Jurnal Rekayasa Kimia & Lingkungan
(Journal of Chemical Engineering and Environment)
Vol. 20, No. 1, Page 150 – 160, June 2025
ISSN 1412-5064, e-ISSN 2356-1661
https://doi.org/10.23955/rkl.v20i1.43793

Conversion of Green Coconut Shell and Husk into Biobriquette Using Jatropha seed Adhesive

Putri Agus Utami[1], Raudhatul Aulianatia Sudarmi[1], Siti Sahara[1], Khairul Anwar[2], Mahidin[1]*, Fauzi[1]

[1] Department of Chemical Engineering, Universitas Syiah Kuala
[2] Master Program, Department of Chemical Engineering, Universitas Syiah Kuala
*E-mail: mahidin@usk.ac.id

Article History
Received: 3 January 2025; Received in Revision: 6 March 2025; Accepted: 17 March 2025

Abstract

Green coconut shell and husk (GCSH) waste had the potential to pollute the environment if not properly utilized. As a solution, innovations in processing GCSH into biobriquettes could generate eco-friendly renewable energy with economic value. This study aimed to optimize the utilization of GCSH as a raw material for biobriquettes by adding jatropha seeds as an adhesive, as well as evaluating the characteristics of the produced biobriquettes. Fabrication of biobriquette was carried out using two methods: conventionally (without burning) and by pyrolysis (with burning) at temperatures of 380°C, 430°C, and 480°C for 3.5 hours. The charcoal obtained from pyrolysis was mixed with jatropha seed adhesive at concentrations of 15%, 20%, and 25%, then molded at a pressure of 110 kg/cm² and dried at 105°C. The results showed that pyrolysis temperature and adhesive concentration affected the moisture content, ash content, calorific value, compressive strength, and combustion rate of the biobriquettes. Optimum conditions were achieved at a pyrolysis temperature of 430°C with the addition of 25% adhesive, resulting in biobriquettes with high calorific value (6367.74 cal/g), low moisture content (7.44%), and good combustion rate (0.10219 g/min). This study proved that utilizing GCSH waste and jatropha seeds for biobriquettes had great potential as an efficient and sustainable source of renewable energy.

Keywords: Green coconut shell and husk, pyrolysis, biobriquette, jatropha seed, renewable energy

Copyright ©2025 Published by JTK-USK

1. Introduction

In responding to global energy challenges and environmental concerns, it is important to find and utilize alternative renewable energy sources from available natural resources. Indonesia with its natural wealth, has great potential in alternative energy. One of the alternative energies that is currently being developed is biobriquettes, a solid fuel made from biomass, which has a high calorific value and can burn for a long time. Biomass that is often used usually comes from the plantation, forestry, and agricultural sectors. One of the biomasses that has the potential to be used as biobriquettes is waste from coconut plantations. Aceh Province has considerable biomass potential from coconut plantation waste. Based on data from Badan Pusat Statistik (BPS, 2023), the area of coconut plantations in Aceh Province reached 102.60 thousand hectares, although specific data on coconut waste in Aceh is not available, but high coconut production indicates the potential for large coconut waste (Agustiar et al., 2023).

A lot of waste that is still an unused material is green coconut waste consisting of coconut shell and husk. Green coconut husk waste is usually just wasted in the trash, even often thrown into the gutter which can cause flooding. In fact, green coconut shell waste contains lignocellulose which has the potential to be utilized in making bio-briquettes (Nunes et al., 2020). Biobriquettes are solid fuels derived from residues of organic matter or from biomass waste. The quality of briquettes depends on the type of raw material and its operation such as humidity, temperature, substrate addition, particle size, and others. Briquettes are solid fuels that require consideration of calorific value, ash content,

To cite this article: Utami, P.A., Sudarmi, R.A., Sahara, S., Anwar, K., Mahidin, M., Fauzi, F. (2025) Conversion of Green Coconut Shell and Husk into Biobriquette Using Jatropha seed Adhesive, *Jurnal Rekayasa Kimia & Lingkungan* 20 (1): 149 - 159 https://doi.org/10.23955/rkl.v20i1.43793

water content (moisture), volatile matter, and carbon content (Dalimunthe et al., 2021).

Biomass naturally contains structural adhesives or intrinsic stabilizing agents. However, these natural adhesive properties are often insufficient to produce dense and durable briquettes, so additional adhesives are commonly added during the production process (Olugbade et al., 2019). To make biobriquettes, in addition to raw materials, an adhesive is also needed to ensure the briquettes are not easily broken. The selection of the type of adhesive is crucial, especially for fine biobriquettes derived from biomass carbonization, which require a strong and environmentally friendly adhesive mixture that does not produce smoke during combustion. Furthermore, key characteristics such as ash content, moisture content, and briquette density are strongly influenced by the type and concentration of adhesive used. Common adhesives in biobriquette production include tapioca, starch, tar, asphalt, and paraffin (Ningsih et al., 2023).

The utilization of GCSH waste for biobriquette production had been widely practiced. Harahap et al. (2023) made briquettes from GCSH with tapioca adhesive through a carbonization process. Meanwhile, Ahmad et al. (2022) used GCSH waste to make biobriquettes with tapioca adhesive without any treatment, where the biomass was only dried. The moisture content of the produced biobriquettes was still quite high, ranging from 11-25%, which exceeded the quality standards for briquettes according to SNI. Green coconut shell and husk waste have high moisture and ash content, with low calorific and carbon values. To overcome this, the study used pyrolysis—a process that converts biomass into charcoal (biochar), bio-oil, and gas by heating without oxygen. Pyrolysis offers high conversion efficiency, produces energy-rich products, and results in low-smoke briquettes, helping reduce harmful emissions (Harahap et al., 2023; Mu et al., 2023).

