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Original Research Article

The Potential of Spent Bleaching Earth In Charcoal Briquettes as Energy Source

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Abstract

Eco-friendly alternative fuels encourage the use of waste biomass as a material for making briquettes. This study aimed to develop briquettes from rice husk biomass and peat moss and add spent leaching earth (SBE). SBE is a hazardous and toxic waste increasingly piling up in landfills. The research method involved carbonizing rice husks and peat moss, mixing them with SBE, molding with a 200 kg/cm^2 Hydraulic Press, and drying. The resulting briquettes had an average water content of 5.86% and an ash content of 2.18%, which meet the SNI No. 01/6235/2000 standard. Morphological analysis revealed that the briquettes were round but exhibited non-homogeneous aggregation. The highest calorific value was found in C4 briquettes of 5030.17 cal/gr. The composition of C4 was 40% rice husk charcoal (4.8 g), 45% peat (5.4 g), and 15% SBE (1.8 g), with SBE dried for seven days. The addition of peat increased the calorific value of the briquettes. Based on scanning electron microscopy (SEM)/ energy-dispersive X-ray (EDX) analysis, the carbon content in the C4 briquettes reached 72.2%. This study shows that the combination of rice husk charcoal, SBE, and peat provides a renewable energy source and contributes to the reduction of environmental waste, thereby promoting sustainability.

Keywords: Charcoal briquettes; spent bleaching earth; peat moss; rice husks; alternative energy

1. Introduction

Fossil fuel-based energy sources significantly contribute to greenhouse gas emissions, leading to rising global temperatures and environmental degradation of the planet. Moreover, fossil fuel reserves are depleting as they are finite and non-renewable (Bilgili et al., 2024; Gendek et al., 2018; Holechek et al., 2022). The increasing global population and rapid industrialization have further escalated energy demand, raising concerns about a potential energy crisis in the future (Fathonah et al., 2023). According to the National Energy Management Blueprint 2006–2025 by the Ministry of Energy and Mineral Resources (ESDM), Indonesia aims to diversify its energy sources by reducing oil consumption to less than 20%, while increasing the use of natural gas and coal to over 30% each, geothermal energy to over 5%, and renewable energy to over 5% by 2025 (Iskandar et al., 2019).

To address the dual challenges of energy security and environmental sustainability. Biomass is a promising alternative energy source. Biomass, derived from agricultural, industrial, and household waste, is renewable, abundant, and environmentally friendly (Melati et al., 2023; Parinduri et al., 2020) . Rice husks, a byproduct of rice milling, are particularly significant because they are readily available in large quantities in Indonesia, where rice is a staple food. Due to its renewability and potential for energy production, rice husk is a viable raw material for briquette production (Brand et al., 2017; Fathonah et al., 2023; Wang et al., 2018).

Previous studies on rice husk briquettes have shown that their calorific value and moisture content can meet the Indonesian National Standard (SNI No. 01/6235/2000) for briquettes, which includes parameters such as moisture content below 8%, ash content of 8%, carbon content of 70%, and calorific value above 5000 cal/g (Iskandar et al., 2019). However, briquettes composed solely of rice husks often exhibit low mechanical strength and reduced calorific value compared to those mixed with other biomass (Du et al., 2024; Qistina et al., 2016). For example, briquettes made with an 80:20 ratio of rice husk to coconut shell showed decreased calorific value as the adhesive concentration increased (Yuliah et al., 2017). Similarly, rice husk briquettes mixed with *tamanu* seeds or water hyacinth exhibited calorific values ranging from 4792.40 to 5100 cal/g, significantly higher than rice husk briquettes alone, which only achieved 2789 cal/g (Almu et al., 2014; M. Faizal et al., 2015; Qistina et al., 2016). Thus, incorporating other biomass materials is necessary to improve the calorific value, volatile matter, and mechanical strength of rice husk briquettes (Elsisi et al., 2025; Lohani et al., 2024).

Peat moss is another biomass material with high carbon content 25,3 % - 52,8% (Falatehan and Puspito Sari, 2020; Wen et al., 2020) and excellent physical properties, including water retention, high porosity, and good aeration capacity (Ulfah et al., 2023). Peat moss consists of cellulose, lignin, humic acid, and wax, making it a potential candidate as both a filler and adhesive in briquette (Aljumaili and Abdul-Aziz, 2023). Studies have shown that peat moss can serve as a binder for biomass fuel, improving its compressive strength and fuel quality (Halim and Razali, 2023).

