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Analysis of the differences in the quality of briquettes made from durian peel and young coconut shells as an alternative energy source

Analisis Perbedaan Kualitas Briket Bahan Kulit Durian dengan Batok Kelapa Muda sebagai Energi Alternatif

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ABSTRACT

Background: *Durian peel and young coconut shells are abundant organic waste in Bengkulu City. Up to 80% of coastal waste consists of coconut shells, while durian peel waste can reach 1.5–2 tons/day during harvest season. Poor management contributes to environmental pollution. Converting this waste into biochar briquettes offers a sustainable solution.*

Objective: *To compare the quality of briquettes from durian peel and young coconut shells based on moisture, ash, fixed carbon, volatile matter, and calorific value.*

Methods: *A quasi-experimental (posttest-only) design was used. Briquettes were produced from durian peel and coconut shell charcoal with 5% tapioca binder (300 g per treatment).*

Results: *Coconut shell briquettes showed better quality, with moisture 3.33%, ash 6.33%, fixed carbon 85.96%, volatile matter 4.38%, and calorific value 5922 cal/g. Durian peel briquettes had moisture 2.38%, ash 11.37%, fixed carbon 81.49%, volatile matter 4.77%, and calorific value 5398 cal/g. Coconut shell briquettes met SNI 1/6235/2000 standards, and all parameters differed significantly (p < 0.05).*

Conclusion: *Coconut shell briquettes are more efficient as a solid fuel, while durian peel briquettes remain potential when combined with other biomass. This study supports the use of organic waste as a renewable energy source and contributes to sustainable environmental management in Indonesia.*

Keywords: *briquettes, durian peels, tapioca flour, young coconut shells, test parameters SNI 1/6235/2000*

ABSTRAK

Latar Belakang: Kulit durian dan tempurung kelapa muda merupakan limbah organik melimpah di Kota Bengkulu. Sekitar 80% limbah pesisir berupa tempurung kelapa, sementara limbah kulit durian mencapai 1,5–2 ton/hari saat musim panen. Pengelolaan yang tidak tepat dapat menyebabkan pencemaran lingkungan. Pemanfaatannya menjadi briket biochar merupakan solusi berkelanjutan.

Tujuan: Membandingkan kualitas briket dari kulit durian dan tempurung kelapa muda berdasarkan kadar air, abu, karbon tetap, zat mudah menguap, dan nilai kalor.

Metode: Penelitian menggunakan desain quasi-eksperimen (posttest only). Briket dibuat dari arang kulit durian dan tempurung kelapa dengan perekat tepung tapioka 5% (300 g per perlakuan).

Hasil: Briket tempurung kelapa menunjukkan kualitas lebih baik dengan kadar air 3,33%, abu 6,33%, karbon tetap 85,96%, zat mudah menguap 4,38%, dan nilai kalor 5922 kal/g. Briket kulit durian memiliki kadar air 2,38%, abu 11,37%, karbon tetap 81,49%, zat mudah

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menguap 4,77%, dan nilai kalor 5398 kal/g. Briket tempurung kelapa memenuhi standar SNI 1/6235/2000, dan seluruh parameter berbeda signifikan (p < 0,05).
Kesimpulan: Briket tempurung kelapa lebih efisien sebagai bahan bakar padat, sedangkan kulit durian tetap berpotensi jika dikombinasikan dengan biomassa lain. Pemanfaatan limbah organik ini mendukung energi terbarukan dan pengelolaan lingkungan berkelanjutan di Indonesia.

Kata kunci: briket, kulit durian, tempurung kelapa muda, tepung tapioka, parameter SNI 1/6235/2000

INTRODUCTION

The global energy crisis and rising global temperatures are pushing many countries to accelerate the transition to renewable energy. According to a 2024 report by the International Energy Agency (IEA), demand for solid biomass as an alternative fuel continues to increase. Solid biomass is the primary source of modern bioenergy, contributing approximately 85% of the world's total modern bioenergy demand[1]. Indonesia has demonstrated a strong commitment to addressing its national waste problem. This effort is being realized through the implementation of innovative solutions, including utilizing waste as a renewable energy source, supported by environmentally friendly technology[2].