In this study, GCSH waste was pyrolyzed, the pyrolysis results were then used as raw materials in making biobriquettes with the addition of jatropha seeds as an adhesive. Jatropha seeds are sticky and viscous due to their high gum content, which helps maintain the density of the briquettes. Jatropha seeds consist of 56.39% carbon, 7.99% hydrogen, 2.81% nitrogen, 0.21% total sulfur, and a calorific value of 5864 kcal/kg. The addition of jatropha seeds as an adhesive has been carried out by Mahidin (2011) on the manufacture of briquettes from a mixture of young coal and palm shells which showed that the concentration of jatropha seed adhesive at 20% gave optimal results in terms of combustion rate. Therefore, further research on the use of jatropha seed adhesive can provide insight into how the effect of the addition of jatropha seeds on the characteristics of the briquettes produced. In addition, it is hoped that this research can be a solution to the utilization of GCSH waste and jatropha seeds, which are very abundant in Indonesia.

2. Methodology

2.1. Materials

Green coconut waste was collected from coconut water sellers around Banda Aceh and jatropha seeds, with greenish-yellow fruit, were obtained from plantations in North Aceh. The equipment used in this research were pyrolysis equipment, grinder mill (Steel Alloy FFC 15), hydraulic press machine, oven (Gemmy888 YCO-010), furnace (Carbolite Furnace CSF 1100), bomb calorimeter (DDS Bomb Calorimeter model CAL3K-S), unit testing machine, 60 mesh sieve, mortar and pestle, analytical scales (Saffron with with an accuracy of 0.0001 g or 0.1 mg), containers/trays, spatulas, stopwatch, and desiccator.

2.2. Briquetting Procedure

GCSH waste that has been collected from coconut water sellers in Banda Aceh city was then reduced in size to 5x5 cm and then dried to reduce the moisture content. The drying process was carried out under sunlight for approximately 7-14 days, depending on weather conditions. The moisture content of GCSH was monitored periodically until it reached 20%. Furthermore, for samples without pyrolysis treatment after drying the GCSH was immediately ground and sieved with a 60 mesh sieve to get a uniform size. As for the sample with pyrolysis treatment after the GCSH was dried, the pyrolysis process was carried out with temperature variations of 380, 430, and 480°C for approximately 3 hours, then the charcoal from pyrolysis was ground and sieved with a 60 mesh sieve to get a uniform size. The experimental procedure for the raw material (GCSH) preparation steps outlined in Fig. 1. After preparing the raw materials, the next step is making biobriquettes, which includes adhesive preparation and briquette shaping, as shown in Fig. 2. The sieved GCSH powder was mixed with adhesive made from jatropha seeds.

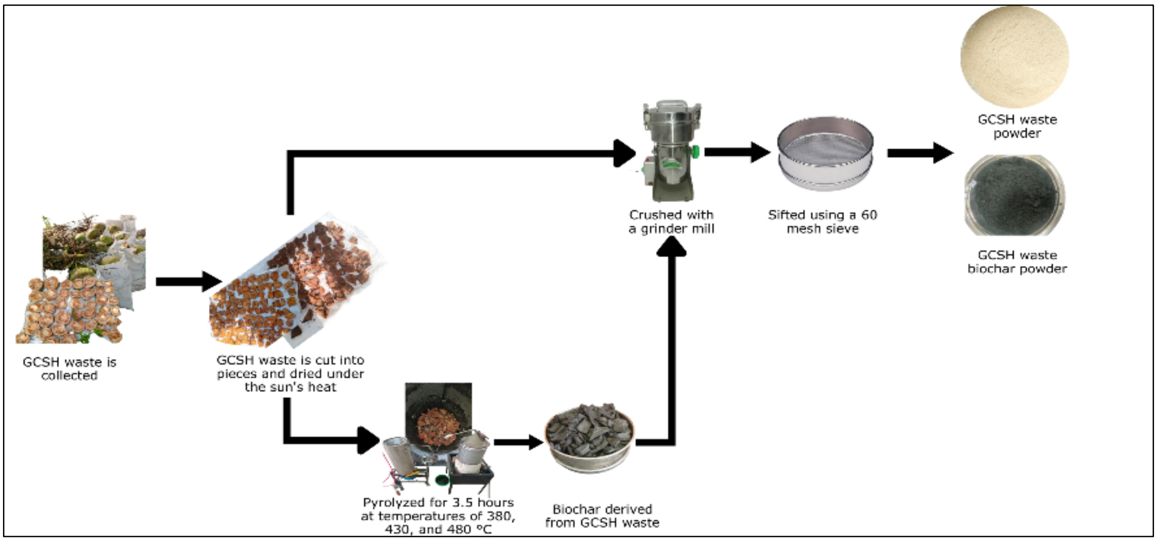

Figure 1. Raw material preparation without pyrolysis and with pyrolysis

(a) (b)

Figure 2. Briquetting procedure (a) Adhesive preparation; (b) Biobriquette manufacturing

The jatropha fruit used had green to yellow skin, as the oil content is highest when the fruit is yellow. Harvesting jatropha at this stage can increase oil yield by 6–9%, with a moisture content of 53.98% and oil content between 38.7–45.8% (Jonas et al., 2020). The adhesive preparation process involved separating the seeds from the fruit skin without drying to preserve the oil and gum content. The Jatropha seeds were then and used as a adhesive with a percentage variation of 15, 20, and 25% for each sample. The biobriquette were molded under a pressure of 110 kg/cm^2. The molded biobriquettes were then dried in an oven for 2 hours with a temperature of 105°C and continued with characteristic analysis as presented in Fig. 2b.

