The Effect of Pressure Variations on the Characteristics of Coconut Shell Based Briquettes Using Tapioca Starch Adhesive

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Abstract

The very limited availability of energy on this planet is one of the main problems that concerns almost all countries. The presence of emergency energy indicates that energy usage is very high. Therefore, encouraging the use of new and sustainable energy sources is of utmost importance. Biomass energy can be the answer to overcoming the limitations of decreasing fossil assets, especially through the production of charcoal briquettes. Biomass energy is derived from plants or easily traceable natural materials that are abundant, such as wood waste, rice husks, bagasse, and coconut shells. Coconut shells, for example, can be a primary ingredient for making charcoal briquettes, using tapioca flour or starch as an adhesive. The briquettes can be produced using pressure variations of 50 kg/cm², 60 kg/cm², and 70 kg/cm², with a drying temperature of 100°C for 3 hours. The recommended ratio for making charcoal briquettes is 3 parts coconut shell to 1 parts tapioca flour adhesive. The purpose of this study is to compare the briquettes produced with coconut shell and tapioca flour adhesive to the SNI Briquette standard No.1/6235/2000. For the conducted tests, the results were as follows: the water content was 6.06%, the ash content was 5.9695%, the carbon content was 43.5946%, and the calorific value was 34,182.6808 calories. Additionally, the substance score yield was 26.845%, and the combustion rate was 0.12179 g/minute.

Kata kunci: *adhesive, biomass briquettes, coconut shells, indonesian national standard*

Abstrak

Ketersediaan energi yang sangat terbatas di planet ini adalah salah satu masalah utama yang diperhatikan oleh hampir semua negara. Adanya darurat energi menunjukkan bahwa pemanfaatan energi sangat tinggi. Dengan cara ini, mendorong pemanfaatan energi Baru dan Berkelanjutan [EBT] sangat penting. Energi biomassa bisa menjadi jawaban untuk menaklukan batasan penurunan aset fosil, khususnya dengan membuat briket arang. Energi biomassa berasal dari tumbuh-tumbuhan atau bahan alam yang mudah terlacak secara melimpah, misalnya limbah kayu, sekam padi, ampas tebu, dan tempurung kelapa. Tempurung kelapa dapat dijadikan salah satu bahan utama pembuatan briket arang dengan perekat menggunakan tepung tapioka atau tepung kanji. Menggunakan variasi penekanan/ pengepresan sebesar 50 kg/cm², 60 kg/cm², dan 70 kg/cm² dengan temperatur pengeringan 100°C selama 3 jam. Untuk rasio pembuatan briket arang bahan dasar tempurung kelapa dengan perekat tepung tapioka yaitu 3:1. Penelitian ini bertujuan untuk membandingkan briket yang telah diteliti dengan berbahan dasar tempurung kelapa menggunakan tepung tapioka sebagai perekat dengan standar SNI Briket No.1/6235/2000. Berdasarkan hasil pengujian yang telah dilakukan didapatkan bahwa hasil pengujian terbaik pada tekanan kg/cm² yaitu untuk pengujian kadar air didapatkan hasil sebesar 6,06 %, pengujian kadar abu didapatkan hasil sebesar 5,9695 %, pengujian kadar karbon didapatkan hasil sebesar 43,5946 %, hasil pengujian nilai kalor sebesar 34182,6808 kalori, hasil pengujian kadar zat terbang didapatkan hasil sebesar 26,845% dan untuk pengujian laju pembakaran sebesar 0,12179 g/menit.

Kata kunci: briket biomassa; ebt; perekat; sni; tempurung kelapa

1. Introduction

The problem of energy on this earth is one of the main concerns that almost all countries pay attention to, as it is a fundamental component that influences a country's economic development. The availability of energy is becoming increasingly limited, and addressing it requires support from more sophisticated innovations to save time and accelerate production [1].

Energy utilization will require a lot of attention due to an energy emergency. Petroleum derivatives are known as non-renewable energy sources. However, in daily life, the use of fuel oil is prevalent, which can lead to the depletion of fuel reserves. Therefore, it is of utmost importance to develop techniques for introducing other energy sources that can supplement the utilization of fossil energy [2][3].

Indonesia is highly committed to promoting the use of environmentally friendly new energy (EBT). According to Indonesian regulation no. 79 of 2014 concerning the Public Energy Strategy (KEN) and the official Indonesian guidelines

No. 22 of 2017 concerning the Public Energy General Plan (RUEN), the target for the use of EBT in 2025 and 2050 is set at 23% and 31% respectively, regardless of the total energy needs of the Indonesian people. However, as of 2020, the share of EBT has only reached 11.31%. It appears that the efforts made so far to foster the EBT segment are still encountering tough challenges, primarily due to the fact that the cost of EBT is not yet competitive with fossil energy. Given the slow progress in adopting new renewable energy sources, Indonesia's dependence on fossil energy, particularly flammable oil and gas, persists [4] [5].

Biomass energy can be the solution to address the issue of diminishing petroleum products. It is a sustainable alternative energy source derived from plant waste or easily decomposable raw materials that are abundantly available, such as wood waste, rice husks, bagasse, and coconut shells [6]. Plant wastes are utilized, among other things, as raw materials for the production of fertilizers, pellets, and charcoal briquettes [7].

According to the Directorate General of Livestock (2019), the area of coconut plantations in Indonesia reached 3.65 million hectares in 2019, with 3.61 million hectares being smallholder plantations, 32,316 hectares guaranteed by people's areas, and the rest owned by private authorities. In that year, all coconut plantations produced a total of 2.865 million tons of coconuts. Indonesia's extensive coconut plantations generate waste in the form of coconut shells, which can serve as a natural material for manufacturing fuel briquettes. Due to its high calorific value of around 6500-7600 kka/kg, coconut shells are effectively used as a fuel source [8] [9].

