Jurnal Rekayasa Mesin
p-ISSN: 1411-6863, e-ISSN: 2540-7678
Vol. 19, No. 1, April **2024**, hal. 65-76

# Analysis of Biomass Briquettes Made from Bagasse Using Tapioca Starch Adhesive with Drying Temperature Variations

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Diajukan: 18-09-2023; Diterima: 09-04-2024; Diterbitkan: 29-04-2024

**Abstrak**

Ketergantungan pada bahan bakar fosil membuat ketersediaannya semakin langka. Oleh karena itu, energi terbarukan dianggap sebagai solusi terbaik untuk menggantikan bahan bakar fosil. Pada saat ini, fokus utama seharusnya adalah mengoptimalkan penggunaan energi terbarukan. Salah satu contoh upaya dalam mengarahkan fokus ini adalah melalui pembuatan briket biomassa yang menggunakan ampas tebu dan tepung tapioka sebagai bahan perekat, dengan perbandingan 2:3. Pada penelitian ini, digunakan tekanan sebesar 50 kgf/cm$^2$ dan variasi suhu pengeringan (100°C, 150°C, dan 200°C) selama 1 jam. Tujuan utama dari penelitian ini adalah untuk membandingkan kualitas briket ampas tebu dengan Standar Nasional Indonesia (SNI) No. 01/6235/2000. Hasil pengujian menunjukkan bahwa kondisi terbaik tercapai pada suhu pengeringan 200°C dengan tingkat kelembaban sebesar 4,47%, nilai kalor mencapai 5077,32 kal/g, laju pembakaran sebesar 0,1386 g/menit, serta kadar karbon, kadar zat volatil, dan kadar abu masing-masing adalah 22,8333%, 26,845%, dan 2,8323%.

**Kata kunci:** briket biomassa; perekat tapioka; ampas tebu; temperatur pengeringan; Standar Nasional Indonesia (SNI)

***Abstract***

*Dependency on fossil fuels is making their availability increasingly scarce. Renewable energy is considered the best solution to replace fossil fuels, and at present, the primary focus should be on optimizing the utilization of renewable energy sources. As an example, biomass briquettes are being manufactured using bagasse and tapioca flour as adhesive in a 2:3 ratio. This study utilized a compression force of 50 kgf/cm$^2$ and variations in drying temperatures (100°C, 150°C, and 200°C) for 1 hour. The main objective of this research is to compare the quality of bagasse briquettes with the Indonesian National Standard (SNI) No. 01/6235/2000. The test results indicate that the best conditions were achieved at a drying temperature of 200°C, with a moisture content of 4.47%, a calorific value of 5077.32 cal/g, a combustion rate of 0.1386 g/min, and carbon, volatile matter, and ash content percentages of 22.8333%, 26.845%, and 2.8323%, respectively.*

***Keywords:*** *Biomass Briquettes; tapioca adhesive; bagasse; drying temperature; Indonesian National Standard (SNI)*

## 1. Introduction

Indonesia is on a path to becoming a developed country and requires a substantial energy supply. Currently, the majority of Indonesia's energy is sourced from non-renewable fossil fuels such as coal, gas, and oil. Unfortunately, the increasing use of these fossil fuels has led to their scarcity. To address this issue, there is a pressing need for alternative, renewable energy sources [1]. The most promising solution is to harness New and Renewable Energy (EBT) to reduce our dependence on fossil fuels. The Indonesian government must prioritize the development of EBT, not only to decrease reliance on fossil fuels but also to create cleaner and more environmentally friendly energy sources [2].

Renewable energy is derived from ongoing natural processes that do not easily deplete. Sources like sunlight, wind, river water, seawater, and vegetation can be converted into energy [3]. Indonesia, as an agricultural nation blessed with abundant natural resources, possesses significant potential for leveraging renewable energy. For instance, agricultural waste, such as the residue from sugarcane milling, can serve as a biomass-based source of renewable energy [4]. Indonesia boasts a substantial sugarcane production, with Lampung Province making a substantial contribution. The leftover waste from sugarcane processing in Lampung Province can be a viable fuel source for renewable energy initiatives [5].

Biomass consists of organic matter derived from the metabolic processes of animals or plants and the resulting waste, typically containing an initial water content of 80-90%. Upon drying, the concentration of hydrocarbon compounds increases, rendering it a valuable energy source [6]. Briquettes are manufactured from agricultural or forestry waste, which possesses a high calorific value [7]. To facilitate molding, bind charcoal particles together, and improve briquette quality, adhesives—either organic or inorganic—are used in the manufacturing process. Examples of adhesive materials include starch, sago, clay, rice flour, glutinous rice flour, and archive [8]. Adhesive materials are categorized into three types: inorganic adhesives [9], organic adhesives [10], and hydrocarbons [11].

The existing literature on biomass briquettes provides valuable insights into various aspects of their production and properties; however, a comprehensive understanding of the specific impact of varying drying temperatures on briquettes made from bagasse with tapioca flour adhesive remains limited. While previous studies have explored drying conditions and adhesive materials in briquette production, few have focused specifically on bagasse briquettes and systematically varied drying temperatures, particularly within the range of 100°C to 200°C. Additionally, comprehensive assessments of properties such as calorific value, combustion rate, and environmental impacts are lacking in the literature. Therefore, this proposed study aims to address these gaps by conducting a systematic investigation of the effects of varying drying temperatures on bagasse briquettes' properties, providing insights into optimizing their production for sustainable energy utilization. Tapioca flour will be used as the adhesive material, and a pressure of 50 kgf/cm$^2$ will be applied during the manufacturing process. The drying temperature for the briquettes will be adjusted to 100°C, 150°C, and 200°C, with a drying duration of 1 hour. The parameters to be assessed in this study include moisture content, calorific value, combustion rate, ash content, carbon content, and volatile matter content.