In addition, spent bleaching earth (SBE), a solid waste generated by the palm oil industry, presents a potential material for briquettes. SBE has organic carbon of 15.5% - 28.52% (Placxedes et al., 2024) and lignin, which can increase the added value of briquettes and reduce the amount of adhesive used in making briquettes. Depending on its residual oil content, SBE can be classified as either hazardous or non-hazardous waste. SBE with more than 3% residual oil is prone to oxidation and fire hazards, posing environmental risks (Muslich et al., 2020). Although SBE has been utilized in fertilizers, fuel, and biodiesel production, its accumulation in landfills remains an environmental concern (Keasavan et al., 2023; Restu Amalia et al., 2023). Previous studies have shown that SBE mixed with adhesives can produce briquettes with high calorific value but low combustion efficiency due to high ash and volatile matter content (Saputri et al., 2020).

Given these challenges, this study aims to produce high-quality briquettes by combining rice husks, peat moss, and SBE. The characteristics of waste that can be used as briquettes must have a high carbon value (15.5% - 28.52%) (Placxedes et al., 2024), low water content, high density, have binding ability, do not contain inorganic materials and are environmentally friendly. Peat Moss has a carbon content (25.3% -52.8%) (Falatehan and Puspito Sari, 2020), water content (61,4%) and calorific value (21,679 Mj/kg atau 5181,4035 cal/g)(Wen et al., 2020). These materials, derived from waste sources, are not only environmentally sustainable but also address the mechanical and calorific limitations of rice husk briquettes. Additionally, the inherent lignin in peat moss and residual oil in SBE may reduce the need for external adhesives, which can otherwise lower the calorific value of the briquettes. The production process involves carbonization, mixing, molding, and drying, followed by quality testing to ensure compliance with SNI No. 01/6235/2000 standards (Almu et al., 2014; Fathonah et al., 2023; Yuliah et al., 2017). This study highlights the potential of rice husks, peat moss, and SBE as sustainable components for producing alternative energy briquettes, contributing to waste management and renewable energy development. It can reduce industrial waste from the palm oil refining process, which is increasing in number and has not been optimally utilized in SBE. The use of peat moss in making briquettes is still infrequent, even though peat moss contains high carbon value, is easily obtained in nature, and is not a food ingredient.

2. Methods

The materials used in making briquettes are spent bleaching earth, peat moss, and rice husks. Spent bleaching earth (SBE) was obtained from PT. Pacific Palmindo Industri. SBE was dried in the sun with variations of 3 days, 5 days, and 7 days. Peat Moss was first removed from its water content by drying it in the sun and then putting it in a furnace at 300°C for 30 minutes (Chand et al., n.d.; Elsisi et al., 2025). In contrast, rice husks were directly furnace at a temperature of 300°C for 30 minutes. Furthermore, all samples were standardized in size by being ground with a ball mill and sieved with a size of 100 mesh(Chaloupková et al., 2018; Junianti et al., 2024; Syukri et al., 2024). The size of 100 mesh indicates a particle size of 0.15 mm with a large surface area so that the resulting briquettes are easy to burn, have high density, and are more efficient. The size of 100 mesh makes briquettes easier to mix rice husks, peat moss, and SBE because they are easier to mold (Junianti et al., 2024; Syukri et al., 2024). Briquettes were made by mixing all samples so that the total weight of the briquettes was 12 grams (Abdillah and Siregar, 2024), with a percentage comparison that can be seen in Table 1 below:

Table 1. Comparison of sample composition in % Weight

Sample	Sample Comparison Percentage (%)			
Rice Husks	40	40	40	40
Peat Moss	30	35	40	45
SBE	30	25	20	15

In making these briquettes, 12 briquettes will be produced based on variations in the composition and drying time of SBE, which can be seen in Table 2 below.