In Indonesia, coconut shells are one of the most widely known types of biomass. Many people use coconuts to extract coconut milk, which is then used as a cooking ingredient. However, coconut shells are generally discarded and simply thrown away, leading to coconut shell waste. Fortunately, certain communities have begun to utilize coconut shell waste to produce coconut shell charcoal [10][11].

Further exploration reveals that the utilization of coconut shell charcoal as activated carbon and an alternative energy source for biomass has significantly reduced the impact of pollution and global temperature changes. One of the advantages of using coconut shell charcoal is the ease of making fuel briquettes from it. Consequently, raising public awareness about the process of making and using coconut shell charcoal briquettes as a preferred fuel is crucial [12]. The process of transforming sand-sized powder or powder into larger, more manageable pieces is known as briquetting. The squeezing system is employed to change the size of the briquetting material by applying pressure and adding or removing adhesives or fasteners [13].

Tapioca flour is a substance or material that can bind two objects through their surface adhesion. An adhesive is used to bond the two materials together, creating a solid surface that can attract water. The presence of a sticky material ensures a better, standardized, and thicker molecular construction, resulting in improved quality and strength for the pressure crusher frame and charcoal briquettes [14]. Charcoal adhesives can be produced using natural or inorganic materials. The selection of the adhesive should be based on its ability to adhere effectively when mixed with charcoal. Additionally, it should be cost-effective, non-toxic, and readily available [8] [15].

Therefore, based on the explanation above, the authors are focusing on the effect of pressure on the quality of briquettes made from coconut shells using tapioca flour or starch glue. This experiment will conduct estimation tests for water content, ash content, carbon content, calorific value, and volatile matter to analyze the briquettes' synthesis and characteristics. The purpose of this research is twofold. First, it aims to determine the effect of variations in the pressure of making coconut shell briquettes on parameters such as moisture content, ash content, carbon content, calorific value, volatile matter content, and combustion rate. Second, it seeks to compare the quality of the studied briquettes with the standards set by SNI (Indonesian National Standard).

2. Materials and Research Methods

The main materials used for this study were coconut shells, and tapioca starch was used as an adhesive. The process of making briquettes in this study began with the drying stage of the coconut shells to reduce the moisture content in the main ingredient. Next, the carbonization or combustion process was allowed to take place for 4 hours, followed by letting it stand for 1 hour. Afterward, crushing was performed using a mortar, and sieving was done using 40 mesh to obtain fine charcoal powder. The fine charcoal powder was then mixed with 15 grams of raw material, 5 grams of adhesive, and 10 grams of water. The mixture was then pressed using a manual hydraulic press, with pressure variations of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2.

The tests conducted in this study included: briquette moisture content, briquette ash content, briquette carbon content, briquette calorific value, and briquette volatile matter content. The process of testing the water content involved taking a 2-gram sample of the finished briquette and then conducting the test using the following formula:

$$\text{Water content (\%)} = \frac{B-C}{B-A} \times 100\% \quad (1)$$

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

$$\text{Carbon content (\%)} = 100\% - (\text{\% evaporating substance} + \text{\% ash}) \quad (3)$$

Where:

A = Empty Cup Mass (grams)
B = Mass of Cup + Sample (grams)
C = Mass of Cup + sample after baking (grams)

The process of testing the calorific value involves using a bomb calorimeter to test each sample for 20 minutes. Each sample has a mass of approximately 0.3 grams. The process includes determining the temperature of the test material before and after the bomb calorimeter is used. The temperature is recorded during minutes one to five as the temperature before bombing, and from 5 minutes and 45 seconds until the 20th minute, the temperature after bombing is recorded.The briquette testing process is carried out with samples that underwent pressure variations of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2. The main ingredients used for these briquettes are coconut shell and tapioca flour as an adhesive..

$$\text{Calorific Value} = \frac{(T_2 - T_1) \times Cv}{M} \quad (4)$$

Where:
T_1 = The temperature before the briquette bombardment (°C)
T_2 = The temperature after the bombing (°C)
C_v = Specific heat capacity bomb calorimeter (73529.6 joule/g°C)
M = Briquette sample mass (gram)

Testing for volatile matter content is carried out to find out how much of the sample or briquettes will evaporate or fly when the test is carried out. The formula used to calculate the levels of volatile matter or volatile matter in briquettes is as follows:

$$\text{Vaporation levels (\%)} = \frac{a-b}{a} \times 100\% \quad (5)$$

Where:
a = Sample mass before heating (grams)
b = Sample mass after heating (grams)

The dried charcoal briquettes were tested for water content, ash content, carbon content, calorific value, and volatile matter content with pressure variations of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2. The test standards for this study are based on SNI Briquette Standards No. 1/6235/2000, including in Table 1.

Table 1. SNI Standards for Briquettes No.1/6235/2000

No.	Parameter	Standards SNI
1	Water content (%)	≤8
2	Volatile matter (%)	≤15
2	Ash content (%)	≤8
3	Calorific value (kal/g)	≥5000

3. Results and Discussion

Research focuses on analyzing the quality of coconut shell-based biomass charcoal briquettes using tapioca flour as an adhesive. Three different samples are made, varying the pressure at 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2 during manufacture with a hydraulic press. After finishing the pressing, the briquettes are dried in an oven for 3 hours at a temperature of 100°C to reduce the water content. Figure 1 below shows the dimensions of the briquette product with variations in pressure, as previously determined. The briquette quality analysis includes burning rate, calorific value, moisture content, ash content, carbon content, and volatile matter content.