Energy diversification through the utilization of biomass waste into biocharcoal briquettes is a strategic step in supporting energy security and environmental health[3]. Utilizing local biomass such as durian peel and young coconut shells has significant potential to reduce the environmental impact of organic waste. The carbonization process of this waste produces briquettes with lower particulate emissions than direct combustion, thus contributing to reduced air pollution and improved environmental health[4]. In addition, this approach supports efforts to transform waste into high-value resources.

Durian peel and young coconut shell waste are commonly found in the Bengkulu region, particularly in the Panjang Beach tourist area. This creates pollution, including unpleasant odors due to the decomposition process, an increase in the population of disease vectors such as flies and rats, and a decline in the aesthetic quality of the tourist area. Furthermore, the decomposition process of organic waste has the potential to produce leachate that can pollute the soil and coastal waters, disrupting the balance of the coastal ecosystem. Polluted environmental conditions can also impact public health, including increasing the risk of respiratory disorders and environmentally related diseases, as well as reducing the comfort and health of visitors to tourist areas[5]–[7]. In fact, both have high energy potential due to their significant lignocellulose and carbon content. Durian peel contains carboxymethylcellulose, a major component, at approximately 50–60%. Furthermore, this material also contains approximately 5% lignin. The processing of durian peel produces a relatively high carbon content, in the range of 80–85%.[8]Young coconut shells have a water content of around 8.0%. Furthermore, the ash content is relatively low, at around 0.6%. The lignin content in young coconut shells is recorded at 29.4%, while the cellulose content reaches 26.6%[9]. So that when the two materials are mixed, it will produce high-quality briquettes. Previous research states that by mixing durian peel with coconut shell, it shows that the best calorific value is 6250.49 cal/gr, the proportion of water is 1.154%, the proportion of ash is 6.501%, the proportion of volatile substances is 7.091% and the proportion of carbon is 85.254% which is obtained from a particle size of 50 mesh with a composition of raw materials of durian peel and coconut shell 50%:50%[10].

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The use of efficient carbonization technology and natural binders such as tapioca starch has been shown to improve the quality of biomass briquettes, particularly in terms of ash content, and indirectly impact the calorific value of the resulting briquettes. The carbonization process and the addition of natural binders (such as starch/tapioca starch) play a crucial role in improving the thermal quality of biomass briquettes. Lower ash content correlates with higher calorific value and cleaner combustion[11].

This study aims to compare the quality of briquettes made from durian skin and young coconut shell based on the Indonesian National Standard (SNI No.1/6235/2000), with test parameters including water content, ash content, bound carbon content, volatile matter content, and calorific value.

METHODS

Study Design

This study employed a quasi-experimental design using a post-test only design. The research was conducted from July to September 2025 at the Environmental Health Workshop, Poltekkes Kemenkes Bengkulu.

Data Source and Sampling Procedure

The samples consisted of biochar briquettes produced from two types of raw materials: durian peel and young coconut shell. Raw materials were obtained from waste generated by vendors in the Pantai Panjang area, Bengkulu City. Sampling was conducted using purposive sampling, considering that not all waste materials met the criteria for briquette production. The inclusion criteria for raw materials were non-rotten, non-moldy, relatively clean, and free from inorganic contaminants such as sand, soil, or plastic. Each treatment used an equal initial weight of raw materials (±5 kg) to ensure consistency.

Variables of the Study

The independent variable was the type of raw material used for briquette production (durian peel and young coconut shell). The dependent variables were briquette quality parameters, including moisture content, ash content, fixed carbon content, volatile matter content, and calorific value.

Data Collection

Data were collected through laboratory testing of briquette samples produced from each treatment. Each treatment was conducted in triplicate. From each treatment group, 10 briquettes were selected as test samples, while additional samples were reserved to ensure consistency.

Measurement and Instruments

Briquette quality testing was conducted in the Chemistry Laboratory of Bengkulu University based on the SNI 01-6235-2000 standard[12]. Moisture content was measured using an oven, ash content using a furnace, fixed carbon through limited combustion methods, volatile matter using standard proximate analysis, and calorific value using a bomb calorimeter.