Tabel 2. Variations in briquette composition

	Compositional Variations (gr)											
Sample Code	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**
Rice Husks	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Peat Moss	3.6	4.2	4.8	5.4	3.6	4.2	4.8	5.4	3.6	4.2	4.8	5.4
SBE	3.6	3.0	2.4	1.8	3.6	3.0	2.4	1.8	3.6	3	2.4	1.8
SBE is dried in the sun for	3 days				5 days				7 Days			

Rice husk becomes a fixed variable with a time variation of SBE drying for 3 days, 5 days, and 7 days. Briquette making is done by adding starch flour (Cassava). It has been gelatinized using hot water 70°C (Dohmen and Briko, 1958) and molded into a tube with a diameter of 2 cm and a length of 3 cm (Surabaya and Santoso, 2022; Utami et al., 2024) using a hydraulic press with a pressure of 200 kg/cm^2. Then, the briquettes are dried in the sun for 3 days (Irvan et al., 2021). The briquettes are tested for water content and ash content at the Goods Quality Certification Testing Center of the Industry, Trade, Energy, and Mineral Resources Service of the North Sumatra Provincial Government. The calorific value is tested in the Basic Chemistry Laboratory of PTKI Medan with a Bomb calorimeter with the Yoshida Nenken brand type Adiabatic Bomb Calorimeter of Approximately 800W, power supply: 1ϕ 100V 10A 50/60Hz, Stirring Speed: Outer tank 1800 rpm, Temperature Sensor: Thermistor. SEM/EDX testing was carried out in the laboratory of Malikul Saleh University, Aceh, to see the morphology and elements contained in the briquettes.