Figure 1. Charcoal briquettes with pressure variations

Burning Rate

The burn rate test is conducted to assess the quality of a briquette made from coconut shell (TK) using tapioca flour (TP) as an adhesive. This test helps determine whether a briquette is suitable for further testing or use as fuel. The author also examined the burning rate to identify which briquettes took the longest and burned the fastest among the three samples, each manufactured under different pressures: 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2, as shown in Table 2.

Table 2. Results of Combustion Rate Analysis

Variation	Pressure (kg/cm^2)	Composition	Mass Briquettes (gram)	Time Burning (minutes)	Burning Rate (gram/minutes)	Temperature Average (℃)
1	50	TK: TP = 3: 1	19	133	0,14	180,92
2	60	TK: TP = 3: 1	19	141	0,13	186,43
3	70	TK: TP = 3: 1	19	156	0,12	196

Table 2 displays the burning durations and burning rates of the briquettes under different pressure and composition conditions. The briquettes with a composition of 15 grams of coconut shell powder and 5 grams of tapioca flour burned the longest when the pressure was 70 kg/cm^2, with a burning time of 156 minutes (equivalent to 2 hours and 36 minutes) and a burning rate of 0.121794 g/minute. When the pressure was 60 kg/cm^2, the burning time reduced to 141 minutes (equivalent to 2 hours and 21 minutes), and the burning rate increased to 0.134751 g/minute. For a pressure of 50 kg/cm2, the burning time decreased further to 133 minutes (equivalent to 2 hours and 13 minutes), and the burning rate increased to 0.142857 g/minute, making it the fastest combustion used. The results indicate that as the burning time of the briquettes increases, the combustion rate decreases. Hence, good quality briquettes have a smaller burning rate.

Table 2 reveals that the best briquettes are obtained at a pressure of 70 kg/cm^2, as they exhibit the longest burning time and the lowest burning rate. The burning rate is calculated by dividing the mass of the briquettes before burning by the burning time from the start to the end of combustion. In Table 2, the average temperature for each pressure variation used in this study is presented. The highest temperature is recorded at a pressure of 70 kg/cm^2, reaching 196°C, while the lowest temperature is observed at a pressure of 50 kg/cm^2, at 180.92°C. The temperature for a pressure of 60 kg/cm^2 is 180.92°C as well.

Based on Table 2, the burning time data was used to create a graph of the burning rate, as depicted in Figure 2. The figure illustrates that the highest combustion rate was achieved at a pressure of 50 kg/cm^2, which amounted to 0.142857 g/minute. On the other hand, the lowest combustion rate was recorded at a pressure of 70 kg/cm^2, with a value of 0.121794 g/minute. For a pressure of 60 kg/cm^2, the combustion rate obtained was 0.134751 g/minute. The results indicate that the higher the pressure used, the lower the combustion rate of the fuel. Table 3 presents the visualization of briquettes from the start of burning to the end of burning under the three pressure variations. The figure illustrates that briquettes at a pressure of 70 kg/cm2 have a relatively brighter flame compared to the ones at 50 kg/cm2 pressure variation. The remaining ash is nearly the same for all three variations.

Research by D. A. Fauzie (2019) was carried out to test the burn rate of the briquettes by changing the pressure, namely 2 tons, 3 tons, and 4 tons. The consequence of the highest ignition rate is briquettes with a pressure of 2 tons, resulting in 0.00464 g/minute. The aftereffect of decreasing the burning rate is most noticeable in briquettes with a pressure of 4 tons, resulting in 0.00410 g/minute. This is because the higher the pressure, the thicker it becomes, making it more difficult for air to enter the ignition process [16]. D. A. Fauzie (2019) 's research is in accordance with research on pressures of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2 by the same author. It turns out that the higher the pressure used, the lower the fuel rate becomes.

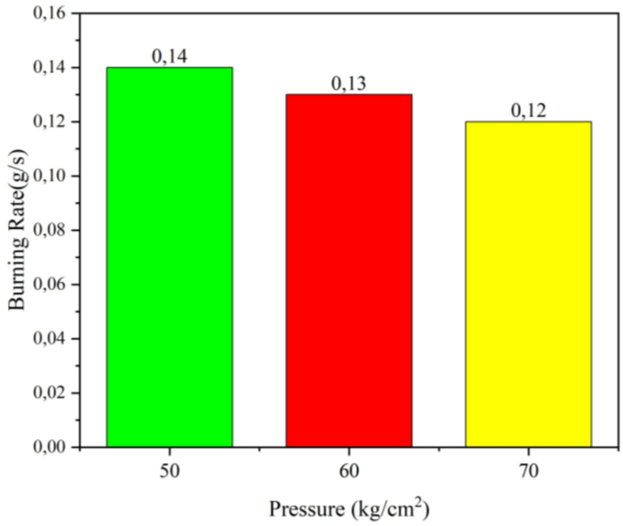
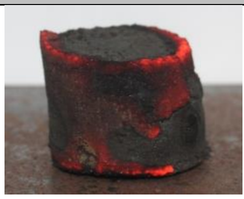
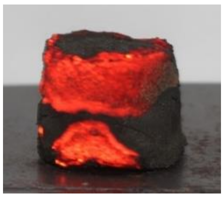
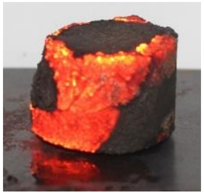