2.3. Moisture Content Analysis

The moisture content analysis was carried out by drying the biobriquettes in an oven until the weight of the biobriquettes was constant. This moisture content test was carried out at a temperature of 105°C for 3 hours. After the weight of the briquette was constant, the sample was removed and cooled in a desiccator (Ajimotokan et al., 2019). As for determining the water content in biobriquettes could be determined by Equation 1.

$$\text{Moisture content} = \frac{W_1 - W_2}{W_1} \times 100\% \qquad (1)$$

Remark:
W_1 : total weight of wet biobriquette (gr)
W_2 : total weight of dry biobriquette (gr)

2.4. Ash Content Examination

The ash content analysis was carried out by placing the biobriquettes in a furnace at a temperature of 800°C for 5 hours. The biobriquette sample was weighed with a petri dish of known weight. Subsequently, the biobriquettes were put into the furnace and heated. After being heated the sample was removed and weighed after cooling (Ajimotokan et al., 2019). As for determining the ash content in biobriquettes could be determined by Equation 2.

$$\text{Ash content} = \frac{A}{B} \times 100\% \qquad (2)$$

Remark:
A : ash weight (gr)
B : biobriquette weight (gr)

2.5. Calorific Value Determination

Calorific value could be measured using a bomb calorimeter. Calorific value testing was used to measure the amount of energy produced when biobriquettes were burned. Calorific value testing was carried out using the dynamic (isoperibol) method.

2.6. Determiantion of Combustion Rate

The combustion rate could be measured by burning the biobriquettes in a container (tray). Subsequently, the time required was seen using a stopwatch until the biobriquettes were completely burned. As for determining the burning rate, it could be determined by Equation 3.

$$\text{Combustion rate} = \frac{m}{t} \quad (3)$$

Remark:
m : weight of burned biobriquettes (gr)
t : burning time (min)

2.7. Compressive Strength Test

The compressive strength test determined the ability of the biobriquettes to withstand the load before being destroyed. The compressive strength test was carried out by following ASTM D2395-17.

3. Results and Discussion

3.1. Comparison of Biobriquette Quality with SNI

To evaluate the quality of the produced biobriquettes, the test results are compared with the Indonesian National Standard (SNI) 01-6235-2000 for biomass briquettes. The results of the comparison between the SNI quality standards and the tested biobriquettes are presented in Table 1.

Table 1 presents a comparison of biobriquette quality based on the Indonesian National Standard (SNI) 01-6235-2000 and the test results obtained in this study. The parameters compared include moisture content, ash content, and calorific value. From the table, it can be determined to what extent the biobriquettes produced in this study meet the established standards or deviate from them.

However, it can be seen that in biobriquettes with treatment without pyrolysis the 25% adhesive concentrations exceed the requirements of SNI. This can be caused by the reaction of the material to the evaporation of water content or dehydration takes place slowly at the low temperatures used. Conversely, higher temperatures will reduce the water content of charcoal so that it has an impact on the low water content of bio-briquettes (Hasibuan et al., 2024). Increased moisture content describes inefficient combustion and will result in excessive smoke emissions. This shows that bio-briquettes produced by the pyrolysis process are better and more profitable because the resulting fuel is efficient and produces no emissions during combustion (Bonsu et al., 2020).

In Fig. 3, it can also be seen the effect of concentration variations where the greater the concentration of jatropha seed adhesive, the higher the water content in the bio-briquettes. The addition of adhesive in higher concentrations tends to increase the moisture content of bio-briquettes, as adhesives generally contain water that is absorbed by the components of the bio-briquettes.

Table 1. Comparison of Biobriquette Quality According to SNI 01-6235-2000 and Experimental Results

Sample		Parameter				
Temperature (°C)	Concentration (%)	Moisture Content (%)	Ash Content (%)	Calorific Value (cal/gr)	Combustion Rate (gr/min)	Compressive Strenght (Kgf/mm^2)
SNI 01-6235-2000		8	8	5000	-	-
0	15	5,10	4,05	3627,65	0,17614	0,4212
	20	6,85	3,39	3778,13	0,16848	0,4613
	25	8,86	3,69	4309,57	0,13861	0,4471
380	15	4,12	7,47	6348,63	0,17164	0,0134
	20	5,47	6,33	5869,98	0,12500	0,0129
	25	7,44	5,18	5575,71	0,10417	0,0103
430	15	3,28	10,11	6454,44	0,12295	0,0116
	20	4,62	8,13	6183,11	0,11240	0,0095
	25	6,71	7,23	6367,74	0,10219	0,0139
480	15	2,59	12,44	6567,66	0,11600	0,0146
	20	3,94	11,1	6181,20	0,08955	0,0109
	25	4,50	10,54	5890,52	0,08940	0,0142

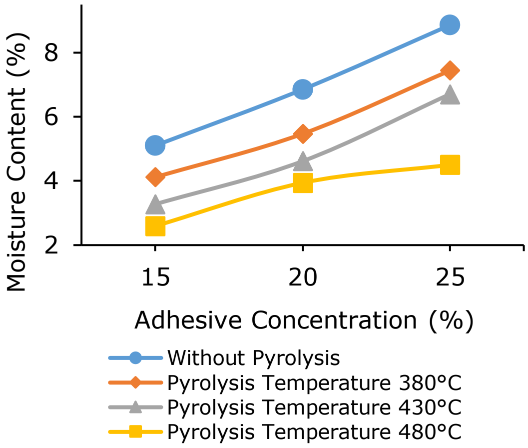

Figure 3. Effect of pyrolysis and adhesive concentrations on the moisture content

This causes the total moisture content in the bio-briquettes to rise. However, higher adhesive concentrations also enhance the binding strength between bio-briquette particles, resulting in a denser structure with smaller pores. This reduction in porosity limits the bio-briquettes' ability to absorb water from the external environment, making bio-briquettes with high adhesive concentrations have lower water absorption capacity compared to those using less adhesive (Ningsih et al., 2023). Based on research that has been done with proximate analysis per 5 grams of jatropha seeds has a water content of 4% so that based on this proximate analysis the water content in the biobriquettes produced can be influenced by the amount of jatropha seeds used (Odey et al., 2018). In addition, the high-water content in briquettes can be caused by several factors. One of them is the water content in the biomass itself, where the water content in newly harvested coconut husks ranges from 29-35%. In fact, according to research, after being dried for 6 days, the water content in coconut husks only drops slightly, which is around 26% (Obeng et al., 2020). The high moisture content in bio-briquette products can cause the briquettes to swell and degrade easily and sometimes break frequently in the furnace during combustion (Bonsu et al., 2020).