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Briquette Production Process

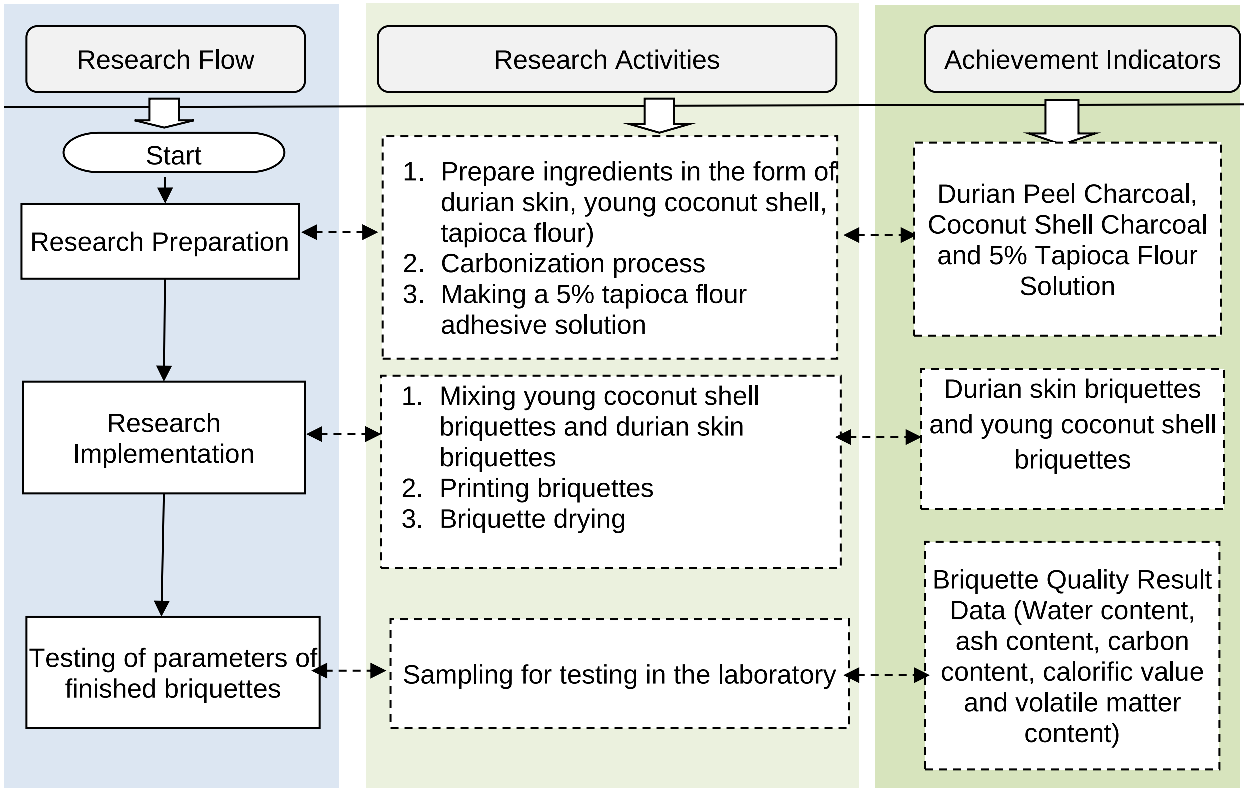

Figure 1.Research Flow Diagram

The briquette production process begins with the preparation of raw materials. Durian peel and young coconut shells were obtained from waste generated by vendors in the Pantai Panjang area, Bengkulu City. The raw materials were selected based on the criteria of being non-rotten, non-moldy, relatively clean, and free from inorganic contaminants such as sand, soil, or plastic. Subsequently, the materials were washed with clean water to remove adhering impurities and dried to reduce the initial moisture content.

The durian peel and young coconut shell used in each treatment have the same initial quantity to ensure treatment uniformity. Each raw material was weighed prior to the carbonization process, with an initial weight of approximately ±5 kg per treatment. The next stage was carbonization, which is an incomplete combustion process under limited oxygen conditions using a drum-based carbonization tool. Carbonization was carried out for 1 hour at a temperature of approximately 400°C. The resulting charcoal was then cooled naturally, followed by grinding into fine powder. The charcoal powder was subsequently sieved using a 100-mesh sieve to obtain a uniform particle size.