Figure 2. Briquette burning rate at various pressure variations

Table 3. Briquette Burning Process

Pressure Variation	Initial Burn	Final Burn
50 kg/cm^2		
60 kg/cm^2		
70 kg/cm^2		

Calorific Value Analysis

The tested briquettes underwent pressure variations of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2, using coconut shell as the main ingredient and tapioca flour as an adhesive shows in Figure 3. The bomb calorimeter tests conducted over 20 minutes yielded the following results. At 50 kg/cm^2 pressure, the temperature before bombing was 28.284ºC, and after bombing, it was 28.838ºC, with a sample mass of 0.3217 grams, resulting in a calorific value of 5551.708 calories. For 60 kg/cm^2 pressure, the temperature before bombing was 28.378ºC, and after bombing, it was 28.907ºC, with a sample mass of 0.3323 grams, producing a calorific value of 4782.818 calories. Finally, at 70 kg/cm^2 pressure, the temperature before bombing was 28.487ºC, and after bombing, it was 29.144ºC, with a sample mass of 0.3381 grams, yielding a calorific value of 5726.611 calories. The highest calorific value was achieved at 70 kg/cm^2 pressure, amounting to 5726.611 calories per grams, while the lowest value was recorded at 60 kg/cm^2 pressure, reaching 4782.818 calories per grams. These results comply with SNI Briquette standards, which require good briquettes to have a heating value of ≥5000 calories per grams. The study demonstrates that higher pressure leads to higher calorific values.

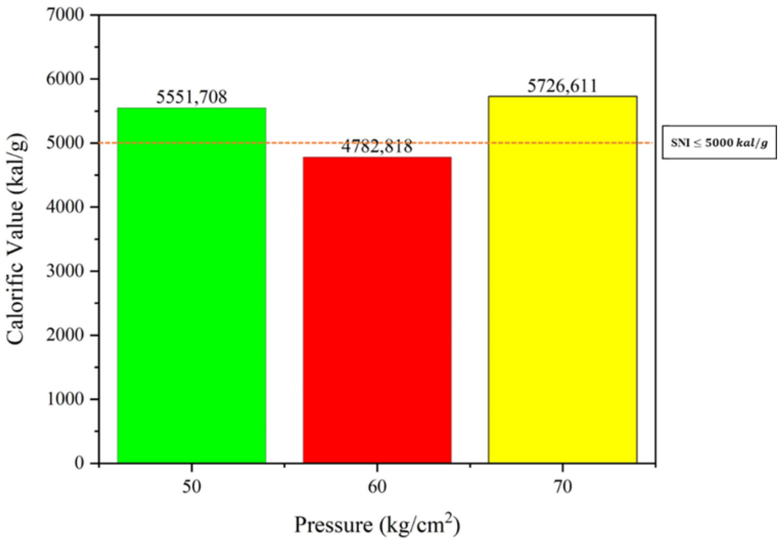


Figure 3. The calorific value of briquettes under different pressure conditions

Research by M. A. Aljarwi et al. (2020) aimed to specifically investigate the calorific value of briquettes using pressures of 20 Psi, 30 Psi, and 40 Psi. The minimum result was obtained at a pressure of 20 psi, amounting to 4793.94 calories. The highest yield was achieved at a pressure of 40 psi, resulting in 5266.52 calories. At a pressure of 30 psi, the results obtained were 5137.64 calories [17]. These findings are consistent with research conducted at pressure variations of 60 kg/cm^2 and 70 kg/cm^2, while at a pressure of 50 kg/cm^2, the results did not align with the author's exploration. This discrepancy could be attributed to low impact content and debris content. It was observed that the higher the calorific value, the better the properties of the briquettes produced [18]. Tests conducted by the authors showed that the highest values were obtained at a pressure of 70 kg/cm^2, supporting the notion that higher pressure leads to a higher heating value.

Water Content Analysis

The water content test is conducted to determine the amount of moisture present in the briquettes. The moisture analyzer is used as the tool for testing the moisture content. Before testing the briquettes, they are first crushed into powder. The average mass of the sample to be tested is approximately 2 grams. During the water content test, the time and temperature can be measured to determine if the water content value remains constant.

Based on Figure 4, the water content for a pressure of 50 kg/cm^2 is 7% for 1 minute and 21 seconds, with a temperature of 104^{o}C. The sample mass before testing is 2.038 grams, and the sample mass after testing is 1.946 grams. At a pressure of 60 kg/cm^2, a water content value of 7.47% was obtained for 1 minute and 35 seconds at a temperature of 105^{o}C. The sample mass before testing was 2.009 grams, and the sample mass after testing was 1.890 grams. For a pressure of 70 kg/cm^2, it produced a water content value of 6.06% for 2 minutes and 12 seconds, with a temperature of 104^{o}C. The sample mass before testing is 2.047 grams, and the sample mass after testing is 1.945 grams. The results show that the temperature and mass of the sample before testing have an impact on the water content results. According to the standard of SNI No.1/6235/2000 for Briquettes, good briquettes should have a moisture content of ≤8%.

The research conducted by A. Trisa et al. (2020) tested the briquettes using a method that involved examining the percentage of water content contained in the briquettes while varying the applied pressure to 75 kg/cm^2, 100 kg/cm^2, 125 kg/cm^2, and 150 kg/cm^2. The highest water content value recorded was 8.8% at a pressure of 75 kg/cm^2, while the minimum water content was 5.06% at a pressure of 150 kg/cm^2 [19]. These results align with the tests carried out by the manufacturer using a pressure range of 50 kg/cm^2 and 70 kg/cm^2, demonstrating that higher pressure levels lead to lower water content values [20]. However, the results at a pressure of 70 kg/cm^2 did not match the findings reported by A. Trisa et al. (2020). The author concluded that the temperature and sample mass before testing had an impact on the water content results. The results of the water content test, indicating that at a pressure of 50 kg/cm^2 and 70 kg/cm^2, the temperature was the same at 104°C, while at a pressure of 60 kg/cm^2, the temperature was higher at 105°C. This is attributed to the lower calorific value, resulting in higher water content in the briquettes [21].