Based on Fig. 3, the optimal operating conditions for producing biobriquettes with low moisture content are at a pyrolysis temperature of 480°C and an adhesive concentration of 15–20%. Increasing the pyrolysis temperature accelerates the dehydration process and significantly reduces moisture content, resulting in higher-quality biobriquettes. On the other hand, excessive adhesive addition increases moisture content due to the water content in jatropha seed adhesive. Therefore, a combination of high pyrolysis temperature and moderate adhesive concentration is the most ideal condition for producing biobriquettes that comply with SNI 01-6235-2000 standards.

3.2. Effect of Pyrolysis and Adhesive concentration on the Moisture Content

Analysis of water content in biobriquettes is carried out to see how much water is still contained in biobriquettes that have been molded with various methods either with pyrolysis or without pyrolysis. Moisture content is an important parameter that affects the quality of briquettes. Briquettes that have a low moisture content will produce less smoke when burned and will be more flammable, while high moisture content will make briquettes difficult to burn and produce a lot of smoke when burned. In addition, the moisture content will also affect the calorific value of the briquettes (Mardawati et al., 2022). Based on Fig. 3, it shows that the water content in green coconut husk and shell biobriquettes with jatropha seed adhesive as a whole has met the requirements of SNI 01-6235-2000, which is max. 8%.

3.3. The Effect of Pyrolysis and Adhesive concentration on the Ash Content

Ash content is one of the characteristics of briquettes that is useful for determining the amount of the mass of incombustible material remaining after burning a given briquette sample, expressed as a percentage (Sanchez et al., 2021). The less ash is produced during combustion, the better the quality of the fuel. This is because the low ash content indicates that the fuel is more efficient at releasing energy without leaving a lot of unburned residues (Novitrie et al., 2023).

Based on Fig. 4, the briquettes from this research have also met the requirements of SNI 01-6235-2000, which is a maximum of 8%. However, the briquettes in the pyrolysis treatment with temperatures of 430ºC and 480ºC have ash content that exceeds the SNI requirements. The increase in pyrolysis temperature directly leads to a rise in ash content in biobriquettes, which occurs through two primary mechanisms. First, at higher temperatures, more carbon particles combust into ash, resulting in a greater amount of residual ash (Kethobile et al., 2019). Second, the pyrolysis process removes volatile and organic compounds, leaving behind inorganic minerals such as phosphorus (P), potassium

(K), magnesium (Mg), and zinc (Zn) in higher concentrations within the ash. This increase in ash content indicates an elevation in certain mineral concentrations, as higher temperatures cause more organic matter in the biomass to evaporate or combust, while these minerals remain as ash.

Scientifically, higher pyrolysis temperatures lead to greater decomposition of volatile compounds, leaving mainly inorganic or mineral components. Consequently, the ash content rises due to the higher proportion of minerals in the combustion residue (Chen et al., 2025). Biobriquettes with low ash content can reduce the corrosive effects on combustion equipment, because ash contains inorganic compounds that can form corrosive substances when reacting with combustion gases (Kumar et al., 2020). In addition, high ash content in biobriquettes can cause fuel blockage and reduce combustion rates, because the resulting residue can block air flow and reduce heat transfer efficiency. Therefore, biobriquettes with low ash content not only improve combustion efficiency but also extend equipment life and reduce maintenance costs (Hasibuan et al., 2024).

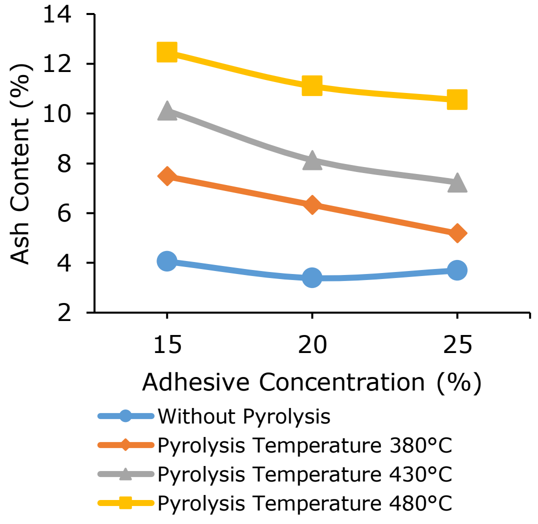

Figure 4. Effect of pyrolysis and adhesive concentrations on the ash content of biobriquettes

Based on Fig. 4, it can also be seen that the higher the adhesive concentrations, the lower the ash content in the briquettes. In the proximate analysis that has been carried out, the ash content in jatropha seeds is only around 3,5%. Therefore, the effect of the adhesive concentrations in this case jatropha seeds does not have a significant effect on the ash content (Eboibi et al., 2018). Another thing can be caused because the higher the concentration of adhesive, the less green coconut is contained in the briquettes. The charcoal produced from the pyrolysis of green coconut shells has a relatively high ash content compared to the adhesive. As a result, increasing the concentration of the adhesive reduces the proportion of charcoal in the mixture, while simultaneously lowering the total ash contribution. This reduction in ash content positively impacts the combustion quality of briquettes, as it produces less residue, enhances combustion efficiency, and minimizes the need for ash cleaning. However, optimizing the adhesive concentration is necessary to ensure low ash content without compromising the mechanical strength and calorific value of the briquettes, resulting in an efficient and high-quality product (Yorijor et al., 2024).