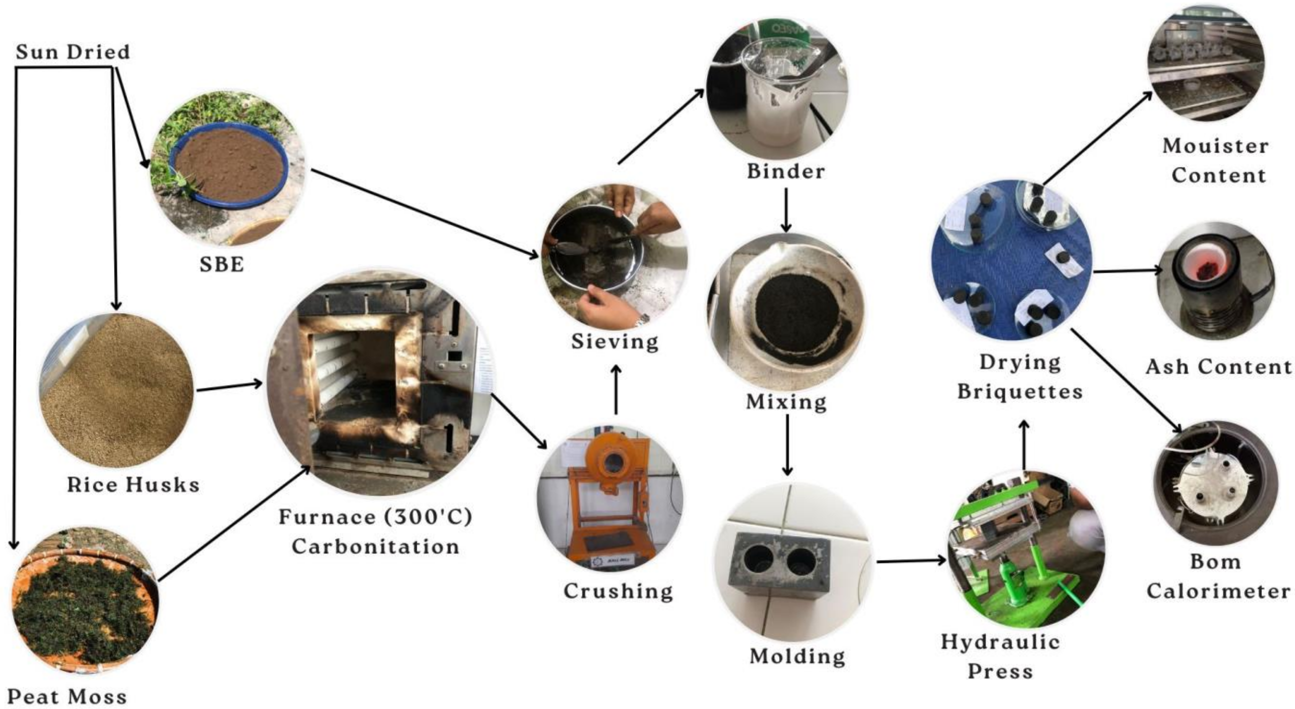


Figure 1. Systematic procedure for briquette production

3. Result and Discussion

Charring rice husks as charcoal briquette material is done by furnacing rice husks at a temperature of 300°C for 30 minutes (Chand et al., n.d.; Elsisi et al., 2025). The rice husk charcoal is grounded and sieved with a 100-mesh sieve (Chaloupková et al., 2018; Junianti et al., 2024; Syukri et al., 2024). Then, an analysis was carried out, and it showed 0.27% water content and 4.76% ash content. While for SBE, it has three variations. SBE dried for 3 days (Irvan et al., 2021). with a water content of 1.96%, dried for 5 days with a water content of 0.99%, and dried for 7 days with a water content of 0.87%. After the sample met the requirements for making briquettes, the materials were molded with variations in composition so that briquettes could be produced, as shown in Figure 2 below.

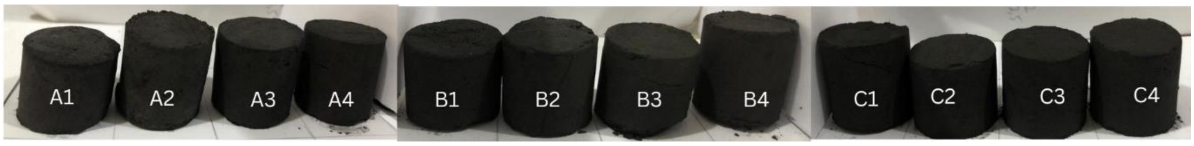


Figure 2. Briquettes based on Composition Variation

The resulting briquettes are then tested for their characteristics based on water content, ash content, calorific value, morphology and to determine the elements in the material.

3.1. Water Content and Ash Content

The moisture content of briquettes affects their calorific value. The lower the moisture content in the briquettes, the higher their calorific value. Also, the higher the composition of the binder, the lower its calorific value. Hence, this results in higher moisture content but lower specific gravity and energi (Nurek et al., 2019). To calculate the moisture content, the principle of water removal is used in an oven at a temperature of 103°C. Meanwhile, to calculate the ash content, the sample is burned in a furnace, and the ash weight is divided by the initial sample weight according to SNI No.01/6235/2000. Analysis of moisture content and ash content refers at Figure 3 below.