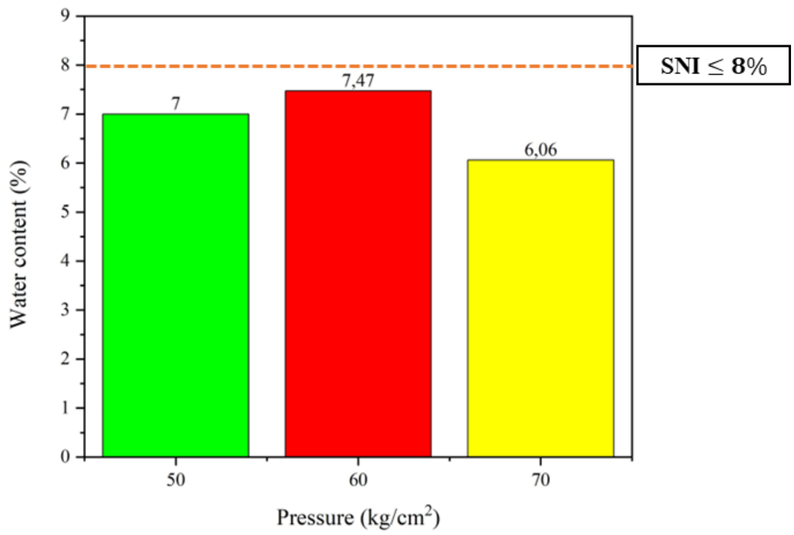


Figure 4. The water content at various pressure levels.

Carbon Content Analysis

The carbon content indicates how much remains from the consumption of coconut shell-based biomass charcoal briquettes that utilize tapioca flour as a binder, with pressure variations of 50 kg/cm^2, 60 kg/cm^2, and 70 kg/cm^2. The furnace is used as a tool to test the carbon content, which greatly affects the briquette's quality (Graph 5). The carbon content at a pressure of 50 kg/cm^2 is 44.4597%, with a sample mass of 2.0450 grams. At a pressure of 60 kg/cm^2, it is 43.3794%, with a sample mass of 2.3608 grams. And at a pressure of 70 kg/cm2, the carbon content is 43.5946%, with a sample mass of 2.1794 grams. The graph illustrates that the highest carbon content is observed at a pressure of 50 kg/cm^2, which is 44.4597%, while the lowest carbon content is found at a pressure of 60 kg/cm^2, measuring 43.3794%. Briquettes with higher carbon content will produce less smoke when used, leading to higher quality briquettes. Additionally, the resulting calorific value increases with the carbon content. When the briquettes contain minimal ash and volatile matter, the carbon content will be higher. A low water content value will also increase the carbon content value.

According to research by D. R.A. Muhammad et al. (2013), charcoal briquettes dried with a tray dryer had a higher carbon content than charcoal briquettes dried in the sun and exceeded Japanese and SNI standards. The calorific value increases with the carbon content [21]. The author's research shows that the highest carbon content value is obtained at a pressure of 50 kg/cm^2, reaching 44.45966 calories. Briquettes with higher carbon content will produce less smoke when used, resulting in higher quality briquettes. Moreover, the resulting calorific value increases with the carbon content. Briquettes containing little ash and volatile matter will have a very high carbon content. Additionally, a lower water content value will increase the carbon content value [22].

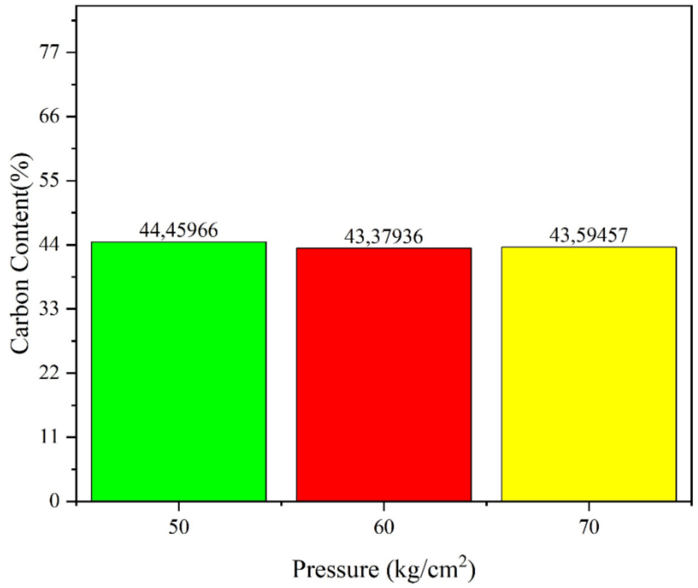


Figure 5. Carbon content results at various pressure levels

Ash Content Analysis

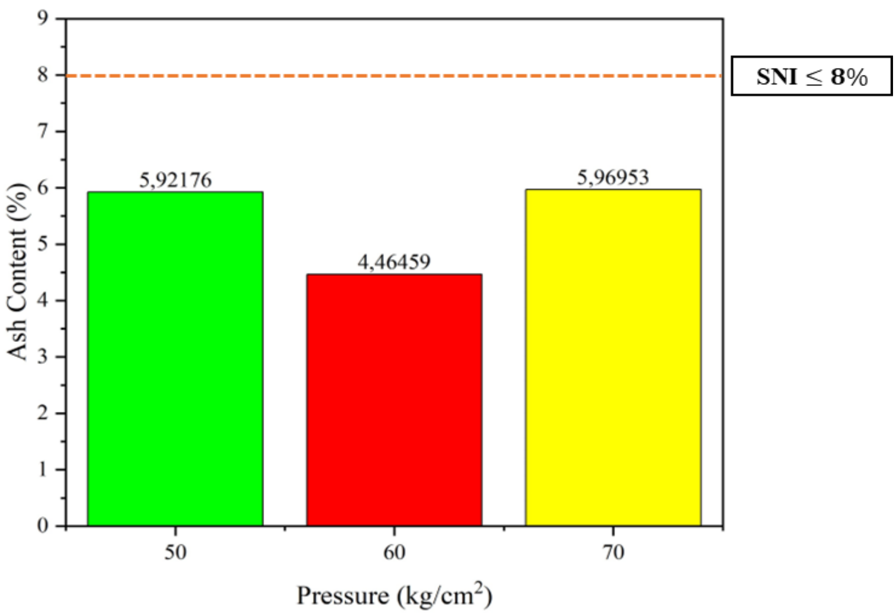


Figure 6. Ash content at different pressure levels.