3.4. The Effect of Pyrolysis and Adhesive concentration on the Calorific Value

Calorific value is a combustion property that determines the balance of biobriquettes as fuel. Calorific value is the amount of heat energy produced by a fuel through a perfect combustion reaction, which is measured per unit of mass or volume of that fuel. Fuel with a high calorific value is able to increase combustion efficiency, in addition, the heat energy produced from combustion will also be more optimal. Therefore, in the manufacture of bio-briquettes, the calorific value greatly affects the quality of briquettes. The higher the calorific value of the briquettes, the better the quality of the briquettes produced (Inegbedion and Ikpoza, 2022).

Based on Fig. 5, it shows that biobriquettes with non-pyrolysis treatment have a calorific value that does not meet the quality requirements of SNI 01-6235-2000, which is a minimum of 5000 cal/g. This can be caused by bio-briquettes with non-pyrolysis treatment do not undergo a carbonization process. Because of the fact that carbonization increases the carbon content in the material (Tomen et al., 2023). Meanwhile, bio-briquettes with pyrolysis treatment have values that have met the quality requirements of SNI 01-6235-2000. This occurs due to the reduction of water content and volatility during the pyrolysis process, so that the concentration of carbon in solid residues increases. Pyrolysis can also increase the calorific value by reducing non-carbon compounds such as hemicellulose and lignin. During pyrolysis, hemicellulose is degraded at a temperature of about 200–260°C, followed by lignin at 280–500°C. This process leaves behind a carbon-rich residue, improving the calorific value. Heating at higher temperatures results in further carbonization, changing the chemical structure of biomass to be more efficient for combustion (Kethobile et al., 2019).

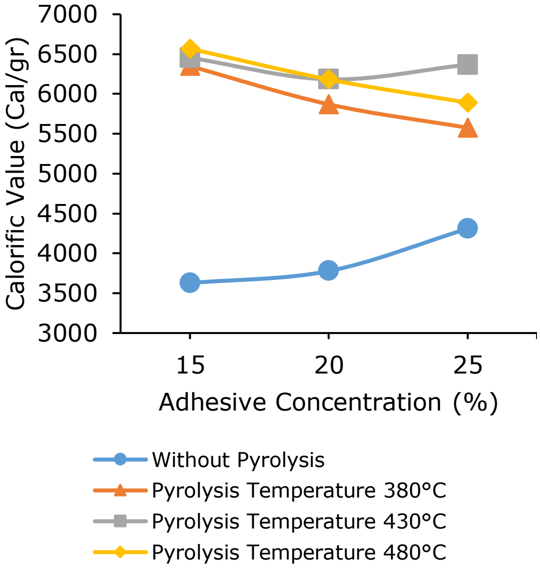

Figure 5. Effect of pyrolysis and adhesive concentrations on the calorific value of biobriquettes

Based on Fig. 5, it can also be seen that the adhesive concentrations affect the calorific value. The calorific value of jatropha seeds is 20.06 MJ/kg or 4793.81 cal/gr (Odetoye et, al., 2018). While the calorific value of green coconut is 30.79 MJ/kg or 7354.07 cal/gr (Espina et al., 2022). Thus, the higher the adhesive concentrations, the lower the amount of coconut contained in the briquette and the lower the calorific value of the bio-briquette. In addition, the high moisture content in the jatropha seed adhesive significantly reduces the calorific value of the briquettes because more energy is wasted to evaporate the water. High moisture content in the briquettes can lead to inefficient combustion, where most of the energy is used to evaporate water, preventing the calorific value from being fully released as heat. Therefore, increasing the concentration of jatropha seed adhesive, which results in high water content, contributes to the reduced combustion efficiency and lower calorific value of the briquettes (Anis et al., 2024).

3.5. The Effect of Pyrolysis and Adhesive concentration on the Combustion Rate

The bio-briquette combustion rate test is carried out to evaluate the effectiveness of briquettes as fuel. Briquettes that burn longer to ash indicate better quality and efficiency. The higher the burning rate, the shorter the briquette's ignition time (Waluyo et al., 2023). The combustion rate is influenced by several factors, one of which is the ash content in the biobriquette. Biobriquettes with high ash content tend to inhibit the entry of air during the combustion process. This occurs because the ash layer forms on the surface of the briquette, covering the charcoal particles and reducing the contact between the fuel and oxygen required for ignition. As a result, oxygen penetration and heat transfer within the briquette are obstructed, which slows down the overall combustion rate (Haryanti et al., 2021). Pyrolysis can enhance the energy efficiency of biomass by converting it into more combustible products such as biochar. This thermal decomposition process also modifies the structural characteristics of the biomass, particularly its porosity, which plays a critical role in combustion dynamics. Biobriquettes produced through pyrolysis tend to exhibit higher porosity, allowing better oxygen penetration, which in turn facilitates faster and more complete combustion.

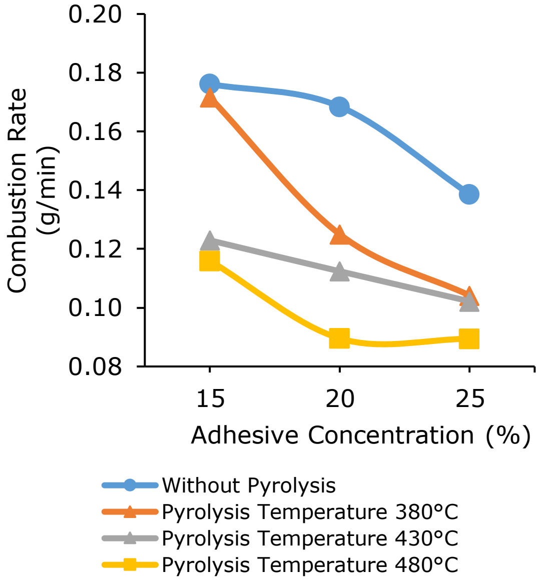

Figure 6. Effect of pyrolysis and adhesive concentrations on the combustion rate of biobriquettes

The structural advantages conferred by pyrolysis are directly linked to the combustion performance of biobriquettes, which is evaluated based on their burning duration and ignition behavior. Briquettes that maintain combustion over a longer period before turning to ash are generally considered to have superior fuel quality and efficiency (Handiso et al., 2024). Parameters such as particle size and porosity also play an important role in terms of combustion rate. Pyrolysis bio-briquettes with small particle size and high porosity tend to have a faster combustion rate due to their larger surface area, which accelerates the reaction with oxygen (Adu-Poko et al., 2022).