The next stage was mixing, in which the charcoal powder was combined with a tapioca binder at 5% of the total mixture weight. The binder was first dissolved in distilled water and heated until it formed a viscous solution, then gradually mixed into the charcoal powder. Each treatment used a total mixture weight of 300 g, and the mixing process was carried out until a homogeneous dough was obtained.

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The briquette dough was then molded using a 550-watt mini briquette press machine to produce briquettes with uniform size and density. Each treatment produced an average of 15 briquettes with a weight of approximately ±15–20 g per unit. All briquettes were then sun-dried until completely dry, after which they were selected homogeneously for quality testing. A total of 10 briquettes from each treatment were used as test samples, while the remaining briquettes were reserved to maintain testing consistency (Figure 1).

Briquette Testing Process

The study was conducted with three repetitions for each treatment. The unit of analysis in this study was the average result of testing several briquettes in each treatment, with a sample weight of 100 g for each parameter test. The use of average values aims to minimize variation between briquettes that may arise during the molding and drying processes, ensuring that the results accurately represent the quality of briquettes for each type of raw material.

The testing process was carried out in the Chemistry Laboratory of Bengkulu University based on the standard method SNI 01-6235-2000 [12]. Each parameter was measured using appropriate techniques, including an oven for moisture content analysis, a furnace for ash content determination, a limited combustion method for fixed carbon content, and a bomb calorimeter for measuring calorific value.

Data Analysis

Data were analyzed descriptively by comparing briquette quality parameters with the Indonesian National Standard (SNI 01-6235-2000)[12], including moisture content ≤ 8%, ash content ≤ 8%, fixed carbon ≥ 77%, calorific value ≥ 5,000 cal/g, and volatile matter ≤ 15%. In addition, inferential statistical analysis was conducted using an independent t-test to determine differences in briquette quality between the two raw material groups. A significance level of $p < 0.05$ was used to assess statistical significance.

RESULTS

This study is a quasi-experimental study that tests the differences in the types of charcoal used on the quality of the resulting briquettes. After the molding process is complete, the formed briquettes are then examined for their moisture content, ash content, bound carbon content, calorific value, and volatile matter content. The following are the results of the briquette molding and the examination of the tested parameters:

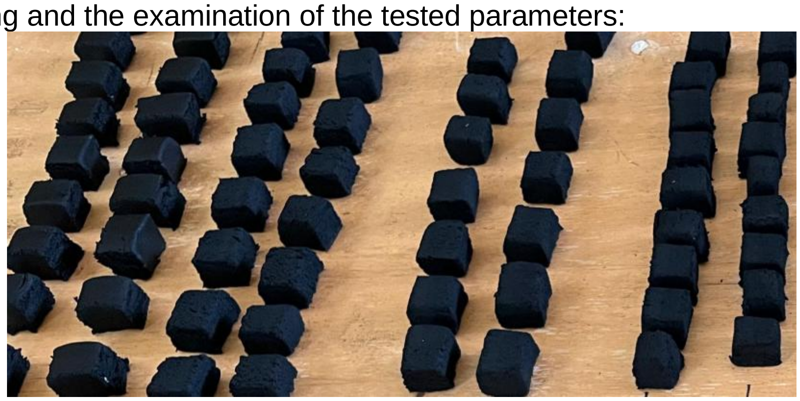

Figure 2. **Briquettes from Durian Skin and Young Coconut Shell**

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Table 1. Results of Briquette Parameter Examination on Durian Peel and Young Coconut Shell Materials with 5% Tapioca Flour Adhesive

Parameters/Repetition	Types of Activated Charcoal		SNI Standard Value
	Durian Skin	Young Coconut Shell	
Briquette Water Content			
Sample 1	2.40%	3.39%	≤ 8%
Sample 2	2.43%	3.31%	
Sample 3	2.30%	3.28%	
Average	2.38%	3.33%	
Briquette Ash Content			
Sample 1	11.50%	6.36%	≤ 8%
Sample 2	11.00%	6.17%	
Sample 3	11.60%	6.47%	
Average	11.37%	6.33%	
Briquette Bound Carbon Content			
Sample 1	81.22%	85.92%	≥ 77%
Sample 2	81.78%	86.12%	
Sample 3	81.47%	85.85%	
Average	81.49%	85.96%	
Volatile Matter Content of Briquettes			
Sample 1	4.88%	4.33%	≤15%
Sample 2	4.79%	4.39%	
Sample 3	4.63%	4.41%	
Average	4.77%	4.38%	
Calorie Value of Briquettes			
Sample 1	5485cal/g	6009cal/g	≥ 5,000 cal/g
Sample 2	5225cal/g	6008cal/g	
Sample 3	5485cal/g	5748cal/g	
Average	5398cal/g	5922cal/g	