The acceptable ash content indicates the amount of residual material resulting from the consumption of coconut shell-based biomass charcoal briquettes that use tapioca flour as an adhesive. Based on figure 6, which represents the ash content in coconut shell biomass charcoal briquettes as a base material with tapioca adhesive, it was observed that the highest ash content was found at a pressure of 70 kg/cm^2, which was 5.9695%. This value was not significantly different from the ash content at a pressure of 50 kg/cm^2, which was 5.9218%. Conversely, the lowest ash content was obtained at a pressure of 60 kg/cm^2, which measured 4.4646%. Thus, it can be concluded that the best biomass charcoal briquettes in terms of ash content are those produced at a pressure of 60 kg/cm^2. It is important to note that all three samples fall under the category of good charcoal briquettes, as they possess an ash content below 8%. The increased thickness of the briquettes contributes to the reduction in ash content. As a result, the higher the pressure used during production, the lower the ash content in the briquettes.

Research conducted by N. H. Haryanti et al. (2020) involved varying the printing pressure, namely 150 kg/cm^2, 200 kg/cm^2, 250 kg/cm^2, 300 kg/cm^2, and 350 kg/cm^2. The normal briquette ash content obtained ranged from 10.507% to 7.178%. The highest debris content was found at a stress of 150 kg/cm^2, which was 10.507%, while the lowest ash content was found at a stress of 350 kg/cm^2, measuring 7.178%. The ash content is affected by the actual manufacture of briquettes [18]. These findings are in accordance with research exploring variations of 50 kg/cm^2 and 60 kg/cm^2, although at an emphasis of 70 kg/cm^2, it shows results that do not align with the examination of N. H. Haryanti et al. (2020) This is because the thickness of the large briquettes causes a reduction in the ash content in the briquettes [23].

Research conducted by Y. Darvina (2011) involved varying the pressing pressure to 10 kg/cm^2, 12 kg/cm^2, 14 kg/cm^2, 16 kg/cm^2, and 18 kg/cm^2. The results of the ash content test show that the higher the pressure, the smaller the ash content obtained. The lowest ash content was found at a pressure of 18 kg/cm^2, measuring 11.27%, while the highest ash content was found at a pressure of 10 kg/cm^2, measuring 13.85% [24]. Research conducted by Y. Darvina (2011) compatibility with the author's research at pressures of 50 kg/cm^2 and 60 kg/cm^2, demonstrating that the higher the pressure, the lower the ash content.

Analysis of Volatile matter

Unstable substances or unpredictable substance levels refer to compounds that can be lost as decomposition byproducts present in charcoal or briquettes, other than water. This test is conducted to determine how much of the sample or briquettes will evaporate or volatilize during the testing process. High levels of volatilization or volatile matter typically occur when the carbonization process is incomplete, influenced by the cooking time of the coconut shell.

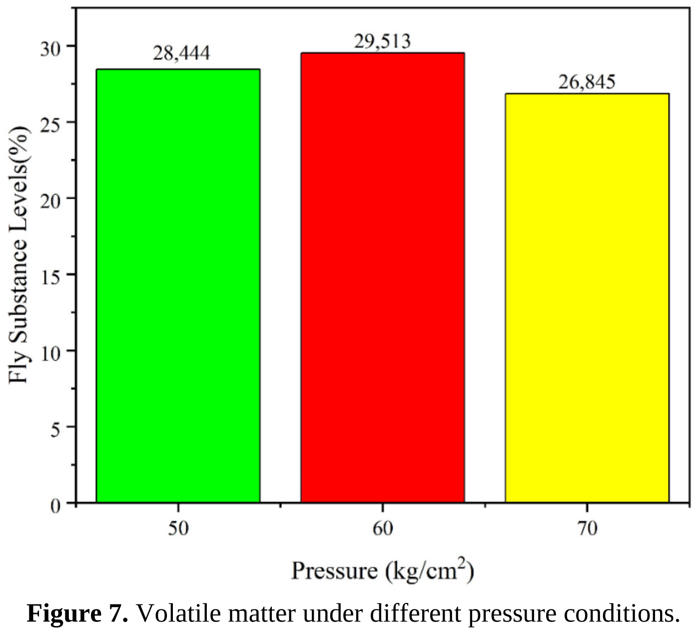


Figure 7. Volatile matter under different pressure conditions.

Based on the graph presented in Figure 7, it can be concluded that briquettes made from coconut shells using tapioca flour as an adhesive with pressure variations yield the highest volatile matter content at a pressure of 60 kg/cm^2, which is 29.513%. The second highest volatile matter content is observed at a pressure of 50 kg/cm^2, at 28.444%. Lastly, the third highest volatile matter content is recorded at a pressure of 70 kg/cm^2, measuring 26.845%. Imperfections in carbonization, such as improper allocation of time and temperature during coking, can lead to elevated levels of volatile matter. The volatile matter content in briquettes made from coconut shells using tapioca flour as an adhesive, as tested by the authors, exceeds the SNI standards for briquettes, where the volatile matter content should not exceed 15%. This is attributed to the incomplete decomposition of non-carbon mixtures, such as H_2, CO, CO_2, and CH_2.