Based on Fig. 6, it can also be seen that the amount of adhesive affects the combustion rate. The higher the adhesive concentration used, the greater the combustion rate of the biobriquette. This is because the adhesive plays a crucial role in forming a stronger and denser structure, allowing fuel particles to bind more effectively. A compact structure enables heat to be distributed more evenly throughout the briquette, resulting in a more uniform and efficient combustion process (Ramdani et al., 2020). The higher the adhesive concentration, the burning rate of the bio-briquette tends to increase because the adhesive functions as a binding material that strengthens the bond between particles, resulting in a denser and more compact structure. In addition, organic-based adhesives, such as jatropha seeds, contain flammable compounds like oil and carbon, which have low ignition points. The presence of these compounds not only accelerates the ignition process but also supports flame propagation, thereby increasing the burning rate (Bonsu, 2020).

3.6. The Effect of Pyrolysis and Adhesive concentration on the Compressive Strength Value

Compressive strength testing to see the quality of biobriquettes that are good enough to be used as effective and efficient fuel. The compressive strength of briquettes is a critical factor determining their durability, handling, and resistance to external forces. Higher compressive strength enhances their ability to withstand transportation, reduces breakage, and improves storage stability. Additionally, stronger briquettes are less likely to absorb moisture, prolonging their shelf life and ensuring better combustion performance (Madhusanka et al., 2025). Based on Fig. 7, it shows that an increase in pyrolysis temperature is inversely proportional to the compressive strength of a biobriquette. This is because the pyrolysis temperature is too high, it can cause the biobriquette to become too brittle due to excessive thermal degradation, which can ultimately cause a strong decrease in pressure (Feng et al., 2020).

Based on Fig. 7, increasing the adhesive concentration did not have a significant effect. The bond between the biomass and jatropha seed adhesive was weak, as the biobriquettes remained fragile and showed cracks after forming. The low compressive strength is mainly due to the high oil content in jatropha seeds (38.7%–45.8%), which creates a non-polar layer. This layer reduces the interaction between biomass particles, making the briquettes less solid. As a result, bio-briquette with jatropha seed adhesive experience a decrease in compressive strength due to the oil in the jatropha seeds reducing adhesive properties that affect the cohesion and mechanical strength of the briquette (Jonas et al., 2020).

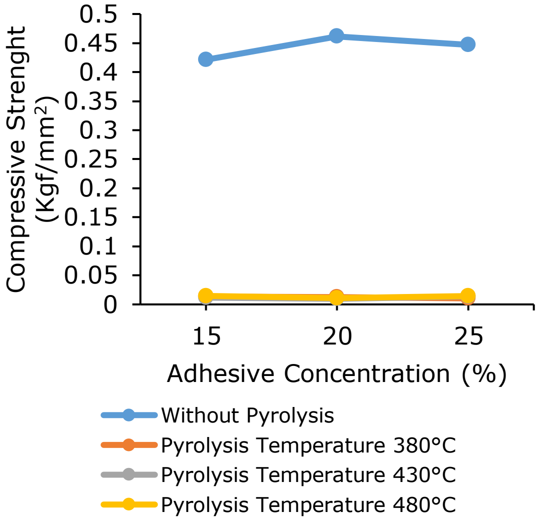

Figure 7. Effect of pyrolysis and adhesive concentrations on the compressive strength value of biobriquettes

4. Conclusion

This study developed a renewable energy source, from green coconut shell and husk (GCSH) waste with jatropha seed adhesive through optimization of biobriquette production. The results showed that pyrolysis at a temperature of 430°C with 25% adhesive produced biobriquettes that met SNI standards, with a water content of 7.44%, ash content of 5.18%, a combustion rate of 0.10219 g/min, and a calorific value of 6367.74 cal/g. The results of this study confirm that biomass waste from GCSH and jatropha seeds has the potential as a source of sustainable energy. The limitations include limited laboratory scale, limited variation of raw materials, and lack of comprehensive emission analysis. Further research should be focused on large-scale production, exhaust gas emission analysis, and exploration of alternative natural adhesives. With optimization, this biomass-based biobriquette can provide an efficient, economical, and environmentally friendly energy solution.

Author Contribution Statement

P.A.U.: Conceptualization, writing—original draft, providing laboratory equipment. R.A.S.: Formal analysis, data evaluation, data interpretation. S.S.: Investigation, conducting experiments, data collection, and validation. K.A.: Project administration, critical review. M.: Writing—review and editing, approval of final manuscript. F.: Writing—review and editing, approval of final manuscript.

Data Availability Statement

Available on request to the corresponding author.

Declaration of Competing Interest

The author declares that there is no conflict of interest regarding the publication of this manuscript.

Acknowledgements

The author would like to thank the parties who have helped carry out this research. The author would like to thank the Ministry of Research and Technology for providing funds in the 2024 Student Creativity Program (PKM) for this research and Syiah Kuala University for providing facilities for this research.