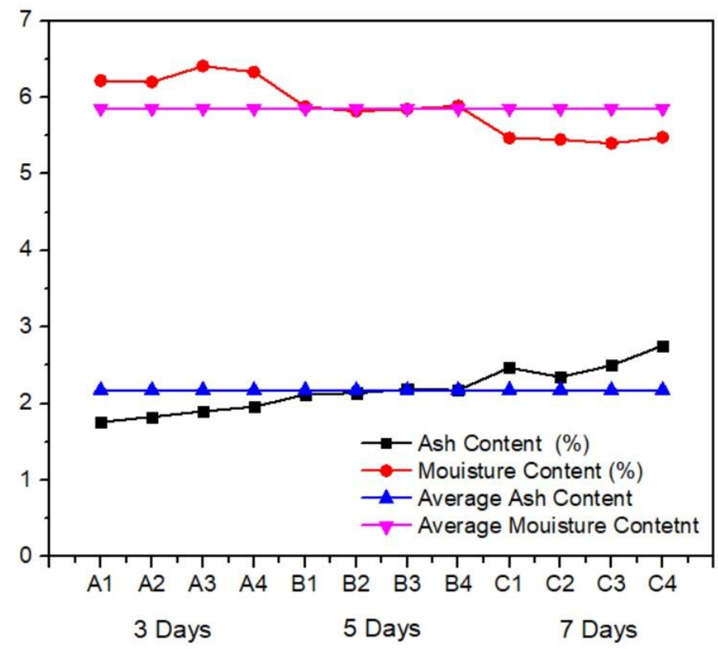
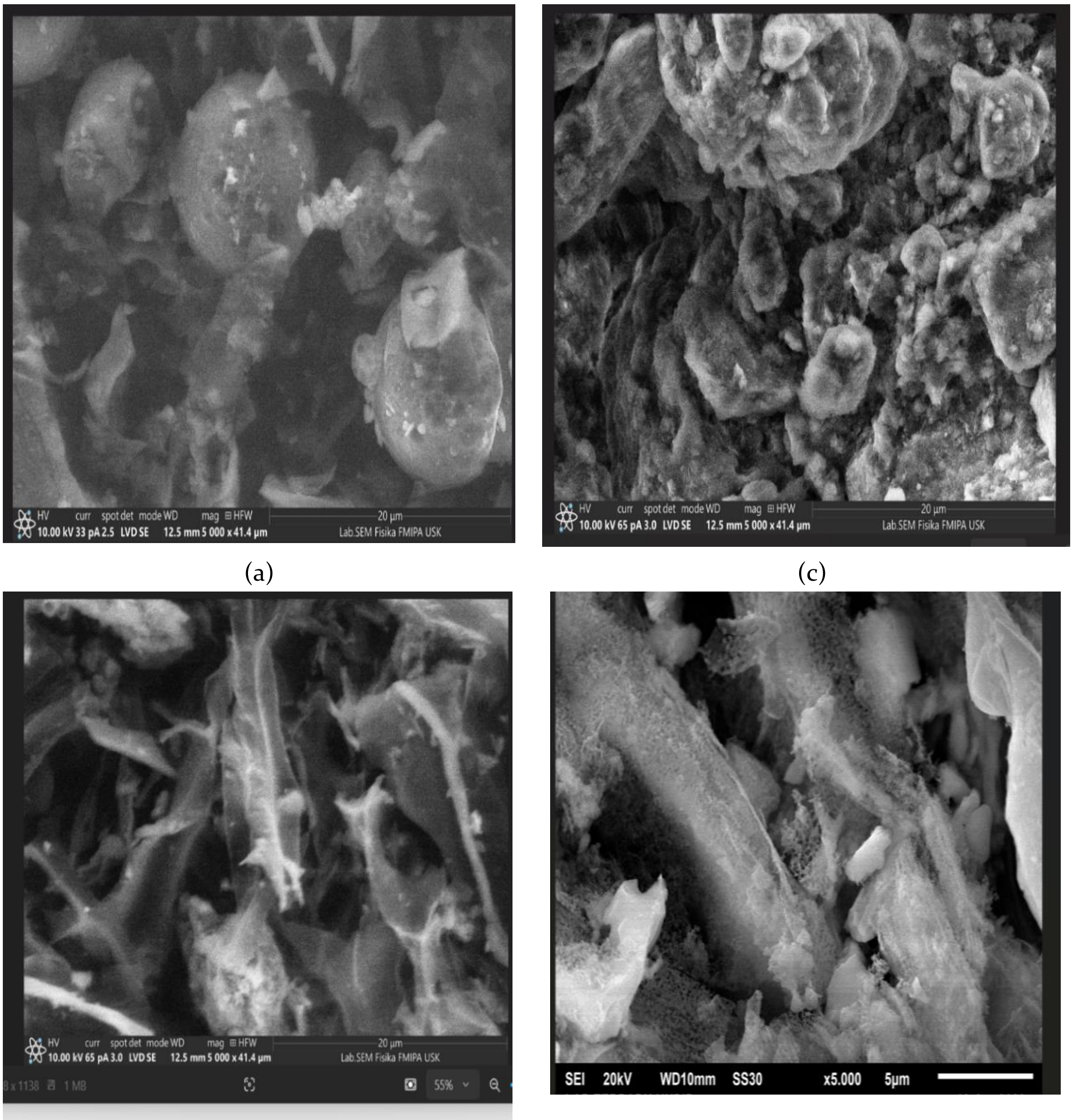


Figure 3. Moisture content and ash content

The graph shows that the drying time of SBE results in a decrease in moisture content, but the ash content in the briquettes tends to increase. This is because during the drying process, water evaporation occurs, leaving behind solid residues, which causes the ash content to increase. The ash content represents the amount of inorganic solid residue left after the material is burned (Vassilev et al., 2017). Water content also has the most significant impact on the mechanical strength of briquettes after drying (Elsadek et al., 2024; Lomunyak et al., 2024). In briquette making, SBE is added based on the drying time, with variations of 3, 5, and 7 days under sunlight. It is indicated that the variation of SBE drying causes the water content in the briquettes to decrease due to the influence of the water evaporation process on the briquettes over time. The water content of the various samples met the SNI Briquette standards.