According to N. Iskandar et al.,(2019) it is stated that the higher the amount of unstable substances in a fuel, the more smoke is produced. When burned at high temperatures, chemical components like volatile matter contribute to increased smoke production. The amount of volatile matter obtained is proportional to the amount of starch present. This is because the unstable substances such as CO, CO_2, H_2, CH_2, and H_2O found in the starch cement and coconut shell charcoal also disappear. Research findings reveal an evaporation rate of 14.8% [25].

Research by R. Bachmid, et al. (2020) the pressure was varied at 35 kg, 400 kg, 450 kg, and 500 kg. The lowest yield of volatile matter was obtained at a pressure of 500 kg, which measured 33.34%, while the highest yield was achieved at a pressure of 350 kg. In the writer's research, the greatest results were observed at a pressure of 60 kg/cm^2. This is due to the low density level of the pressure load of 60 kg/cm^2, which results in relatively large air cavities being formed [26]. Imperfections in carbonization, along with the allocation of time and temperature during coking, can cause high levels of volatile matter [9].

Comparison of the briquette products from the research with the SNI standards on briquettes.

The comparison between SNI Briquette Standards No.1/6235/2000 and the results of the research conducted by the author is shown in Table 4. This table presents a comparison of SNI Briquette standards with the author's research findings. One of the outcomes of the briquette experiment did not align with SNI standards, especially in the testing for volatile matter content, which exceeded 15%. The accuracy of the carbonization process, as well as the duration and temperature of the carbonization cycle, can both influence the level of volatile matter increase. Prolonged high temperatures during the carbonization process can result in more volatile matter evaporation or loss.

The author introduced a compression test to determine the pressure that yielded the highest briquette results. Based on the pressure test conducted, it was found that the highest yield was achieved at 70 kg/cm^2, namely 6.63, while the lowest yield was at 50 kg/cm^2 with 2.86, and 2.98 at 60 kg/cm^2. For testing the water content, ash content, carbon content, and calorific value, the briquettes met the SNI guidelines. The results of the pressure test were as follows: 2.86 for 50 kg/cm^2, 2.98 for 60 kg/cm^2, and 6.63 for 70 kg/cm^2.

Table 4 Comparison of SNI Briquette Standards and Author Research Results

Variable	SNI Briquette Standards	Pressure Variation (kg/cm^2)		
		50	60	70
Water Content (%)	≤8	7.00	7.47	6.06
Ash Content (%)	≤8	5.92	4.46	5.96
Carbon Content (%)	-	44.45	43.37	43.59
Calorific Value (kal/g)	≥5000	5551.708	4782.818	5726.611
Volatile matter (%)	≤15	28.44	29.51	26.84
Compression Test	-	2.86	2.98	6.63

4. Conclusion

The research findings reveal that varying pressure levels during briquette production significantly impact the properties of the resulting briquettes. Higher pressure leads to reduced water content, lower ash content, higher carbon content, increased calorific value, decreased volatile matter content, and a slower combustion rate. This suggests that briquettes manufactured at higher pressures are more efficient, cleaner-burning, and provide higher energy output. Notably, briquettes produced at 70 kg/cm^2 demonstrated the most favorable properties, making them the preferred choice for effective and sustainable fuel consumption. Overall, the study highlights the importance of considering pressure variations in the manufacturing process to optimize the quality and performance of coconut shell-based biomass charcoal briquettes with tapioca flour as an adhesive.

Bibliography

[1] Az. Syaiful and M. Tang, "Pembuatan Briket Arang Dari Tempurung Kelapa Dengan Metode Pirolisis," *Saintis*, vol. 1, no. 2, 2020.

[2] A. Hapid, Muthmainnah, and Ahmad, "KARAKTERISTIK BRIKET ARANG DARI CAMPURAN TEMPURUNG KELAPA DAN SERBUK GERGAJI KAYU PALAPI (Heritiera Sp)," vol. 15, no. 2, 2018.

[3] F. Paundra and A. Nurdin, "Study of the Potential and Development of Renewable Energy Power in Indonesia : a Review," *Steam Eng.*, vol. 3, no. 2, pp. 62–72, 2022, doi: 10.37304/jptm.v3i2.4024.

[4] A. E. Setyono and B. F. T. Kiono, "Dari Energi Fosil Menuju Energi Terbarukan: Potret Kondisi Minyak dan Gas Bumi Indonesia Tahun 2020 – 2050," *J. Energi Baru dan Terbarukan*, vol. 2, no. 3, pp. 154–162, 2021, doi: 10.14710/jebt.2021.11157.

[5] H. Anizar, E. Sribudiani, and S. Somadona, "Pengaruh Bahan Perekat Tapioka Dan Sagu Terhadap Kualitas Briket Arang Kulit Buah Nipah," *Perennial*, vol. 16, no. 1, pp. 11–17, 2020, [Online]. Available:

http://dx.doi.org/10.24259/perennial.v16i1.9159

[6] A. Zaenul amin, J. T. Mesin, F. Teknik, and U. N. Semarang, "Pengaruh Variasi Jumlah Perekat Tepung Tapioka Terhadap Karakteristik Briket Arang Tempurung Kelapa," *Sainteknol J. Sains dan Teknol.*, vol. 15, no. 2, pp. 111–118, 2017.

[7] L. Hanandito and W. Sulthon, "Pembuatan Briket Arang Tempurung Kelapa Dari Sisa Bahan Bakar Pengasapan Ikan Kelurahan Bandarharjo Semarang," *Tek. Kim.*, vol. 2, no. 1, pp. 1–9, 2012, [Online]. Available: http://eprints.undip.ac.id/36696/1/3.Artikel_Ilmiah.pdf

[8] R. Herjunata, S. R. Noviandini, and S. D. Kholisoh, "Pengaruh Variasi Perekat pada Briket Berbahan Limbah Tempurung Kelapa," *Semin. Nas. Tek. Kim. "Kejuangan,"* vol. 11, no. J, pp. 1–5, 2020.