References

Adu-Poku, K.A., Appiah, D., Asosega, K.A., Derkyi, N.S.A., Uba, F., Kumi, E.N., Gyamfi, D. (2022) Characterization of fuel and mechanical properties of charred agricultural wastes: Experimental and statistical studies, *Energy Reports*, 8, 4319-4331. https://doi.org/10.1016/j.egyr.2022.03.015

Agustiar, Bantacut, T., Romli, M., Pramudya, B., Aulia, M. R. (2023) The Potential of Bio-Try Briquettes for Biomass Power Plant in Aceh Province–Case Study in South West Aceh, Indonesia, *Journal of Ecological Engineering*, 24(10), 115-124. https://doi.org/10.12911/22998993/170079

Ahmad, R. K., Sulaiman, S. A., Yusup, S., Dol, S. S., Inayat, M., Umar, H. A. (2022) Exploring the potential of coconut shell biomass for charcoal production, *Ain Shams Engineering Journal*, 13(1), 101499. https://doi.org/10.1016/j.asej.2021.05.013

Ajimotokan, H.A., Ehindr, A.O., Ajao, K.S., Adeleke, A.A., Ikubanni, P.P., Babata, Y.L.S. (2019) Combustion Characteristics of Fuel Briquettes Made from Charcoal Particles and Sawdust Agglomerates, *Scientific African*, 6, 1-9. https://doi.org/10.1016/j.sciaf.2019.e00202

Anis, S., Fitriyana, D.F., Bahatmaka, A., Anwar, M.C., Ramadhan, A.Z., Anam, F.C., Permana, R.A., Hakim, A.J., Guterres, N.F.D.S., Silva, M.D.S.D. (2024) Effect of Adhesive Type on the Quality of Coconut Shell Charcoal Briquettes Prepared by the Screw Extruder Machine, *Journal of Renewable Materials*, 12(2), 381-396. https://doi.org/10.32604/jrm.2023.047128

Badan Pusat Statistik. 2023. *URL: https://www.bps.go.id/id/statistics-table/2/MTMxIzI=/luas-tanaman-perkebunan-menurut-provinsi--ribu-hektar-.html.* Diakses tanggal 11 Juli 2024.

Bonsu, B.O., Takase, M., Mantey, J. (2020) Preparation of charcoal briquette from palm kernel shells: case study in Ghana, *Heliyon*, 6(10), 1-8. https://doi.org/10.1016/j.heliyon.2020.e05266

Chen, L., Al-Dhabi, N.A., Ai, W., Sun, S., Peng, Y., Gao, C., Zhuo, Y., Tang, W., Zhao, Y., Sun, C. (2025) Impact of low-temperature pyrolysis on ash and physicochemical properties of straw biochar: Multivariate analysis and implications for agricultural and environmental use, *Industrial Crps & Products*, 224, 1-8. https://doi.org/10.1016/j.indcrop.2024.120431

Dalimunthe, Y. K., Kasmungin, S., Sugiarto, E., Sugiarti, L., Lagrama, A. (2021) Making briquettes from waste of coconut shell and peanut shell, *Indonesian Journal of Urban and Environmental Technology*, 4(2), 196. https://doi.org/10.25105/urbanenvirotech.v4i2.7417

Eboibi, B.E., Eboibi, O., Okputu, J., Okpohwo, K.A. (2018) Production and analysis of biodiesel from Jatropha curcas seed, *Journal of Applied Sciences and Environmental Management,* 22(1), 26-

33. https://doi.org/10.4314/jasem.v22i1.6

Espina, R.U., Abundo, M.L.S., Barroca, R.B. (2022) The Optimal High Heating Value of the Torrefied Coconut Shells, *Engineering, Technology & Applied Science Research*, 12(3), 8605-8610. https://doi.org/10.48084/etasr.4931

Feng, Z., Zhang, T., Yang, J., Gao, Q., Ni, L., Liu, Z. (2020) Fuel Characteristics of Briquettes Manufactured by Natural Stacking Bamboo/Chinese Fir Mixtures, *ACS Omega*, 5(39), 25281-25288. https://doi.org/10.1021/acsomega.0c03413

Handiso, B., Pääkkönen, T., Wilson, B. P. (2024) Effect of pyrolysis temperature on the physical and chemical characteristics of pine wood biochar, *Waste Management Bulletin,* 2(4), 281-287. https://doi.org/10.1016/j.wmb.2024.11.008

Harahap, M., Purwandari, V., Waruwu, S.S., Telambanua, F., Laia, S. (2023) Pemanfaatan Tempurung Kelapa PT. Eramas Coconut Industries Sebagai Bio-arang, *Jurnal Abdimas Mutiara*, 4(1), 290-294.

Haryanti, N.H., Surjaya, Wardhana, H., Husain, S., Noor, R., Anggraini, Y., Sofi, N., Aprilia, D. (2021) Biobriquettes from Biomass Waste, Journal of Physics: Conferense Series. http://dx.doi.org/10.1088/1742-6596/2104/1/012003.

Hasibuan, R., Hidayati, J., Misran, E., Purba, I.P.S., Erlangga, F., Pramananda, V., Siregar, F.S. (2024) Effect of Pyrolysis Temperature and Adhesive Type on the Quality of Biobriquette from Coffee Stem Biomass, *TALENTA CEST-5 2024*, 519, 1-6. https://doi.org/10.1051/e3sconf/202451902001

Inegbedion, F., Ikpoza, E. (2022) Estimation of the Moisture Content, Volatile Matter, Ash Content, Fixed Carbon and Calorific Values of Rice Husk Briquettes, *Proceedings of the 3rd African International Conference on Industrial Engineering and Operations Management*. https://doi.org/10.46254/AF03.20220100

Jonas, M., Ketlogetswe, C., Gandure, J. (2020) Variation of Jatropha curcas seed oil content and fatty acid composition with fruit maturity stage, *Heliyon*, 6, 1-6. https://doi.org/10.1016/j.heliyon.2020.e03285

Kethobile, E., Ketlogetswe, C., Gandure, J. (2019) Characterisation of the Non-Oil Jatropha Biomass Material for use as a Source of Solid Fuel, *Biomass Conversion and Biorefinery.* 10, 1251-1267. https://doi.org/10.1007/s13399-019-00511-4

Kumar, J.A., Kumar, K.V., Petchimuthu, M., Iyahraja, S., Kumar, D.V. (2020) Comparative analysis of briquettes obtained from biomass and charcoal, *Materialstoday:PROCEEDING*, 45(2), 857-861. https://doi.org/10.1016/j.matpr.2020.02.918

Madhusanka, L., Nilmalgoda, H., Wijethunga, I., Ampitiyawatta, A., Koswattage, K. (2025) Agri-Eco Energy: Evaluating Non-Edible Binders in Coconut Shell Biochar and Cinnamon Sawdust Briquettes for Sustainable Fuel Production, *AgriEngineering*, 7(5), 1-20. https://doi.org/10.3390/agriengineering7050132

Mahidin. (2011) Pengaruh Penambahan Biji Jarak dalam Briket Campuran Batubara Peringkat Rendah dan Cangkang Sawit (Bio-Briket) terhadap Laju Pembakarannya, *Jurnal Sains, Teknologi dan Industri*, 9(1), 81-87.