Based on Table 1, the test results show that the average water content of both durian peel and young coconut shell briquettes has met SNI requirements, which is below 8%. The lowest water content value was obtained in briquettes made from durian peel with an average of 2.38%. The results of the ash content analysis show that briquettes from young coconut shells also comply with SNI standards because the value is below 8%. In this parameter, young coconut shell briquettes showed the lowest average value, which is 6.33%. The bound carbon test showed that both types of briquettes have exceeded the minimum SNI limit, which is more than 77%. The highest average bound carbon value was found in briquettes made from young coconut shells at 85.96%. For the volatile matter parameter, the measurement results showed that all briquettes met SNI requirements with a value of ≤15%. Young coconut shell briquettes had the lowest volatile matter content with an average of 4.38%. The calorific value of briquettes made from both materials also met SNI standards, exceeding 5,000 cal/g. The highest average value was achieved by briquettes made from young coconut shells, with a calorific value of 5,922 cal/g.

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Table 2. Quality of durian peel and young coconut shell briquettes using independent t-test on the parameters of water content, ash content, carbon content, volatile matter content, and calorific value.

	Charcoal Briquette Material	N	Mean	Standard Deviation	p-value
Briquette Moisture Content (%)	Durian Skin	3	2.38	0.068	0,000
	Young Coconut Shell	3	3.33	0.057	
Briquette Ash Content (%)	Durian Skin	3	11.37	0.321	0,000
	Young Coconut Shell	3	6.33	0.152	
Briquette Bound Carbon (%)	Durian Skin	3	81.49	0.281	0,000
	Young Coconut Shell	3	85.96	0.140	
Volatile Matter Content of Briquettes (%)	Durian Skin	3	4.77	0.127	0.024
	Young Coconut Shell	3	4.38	0.042	
Caloric Value of Briquettes (cal/g)	Durian Skin	3	5398.33	150.11	0.013
	Young Coconut Shell	3	5921.67	150.40	

Table 2 shows that the results of the Independent T-Test obtained p-value values on the parameters of water content, ash content, bound carbon, volatile matter content and calorific value are 0.000; 0.000; 0.000; 0.024; 0.013 <0.05 can be interpreted that statistically Ho is rejected and Ha is accepted, so it can be concluded that there is a significant difference between durian skin briquette materials and young coconut shells in the parameters of water content, ash content, bound carbon, volatile matter content and calorific value.

DISCUSSION

Briquette Water Content

The moisture content of biomass briquettes is a key indicator of solid fuel quality because water must be evaporated before effective combustion can occur. A low moisture content (<8%) increases the calorific value and combustion efficiency. Previous research also indicates that industry quality standards recommend a moisture content of ≤8% in briquettes to meet standards and achieve efficient combustion[13]. The research results show that young coconut shell briquettes have a lower moisture content than durian peel briquettes, making them potentially more efficient and environmentally friendly as an alternative fuel. A low moisture content indicates that the briquettes are sufficiently dry, allowing for easier and more stable combustion. Furthermore, the low moisture content contributes to an increase in the effective calorific value because less combustion energy is used to evaporate water. This also reduces the amount of smoke produced during the combustion process.

These findings align with other studies showing that varying adhesives can produce briquettes with low moisture content (6.65%) and low volatile matter (14.88%) that meet SNI standards. Lower moisture content tends to provide better combustion control[14].