[9] N. -, N. M. Sari, and M. F. Mahdie, "Pengaruh Persentase Perekat Tapioka Terhadap Karakteristik Briket Arang Tempurung Kelapa," *J. Sylva Sci.*, vol. 4, no. 2, p. 324, 2021, doi: 10.20527/jss.v4i2.3343.

[10] A. Ningsih, "Analisis kualitas briket arang tempurung kelapa dengan bahan perekat tepung kanji dan tepung sagu sebagai bahan bakar alternatif," *JTT (Jurnal Teknol. Terpadu)*, vol. 7, no. 2, pp. 101–110, 2019, doi: 10.32487/jtt.v7i2.708.

[11] J. Kurniati, Rezki, "Seminar Nasional Industri dan Teknologi (SNIT), Politeknik Negeri Bengkalis," *Peranc. Apl. Antrian Pasien Di Rumah Sakit Menggunakan Metod. Fast*, no. Lcm, pp. 270–276, 2019.

[12] E. Budi, "Pemanfaatan Briket Arang Tempurung Kelapa Sebagai Sumber Energi Alternatif," *Sarwahita*, vol. 14, no. 01, pp. 81–84, 2017, doi: 10.21009/sarwahita.141.10.

[13] J. Priatna, "Pengaruh Variasi Tekanan Terhadap Karakteristik Briket Serbuk Gergaji Pohon Kelapa Dengan Metode Cetak Panas," 2019, [Online]. Available: https://lib.unnes.ac.id/35487/

[14] R. Setiowati, "Pengaruh variasi tekanan pengepresan dan komposisi bahan terhadap sifat fisis briket arang".

[15] M. L. Umrisu, R. K. Pingak, and A. Z. Johannes, "Pengaruh Komposisi Sekam Padi Terhadap Parameter Fisis Briket Tempurung Kelapa," *J. Fis. Fis. Sains dan Apl.*, vol. 3, no. 1, pp. 37–42, 2018, doi: 10.35508/fisa.v3i1.592.

[16] D. A. Fauzie, "Pengaruh tekanan terhadap nilai kalor pada briket berbahan kulit kedelai," *Skripsi*, pp. 1–49, 2019.

[17] M. A. Aljarwi, D. Pangga, and S. Ahzan, "Uji Laju Pembakaran Dan Nilai Kalor Briket Wafer Sekam Padi Dengan Variasi Tekanan," *ORBITA J. Kajian, Inov. dan Apl. Pendidik. Fis.*, vol. 6, no. 2, p. 200, 2020, doi: 10.31764/orbita.v6i2.2645.

[18] N. H. H. H. W. Suryajaya, "Pengaruh Tekanan Pada Briket Arang Alaban Ukuran Partikel Kecil," *Risal. Fis.*, vol. 4, no. 1, pp. 19–26, 2020, doi: 10.35895/rf.v4i1.170.

[19] A. Trisa, W. Nuriana, and Mustafa, "Pengaruh Variasi Tekanan Terhadap Densitas , Kadar Air Dan Laju Pembakaran Pada Briket Pelepah Kelapa," *Semin. Nas. Sains dan Teknol. Terap. VII*, vol. 7, p. 422, 2020.

[20] A. A. Widodo, "Pengaruh Tekanan Terhadap Karakteristik Briket Bioarang Dari Sampah Kebun Campuran Dan Kulit Kacang Tanah Dengan Tambahan Minyak Jelantah," *Skripsi*, no. Jurusan Teknik Lingkungan, Universitas Islam Indonesia, Sleman, 2016, [Online]. Available: https://dspace.uii.ac.id/handle/123456789/2461

[21] D. R. A. Muhammad, N. H. R. Parnanto, and F. Widadie, "Kajian Peningkatan Mutu Briket Arang Tempurung Kelapa Dengan Alat Pengering Tipe Rak Berbahan Bakar Biomassa The Study Of Quality Improvement Of Charcoal Briquette Made Of Coconut Shell With Biomass-Fuel Tray Dryer," *Teknol. Has. Pertan.*, vol. VI, no. 1, pp. 23–26, 2013, [Online]. Available: www.uns.ac.id

[22] B. Setiawan and I. Syahrizal, "Unjuk Kerja Campuran Briket Arang Ampas Tebu Dan Tempurung Kelapa," *Turbo J. Progr. Stud. Tek. Mesin*, vol. 7, no. 1, pp. 57–64, 2018, doi: 10.24127/trb.v7i1.677.

[23] R. P. Dewi, T. J. Saputra, and S. J. Purnomo, "Analisis karakteristik briket arang dengan variasi tekanan kempa pembriketan," vol. 23, no. 1, pp. 13–19, 2020.

[24] Y. Darvina and N. Asma, "Upaya Peningkatan Kualitas Briket Dariarangcangkangdantandankosong Kelapa Sawit (Tkks) Melalui Varlasl Tekanan Pengepresan," *Lap. Penelit. Dana Jur. Univ. Negeri Padang*, pp. 1–50, 2011, [Online]. Available: http://repository.unp.ac.id/1378/1/Yenni Darvina_535_14.pdf

[25] N. Iskandar, S. Nugroho, and M. F. Feliyana, "Uji Kualitas Produk Briket Arang Tempurung Kelapa Berdasarkan Standar Mutu Sni," *J. Ilm. Momentum*, vol. 15, no. 2, 2019, doi: 10.36499/jim.v15i2.3073.

[26] R. Bachmid, H. Halim, S. P. Yudha, and A. Halim, "Journal of Chemical Process Engineering Pengaruh Penekanan Briket Limbah Kayu Merbau (Bayam) Dengan Perekat," vol. 5, no. 2655, 2020.