & Jaswella (2022), who reported that high moisture content in briquettes reduces their calorific value[13]. This reduction occurs because a portion of the heat is initially consumed to evaporate the water contained within the briquettes. In this study, the lowest moisture content was observed in

briquettes with 10% adhesive and a 30-mesh size, as indicated in the previous moisture content analysis.
The calorific value also tended to decrease with smaller particle sizes of charcoal briquettes. This result aligns with Alfajriandi (2017), who reported that particle size differences significantly affect the heating value produced(16). Smaller particle sizes generally reduce the carbon content, thereby decreasing the heat output(18).
An increase in calorific value was associated with lower adhesive content. This is consistent with the findings of Saukani (2019), who concluded that using a larger amount of adhesive in briquette production reduces calorific value, whereas using less adhesive increases it(19).
According to Septinai & Septiani (2015), ash content is another factor affecting calorific value. Lower ash content corresponds to a higher amount of bound carbon, which in turn increases the calorific value. Briquettes that have undergone proper carbonization or charring exhibit higher bound carbon content, making them more efficient as fuel compared to raw materials. Based on SNI 01-6235-2000 on Wood Charcoal Briquettes, the minimum permissible calorific value is 5000 cal/g. All briquettes produced in this study met or exceeded this standard, demonstrating that kluwek shell biomass waste can achieve the required quality as confirmed by the analysis results.

Briquette Burning Rate Analysis

The burning rate reflects the speed at which a briquette combusts. A higher burning rate indicates faster consumption of the briquette. Combustion rate testing was conducted by igniting the briquettes and measuring the duration of the flame. The briquette mass was weighed before and after burning, with ignition time recorded using a stopwatch and the mass measured using a digital scale.

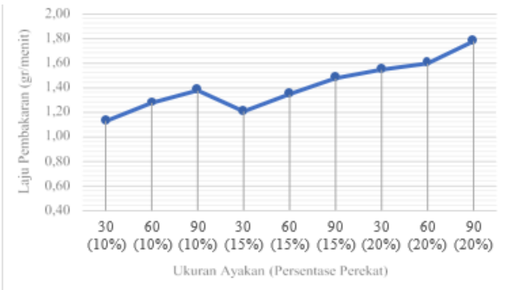

Figure 4 Results of Ash Content of Kluwek Shell (*Pangium edule*)

Based on the data in Table 4.4, the lowest combustion rate was observed in briquettes with 10% adhesive and a 30-mesh particle size, at 1.13 g/min for 10% NaOH-activated briquettes. Conversely, the highest combustion rate was found in briquettes with 20% adhesive and a 90-mesh particle size, at 1.78 g/min for 10% NaOH-activated briquettes.
A higher burning rate indicates faster consumption of the briquette(20). According to Jamilatun (2008) cited in Aziz (2019), longer burning times reflect better combustion quality and efficiency, as briquettes that burn steadily with a consistent flame are considered superior. Smaller particle sizes result in higher density, which can make charcoal briquettes more difficult to ignite(18).
The burning rate also increased with higher adhesive content. This corresponds to the observation that higher adhesive percentages lead to increased moisture content in the briquettes, which requires more heat for evaporation during combustion. Consequently, the briquettes lose mass more rapidly, resulting in a higher burning rate(21).
Additionally, the calorific value influences the burning rate. Higher calorific values contribute to a more stable combustion rate. The flame size and color during burning also serve as qualitative indicators of briquette performance, with high-quality briquettes producing larger, bluish flames. It is important to note that the burning rate is not regulated by the Indonesian National Standard (SNI), and no formal quality standard exists for this parameter.

Nonetheless, burning rate remains a significant factor in evaluating fuel performance. Briquettes with lower burning rates are considered higher quality, as they burn more slowly, provide longer-lasting energy, and emit minimal dust due to efficient heat transfer and lower carbon content.

Briquette Compressive Strength Analysis

Compressive strength analysis is conducted to evaluate the durability of briquettes, which is crucial for packaging, transportation, and marketing. Briquettes with higher compressive strength are more durable and less prone to breakage during handling and combustion[22].

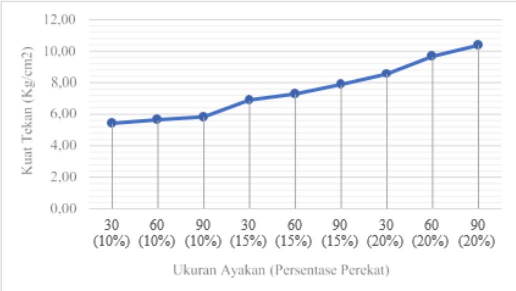

Figure 5 Compressive Strength Result of Kluwek Shell (*Pangium edule)*

Based on the data presented in Table 4.5, the highest compressive strength was observed in briquettes with 20% adhesive and a 90-mesh particle size, reaching 10.41 kg/cm^2. In contrast, the lowest compressive strength was found in briquettes with 10% adhesive and a 30-mesh particle size, at 5.21 kg/cm^2. These results are consistent with the study by Sudiro and Suroto (2014), which reported that smaller particle sizes lead to higher compressive strength, as smaller particles result in smaller pores within the briquette[23]. Conversely, larger particle sizes produce larger pores, reducing compressive strength.

Figure 5 shows that compressive strength increases with both higher adhesive content and smaller particle sizes. The combination of smaller particle size and higher adhesive content produces briquettes with greater compressive strength. This is because smaller particles increase the contact area and the number of particle contacts, allowing the briquettes to better withstand compressive forces during testing. Compressive strength is also influenced by pressing pressure, as higher pressing pressure results in denser and sturdier briquettes, allowing the adhesive to bind the charcoal components more effectively.

Briquette brittleness typically occurs when adhesive content is low, resulting in weak particle bonding. The findings of this study also demonstrate that rubber gum can function effectively as a binder. According to PERMEN ESDM No. 10 of 2021 on New and Renewable Energy Policy for Electricity, provisions for renewable energy in the electricity sector are regulated. Furthermore, Law No. 47 of 2006 specifies that the minimum standard for compressive strength of bio-coal briquettes is 65 kg/cm^2. However, none of the briquettes produced in this study met this minimum standard.

CONCLUSIONS AND RECOMMENDATIONS

Activated kluwek shell charcoal briquettes meet the SNI 01-6235-2000 standards for moisture content, ash content, calorific value, and burning rate, demonstrating their potential as an alternative renewable energy source, although their compressive strength remains below the minimum standard specified in PERMEN ESDM No. 47 of 2006, with a maximum value of 10.41 kg/cm^2. The best-performing sample, N10-30, showed 1.65% moisture content, 3.30% ash content, 6191.17 cal/g calorific value, and a burning rate of 1.13 g/min. Adhesive percentage, particle size, and NaOH activation were found to significantly influence briquette quality. To improve practical application, it is recommended to optimize adhesive composition, particle size, and pressing pressure to enhance compressive strength, consider

N10-30 for small-scale production due to its optimal properties, and explore alternative binders or activation methods to maintain high calorific value while increasing durability.

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