Mardawati, E., Ramadhan, A.K.R., Kusnayat, A., Ardiansah, I., Fitriana, H.N. (2022) Biobriquette: A Mixture of Palm Kernel Shell and Coconut Shell, an Indonesian Study Case, *Ecology, Environment and Conservation*, 28(3), 1611-1618. http://dx.doi.org/10.53550/EEC.2022.v28i03.070

Mu, L., Wang, R., Xie, P., Li, Y., Huang, X., Yin, H., Dong, M. (2023) Comparative Investigation on the Pyrolysis of Crop, Woody, and Herbaceous Biomass: Pyrolytic Products, Structural Characteristics, and CO_2 Gasification, *Fuel*, 335, 1-12. https://doi.org/10.1016/j.fuel.2022.126940

Ningsih, L. A., Setiawan, I., Syarif, T., Nurdjannah, N., Ifa, L., Afiah, I.N., Kusuma, H.S. (2023) Pine-to-Bioenergy: Potential of pine sap as adhesive and pine flower biomass waste in the production of biobriquettes, *Fuel*, 350, 1-10. https://doi.org/10.1016/j.fuel.2023.128872

Novitrie, N.A., Setiani, V., Camalia, A.D. (2023) The Effect of Composition, Pyrolysis Temperature and Adhesive Concentration on the Proximate Content and Calorific Value of Biobriquettes from Durian Skin, Corn Husk and Fish Bones Waste, *Jurnal Presipitasi*, 20(3), 727-739. https://doi.org/10.14710/presipitasi.v20i3.727-739

Nunes, L. A., Silva, M. L., Gerber, J. Z., Kalid, R. D. A. (2020) Waste green coconut shells: Diagnosis of the disposal and applications for use in other products, *Journal of Cleaner Production*, 255, 120169. https://doi.org/10.1016/j.jclepro.2020.120169

Obeng, G.Y., Amoah, D.Y., Opoku, R., Sekyere, C.K.K., Adjei, E.A., Mensah, E. (2020) Coconut wastes as bioresource for sustainable energy: Quantifying wastes, calorific values and emissions in Ghana, *Energies*, 13(9), 1-13. https://doi.org/10.3390/en13092178

Odetoye, T.E., Afolabi, T.J., Bakar, M.S.A., Titiloye, J.O. (2018) Thermochemical characterization of Nigerian Jatropha curcas fruit and seed residues for biofuel production, *Energy, Ecology and Environment,* 3, 330-337. https://doi.org/10.1007/s40974-018-0104-0

Odey, M. T., Hitler, L., Nelson, N., Aniedi, S. E., Nakachy, U. V., Ayinu, U. J., Anwan, O. I. E. (2018) Proximate Analysis and Mineral Composition of Jatropha curcas Seeds Obtained from Pankshin Local Government Area of Plateau State of Nigeria, *Journal of Physics Chemistry & Biophysics*, 8(1), 1-6. http://dx.doi.org/10.4172/2161-0398.1000265

Olugbade, T., Ojo, O., Mohammed, T. (2019) Influence of Binders on Combustion Properties of Biomass Briquettes: A Recent Review, *BioEnergy Research,* 12, 241-259. https://doi.org/10.1007/s12155-019-09973-w

Ramdani, L.M.A., Ahzan, S., Prasetya, D.S.B. (2020) The Effect of the Type and Composition of the Adhesive on the Physical Propertiesand the Rate of Combustion Hyacinth Biobriquettes, Lensa:Jurnal Kependidikan Fisika, 8(2), 85-92. http://dx.doi.org/10.33394/j-lkf.v8i2.2786

Sanchez, P.D.C., Aspe, M.M.T., Sindol, K.N. (2022) An Overview on the Production of Bio-briquettes from AgriculturalWastes: Methods, Processes, and Quality, *Journal of Agricultural and Food Engineering*, 1, 1-17. http://dx.doi.org/10.37865/jafe.2022.0036

Standar Nasional Indonesia. 2000. *Briket Arang Kayu SNI 01-6235-2000*. Badan Standarisasi Nasional – BSN.

Tomen, W. T., Diboma, B. S., Bot, B. V., Tamba, J. G. (2023) Physical and combustion properties investigation of hybrid briquettes from tropical Sawdust: case study of Iroko (*Milicia excelsa*) and Padouk (*Pterocarpus soyauxii*), *Energy Reports*, 9, 3177-3191. https://doi.org/10.1016/j.egyr.2023.02.006

Waluyo, J., Setianto, M. M., Safitri, N. R., Pranolo, S. H., Susanti, A. D., Margono, Paryanto. (2023) Characterization of Biochar Briquettes from Coconut Shell with the Effect of Binder: Molasses, Cow Manure and Horse Manure, *EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy*, 10(1), 539-545. https://doi.org/10.5109/6782158

Yorijor, J., Bere, A. A. T. (2024) Production and characterization of coconut shell charcoal-based bio-briquettes as an alternative energy source for rural communities, *Heliyon*, 10, 1-13. https://doi.org/10.1016/j.heliyon.2024.e35717