3.2. Characterization of Briquettes

Scanning Electron Microscope (SEM) tools were used to characterize the morphology and composition of briquette samples made from rice husks, peat moss, and spent bleaching earth (SBE). The morphology of the briquette sample can be seen in Figure 4. The morphology of the briquette sample is round with non-homogeneous particle sizes, and algomerization occurs (Wang et al., 2018) (Peng et al., 2023). This shows that the mixture of materials with different characteristics has interacted well. The morphology of briquettes, SBE, peat moss, and rice husks can be seen in Figure 4 below.



(a) (c)

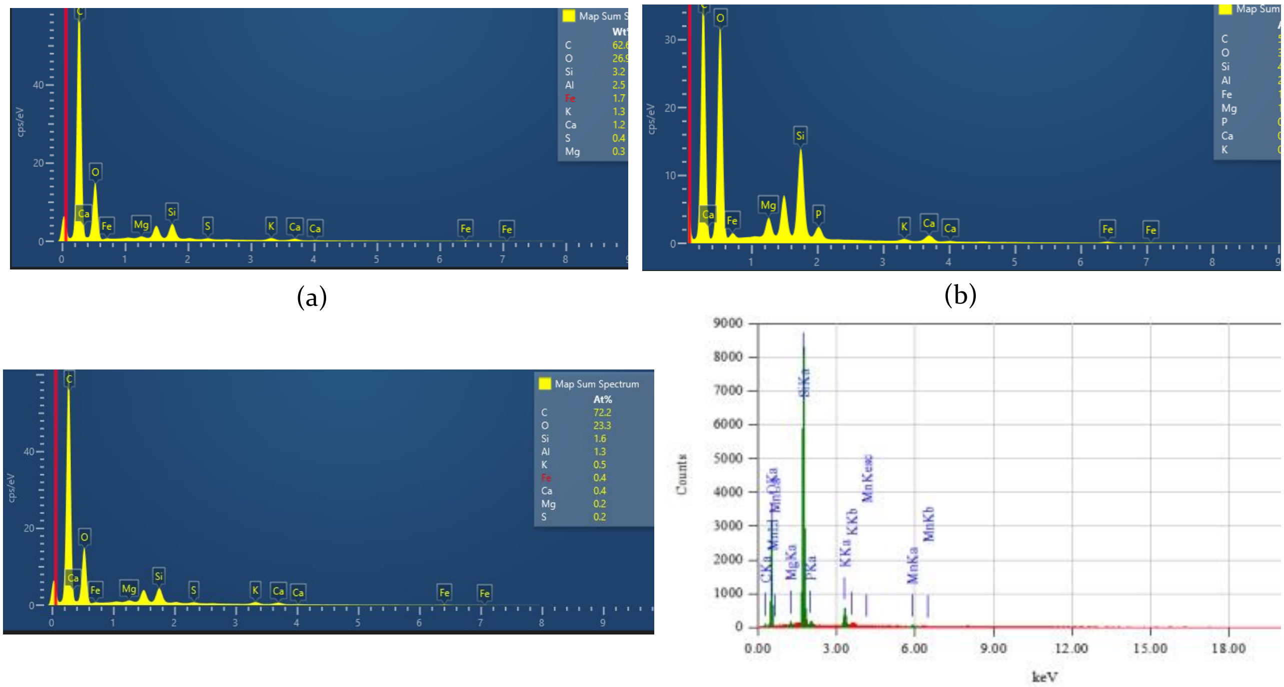
(b) (d)

Figure 4. Morphology of Briquettes (a), Peat Moss (b), SBE (c), and Rice Husks (d)

From Figure 4, the particle shape of SBE can be seen with a magnification of 5000 times, namely the uneven particle surface shape and the protruding and clumped pores, which show the characteristics of the adsorbent. The surface morphology of peat moss (Figure 4c) looks like a layer with an irregular arrangement (Tarigan et al., n.d.), while the morphology of rice husks in Figure (4d) looks like fractures or cracks (Tarigan et al., 2024) and the morphology of peat moss and rice husks shows significant pores. The formation of pores in peat moss and rice husks is indicated by heat treatment, and the pore size provides high porosity properties (Hasibuan and Pardede, 2023). Rice husk has a thicker, more rigid, and uneven fibrous structure, indicating high silica, as shown in the EDX results in Table 2, namely 37.68%.