Briquette Ash Content

Ash content reflects the mineral fraction remaining after combustion and influences energy efficiency and the resulting residue. Reducing the mineral fraction/lowering the ash content can increase the specific calorific value of the fuel[15]. Several studies have shown that ash content is an important parameter in determining the combustion quality of biomass briquettes. Briquettes made from durian (Durio zibethinus) peel generally have a relatively low ash content. Another study reported an ash content of 3.56%, indicating clean combustion and good energy efficiency.[16]Meanwhile, other research found that the ash content in briquettes made from a mixture of durian skin and coconut shells ranged from

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12.29–13.09%, depending on the composition and carbonization treatment[17]. In this study, only the ash content of young coconut shell briquettes met the SNI criteria, namely ≤8%[12]. Low ash content indicates that the briquettes produce less combustion residue, making them more efficient and practical to use. Technically, low ash content indicates a smaller inorganic mineral content, which results in more complete combustion, higher calorific value, and reduced particulate emissions and solid residues. This condition makes young coconut shell briquettes more suitable for clean energy use at the household level because it minimizes ash waste, facilitates post-combustion handling, and increases user comfort.

Carbon Bonded Briquettes

Bound carbon indicates the percentage of combustible carbon after volatile components and water are removed. The higher the bound carbon content, the longer and more stable the combustion process. Other research on durian peel briquettes showed a bound carbon content of 69.2–77.9%, resulting from an optimal carbonization process and contributing to longer burning times[16], [18],[19]. Similar results were also found in briquettes made from young coconut shells, where the bound carbon content was in the range of 60–80%, and increased with the length of the carbonization process.[20]The high-bound carbon value in young coconut shell briquettes (85.96%) indicates the potential for a relatively longer burning time and more stable ember formation compared to durian shell briquettes, with an estimated effective flame duration ranging from 60–90 minutes under natural combustion conditions, thus supporting energy efficiency and flame stability. In general, solid fuels with high bound carbon content tend to have a slower burning rate and better energy efficiency, thus being able to maintain a more stable flame during the combustion process[10], [21].

Volatile Briquettes

Volatile substances are combustible components released when biomass is heated. A balanced volatile content is crucial for briquettes to ignite easily yet efficiently. Previous research has shown that volatile content levels in coconut shell charcoal briquettes range from 12–15%, with the lowest values obtained at high carbonization temperatures, which result in more stable combustion and higher calorific value.[22]On the other hand, briquettes made from durian (Durio zibethinus) skin generally have a higher volatile content[16],[19]. The results of this study show that the volatile matter content of young coconut shell briquettes is lower than that of durian shells, resulting in more stable and cleaner combustion. The volatile matter content determines the pattern of volatile gas release during initial combustion. Briquettes with a lower volatile matter content will undergo a slower and more controlled devolatilization process, resulting in a gradual release of combustible gas. This condition results in a more constant combustion rate and a more stable flame, without excessive flame surges. Conversely, a high volatile matter content causes the rapid release of volatile gas in the initial stages of combustion, resulting in an unstable flame, prone to fluctuations, and potentially producing more smoke. This finding is in line with similar research that shows very low volatile matter (<1%) in biomass composite biocharcoal indicates good combustion performance[23].

Calorie Value of Briquettes

The calorific value or combustion energy is the most important parameter for assessing the potential of a material as an alternative energy source. Several experimental studies have shown that briquettes made from young coconut shells achieve a calorific value above the minimum threshold of ≥ 5,000 cal/g. One study stated that the calorific value of coconut

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shell charcoal briquettes is in the range of 26,791–31,510 kJ/kg (≈ 6.4–7.5 kcal/g × 10^3, equivalent to ≈ 6400–7500 cal/g), thus clearly exceeding 5000 cal/g and indicating high energy potential for commercial and export applications[22]. In addition, several studies on durian peel also documented an increase in calorific value after carbonization or combination with other materials. The calorific value was up to 24,674 MJ/kg (≈ 5,900 cal/g) for a formulation mixed with durian peel and rice straw. The results of both studies all exceeded 5,000 cal/g and confirmed that thermal treatment/carbonization can produce durable and high-energy products from durian peel[24].