Briquette fillers have porosity, so the resulting briquettes have high porosity. The increasing concentration of adhesive also causes the presence of pores (Yirijor and Bere, 2024). Pores cause water in the briquettes to be retained, which increases the volatile content. However, another advantage of briquettes having large pores is that they can accelerate combustion and absorb heat better. Getting the best composition must be considered to get briquettes that balance mechanical strength and high calorific value (Ngene et al., 2024; Pathaveerat et al., 2024). Meanwhile, the composition of peat moss from the Energy Dispersive X-Ray (EDX) test results shows that it has a high carbon content of around

72.2% which is expected to increase the calorific value of rice husks. Rice husks based on SEM test results show the morphology of rice husks with constituent components (EDX results in figure 4d) showing a carbon content of around 71.2%.



(a) (b)

(c) (d)

Figure 5. EDX results of Briquettes (a), SBE (b), Peat Moss (c), Rice Husks (d)

From Figure 5, it can be seen that all components have almost the same proportion and the highest carbon value. The composition of carbon values in the material can be seen in Table 3 below

Table 3. Components of Spent bleaching earth, Rice husk, Peat moss, and briquettes

No	Component	Spent bleaching earth (%)	Rice husks (%)	Peat moss (%)	Briquettes (%)
1	C	54.0	11.04	72.2	62.6
2	O	35.2	45.24	23.3	26.9
3	Si	4.8	37.68	1.6	3.2
4	Al	2.1	-	1.3	2.5
5	Fe	1.2	-	0.4	1.7
6	Mg	1.0	0.44	0.2	0.3
7	P	0.8	0.76	0	0
8	Ca	0.8	-	0.4	1.2
9	K	0.2	0.3	0.5	1.3
10	S	0	0	0.2	0.4
11	Mn	-	0.51	-	-
12	K	-	4.32	-	-

Table 3 is the result of the EDX test, which obtained the carbon component content in briquettes, which is around (62.6%), more significant than the constituent materials of rice husk (11,04%) and peat moss (72.2%). It is because in the briquette-making process, which is added a starch binder (Qistina et al., 2016).The addition of SBE indicates that it can reduce carbon content because SBE contains silica and other inorganic materials. From the table, it can also be seen that the mixture of rice husk, peat moss, and SBE as briquette material has been mixed well, which can be seen from the more uniform element composition.

Briquettes result from rice husk, peat moss, and SBE. The carbon value of the briquettes is 62.6% higher than rice husk and SBE but lower than Peat Moss. This shows that Peat Moss, the material with the highest carbon composition, significantly contributes to increasing the total carbon in the briquettes. Peat Moss dominates the carbon content because its composition is rich in organic matter. Spent Bleaching Earth (SBE) also contributes a significant amount of carbon, although it is lower than Peat Moss. Adding peat moss containing organic compounds rich in carbon will increase the carbon value of the briquette because the carbon in the peat moss will combine with the main ingredients in the briquette. A high carbon value is expected to increase the calorific value of the briquette. Peat moss, which is biomass, can produce activated carbon through a heating process without oxygen, thereby increasing the carbon value. Increasing the carbon value can improve energy efficiency because carbon has a high capacity to produce heat. Carbon has a C-H structure, and when the C-H bond is broken in a combustion reaction, the energy is released in the form of heat(Yang et al., 2011). Carbon in briquettes is a source of energy in the combustion process.

3.3. The Calorific Value

It is essential to analyze the calorific value of briquettes. This is because briquettes are used as an alternative energy source. The calorific value can be calculated using briquettes to boil one liter of water using the following equation (1):

$$Q = (m_{water} \times Cp_{water} (T2\text{-}T1)) + (m_{vapour} \times H_{fg}) \quad (1)$$

Where

Q = Heat received by water (kJ),

m_{air} = Mass of water (kg),

Cp_{air} = Specific heat of water (41.662 kJ/kg°C),

T1 = Initial boiling temperature of water (°C),

T_2 = Final boiling temperature of water (°C),

m_{uap} = Mass of water evaporated during cooking (kg)

Hfg = Latent heat of vaporization of water (225 kJ/kg).

The calorific value for each sample can be seen in Table 4 below.

Table 4. Calorific value of briquettes

No	Sample	Calorifivic Value (cal/g)	Spent Bleaching Earth Drying Time
1	A1	16.990	3 Days
2	A2	10.120	
3	A3	10.920	
4	A4	9.230	
5	B1	16.990	5 Days
6	B2	19.120	
7	B3	18.920	
8	B4	19.230	
9	C1	24.220	7 Days
10	C2	23.600	
11	C3	20.540	
12	C4	21.960	

From the table above, it can be seen that the results of measuring the calorific value of briquettes from mixing rice husks, peat moss, and SBE increased in each of the test samples. The highest calorific value was in the C4 briquette of 5030.17 cal/gr. The composition of C4 is 40% rice husks (4.8 gr), 45% peat moss (5.4 gr), and 15% SBE (1.8 gr), which were dried for 7 days. This is higher than the calorific value of rice husk briquettes plus coconut shells with a ratio of (50%: 50%), which is 4526 cal/gr (Qistina et al., 2016). The calorific value of SBE itself is 2400 - 2600 cal/g of air (Restu Amalia et al., 2023). Adding peat moss biomass and SBE waste indicates an increase in calorific value in rice husks of 80,35%. The results of carbon content measurements in peat moss obtained 72.2%, and SBE obtained 54% using the EDX test. High carbon content can increase the calorific value of briquettes. In addition, water content can also affect the calorific value. Graph 3 shows that the water content in briquettes decreases along with the drying time of SBE. The briquette components' uniform and fine particle size (100 mesh) allow for increased density and better binding of the briquettes so that heat transfer and release are better (Yirijor and Bere, 2024).

The use of SBE in making briquettes is expected to have a dual function, namely, it can be used to increase the calorific value and as an adhesive. SBE still contains a lot of crude palm oil. According to the research of Bima Prasetya Pancasakti and Vincent in 2021, olive oil can improve the quality of natural adhesives made from tapioca flour. The content of phenol groups can be an additive in making adhesives (Pancasakti and Vincent, 2021). Olive oil and crude palm oil have the same composition. The adhesive used in this study was 5%, other studies using 7% adhesive produced the best briquettes (Novitrie et al., 2023).

The low ash and sulfur content is vital in making briquettes, but the carbon value remains high (Fauzy et al., 2023; Guibunda et al., 2024; Kamdem et al., 2025; Novitrie et al., 2023). This also occurs when making briquettes with rice husks, peat moss, and SBE. SBE and peat moss do not have sulfur elements, while peat moss contains 0.2% sulfur. But briquettes contain 0.4% sulfur. This does not affect the potential of briquettes, which have a high calorific value, which proves that SBE waste can be used as a filler for briquettes as an alternative source and can reduce the accumulation of SBE waste in landfills.

Using briquettes is harmful if it produces carbon monoxide, nitrogen oxide, and particulate compounds (Bamisaye et al., 2023; Oduro et al., 2024). Briquettes with a mixture of Rice Husk, peat moss, and SBE are indicated to have low emissions, because rice husks and moss have cleaner sulfur and carbon content. As in Narathip Pawaree's research, the use of waste as a filler for briquettes is an integral component of green economic initiatives to implement environmentally friendly processes (Ke et al., 2024; Lomunyak et al., 2024; Nonsawang et al., 2024; Pawaree et al., 2024). Briquettes with a mixture of SBE and Peat Moss are used as fuel in industries such as palm oil mills.

4. Conclusions

The calorific value, which consists only of rice husk, has a calorific value of 2789 cal/gr. With the addition of peat moss and SBE, the calorific value of the briquette becomes 5030.17 cal/gr, an increase of 80.35%. The increase in calorific value is due to the addition of peat moss and SBE biomass, which have 72.2% and 54% carbon values. High carbon content can increase the calorific value of the briquettes. The water content and ash content of the briquettes produced have met the SNI briquette standards, namely 5.86% for water content, and the average ash content of the briquettes is 2.18%. The addition of SBE as an adhesive has yet to be successful, but the oil content in the briquettes, if further treatment is carried out, can increase the strength of the briquettes. Briquettes with a mixture of SBE, rice husks, and peat moss have the potential to be an alternative energy source and can reduce SBE waste which is hazardous and toxic waste.

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