In this study, the calorific value of young coconut shell briquettes reached 5922 cal/g, meeting SNI 1/6235/2000 standards and exceeding that of most other agricultural biomass. This finding indicates significant potential for development as an environmentally friendly fuel that supports reduced dependence on fossil fuels. The results of the study indicate that almost all briquette quality parameters from both materials meet SNI standards, except for the ash content of durian peel. The non-compliance of one of the quality parameters with the SNI standard does not automatically indicate that the durian peel briquettes cannot be used as an alternative fuel. However, this condition indicates that the briquettes do not fully meet the criteria for standardized briquettes according to SNI provisions. SNI standards are designed to guarantee quality, combustion efficiency, and environmental impact, so failure to meet one of the parameters indicates quality limitations in certain aspects, particularly related to combustion residues and energy efficiency. Durian peel briquettes still have the potential to be used as an alternative fuel, especially on a non-standard scale or for limited use. For durian peel briquettes to meet SNI standards, production process improvements are needed, such as raw material optimization, mineral content reduction, or adjustments to the carbonization process and binder selection, to ensure all quality parameters are met. This finding is in line with the results of other studies that emphasize the importance of selecting raw materials with high lignin content to increase energy density and combustion stability[25].

Utilizing organic waste to produce biocharcoal briquettes has a positive impact on reducing organic waste accumulation, reducing methane emissions from open decomposition, and promoting a clean energy-based circular economy. Furthermore, using young coconut shells as a solid fuel can reduce dependence on firewood and LPG in coastal communities.

The statistical test results for all test parameters indicate significant differences in quality between the two materials. The significant differences demonstrated by the statistical test results across all parameters reflect not only differences in terms of meeting quality standards but also differences in the characteristics of the raw materials. The SNI standard serves as a threshold for suitability, while the statistical test results describe the relative quality levels between materials, including combustion efficiency, flame stability, and emission potential. Although both types of briquettes can meet or approach quality standards, statistically significant differences still indicate that one material has superior performance compared to the other in certain technical aspects. Durian peel briquettes still have the potential to be developed as a mixture material due to their abundant availability and relatively high calorific value (>5000 cal/g). The combination of the two materials could be an optimal solution for waste management and renewable energy in areas with high coconut and durian production.

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Based on the results of the study, it shows that briquettes made from durian peel and young coconut shell waste produce a briquette quality that meets the Indonesian National Standard for parameters of water content, bound carbon, volatile matter, and calorific value. So it can be used as an alternative fuel to replace coal. The availability of raw materials in the form of durian peel and young coconut shells is very abundant and can reduce waste or garbage that is not managed properly. The limitation of this study was that during charcoal production, it still produces air pollution; it is necessary to develop a more effective and more environmentally friendly carbonization tool. This development is carried out through the application of a closed carbonization furnace with a pyrolysis gas reuse system, carbonization temperature control, and the addition of a smoke condensation unit to reduce air pollutant emissions[26]. The use of a pyrolysis reactor that reuses pyrolysis gas as an internal heating source has been proven to reduce the release of harmful gases into the environment while increasing energy efficiency during the carbonization process compared to traditional open carbonization systems[27]. Reusing pyrolysis gas allows for more controlled secondary combustion, allowing the heat generated to be reused to maintain the carbonization temperature stably and efficiently[28]. The design of a closed carbonization system like this is in line with the principles of sustainable bioenergy production, because it not only improves the quality and yield of biochar, but also reduces air pollutant emissions through better process control and optimization of internal energy utilization[29], [30].

CONCLUSION

Briquettes made from young coconut shells have better quality than durian shell briquettes based on parameters such as water content, ash content, bound carbon, volatile matter, and calorific value. All results have met the quality standard of SNI 1/6235/2000, except for the ash content parameter of durian shells. Utilizing durian shell waste and young coconut shells as raw materials for biocharcoal briquettes has the potential to be a practical solution in providing alternative energy on a household scale while managing organic waste in an environmentally friendly manner. Implementation of this briquette technology can reduce dependence on fossil fuels and reduce the volume of solid waste that ends up in landfills. Further research can be conducted by testing mixtures of briquette raw materials, such as young coconut shells with sawdust, rice husks, or bagasse, as well as the use of alternative natural binders/adhesives such as cassava starch, sago flour, or molasses. Variations in the composition of these materials and binders are expected to increase combustion efficiency, extend burning time, and reduce emissions of harmful gases such as CO2 and particulates.

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