## 2. Materials and Methods

The main ingredients used in this study for making briquettes were bagasse combined with tapioca flour adhesive, along with variations in drying temperature. The initial step involved drying the bagasse in the sun for 1-2 days. Subsequently, the carbonization process was conducted for 1 hour, followed by a 1-hour cooling period. Next, the bagasse charcoal was refined and sifted using a 40-mesh sieve [12]. Afterward, a mixture of bagasse (8 grams), tapioca flour (12 grams), and water (14 grams) was prepared. The compaction process followed, utilizing a compressive strength of 50 kgf/cm$^2$ [13]. Finally, the briquettes were dried in an oven with temperature variations of 100°C, 150°C, and 200°C . An illustration of the briquette making process is shown in Figure 1.

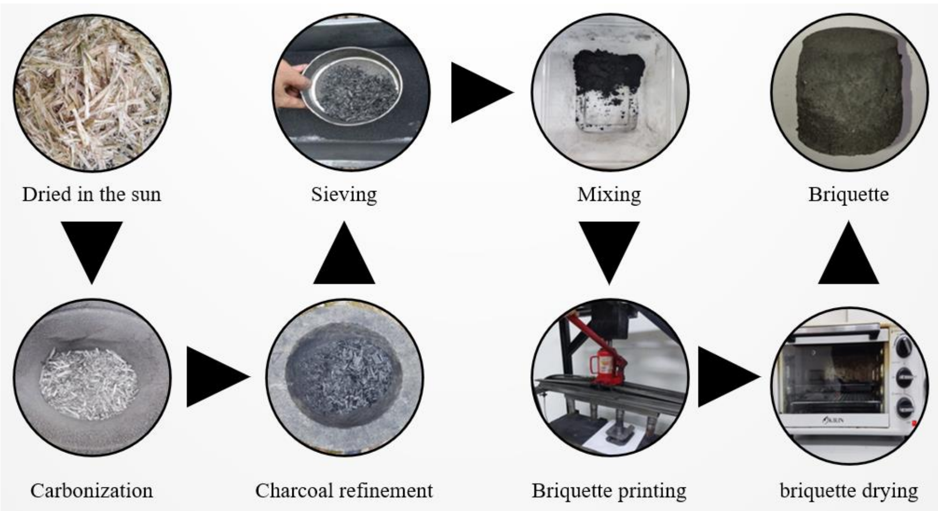


**Figure 1.** Process of making briquettes

After completing the briquette-making process, a series of tests is conducted to assess the quality of the produced briquettes. The tests carried out in this study were moisture content, calorific value, combustion rate, carbon content, volatile matter content, and ash content.

The moisture content can be determined by calculating the weight loss of the sample heated under standard conditions. Calculate the water content using the formula [14]:

$$\boldsymbol{Moisture\ content} = \frac{\boldsymbol{initial\ mass - final\ mass}}{\boldsymbol{initial\ mass}} \times \mathbf{100}\% \quad (1)$$

A bomb calorimeter is a tool utilized for measuring the heat release (calorific value) during the complete combustion (in excess of oxygen) of compounds, foods, or fuels. Multiple samples are inserted into an oxygen-filled tube immersed in a heat-absorbing medium (calorimeter). An electric flame, generated by a metal wire attached to the tube, is used to ignite the sample.

$$\boldsymbol{Calorific\ value} = \frac{\boldsymbol{tW - e_1 - e_2 - e_3}}{\boldsymbol{m}} \quad (2)$$

Description :

- t = Temperature increase (°C)
- W = Energy equivalent to a bomb calorimeter (2426 cal/°C)
- $e_1$ = Adjustment to the calorific value produced during the formation of nitric acid ($NH_3$)
- $e_2$ = Adjustment of calories made for heat in the formation of sulfuric acid ($HSO_4$)
- $e_3$ = Adjustment of calories for heat on burning wire (wire)
- m = mass of sample tested (g)

Combustion rate is employed to assess briquette quality, optimize formulation, or compare briquettes to other solid fuels.

$$\boldsymbol{Combustion\ rate} = \frac{\boldsymbol{mass\ of\ sample}}{\boldsymbol{time}} \quad (3)$$

The carbon (C) fraction combined with the ash, water, and volatile matter fractions in the briquette is referred to as the bound carbon content [15].

$$\boldsymbol{Carbon\ content} = \mathbf{100}\% - (\%\ \boldsymbol{volatile\ matters} + \%\ \boldsymbol{ashes}) \quad (4)$$

Volatile matter consists of flammable gases, such as methane ($CH_4$) and carbon monoxide (CO), and non-combustible gases, such as carbon dioxide ($CO_2$) and water ($H_2O$).

$$\boldsymbol{Volatile\ matter\ content} = \frac{\boldsymbol{initial\ mass - final\ mass}}{\boldsymbol{initial\ mass}} \times \mathbf{100}\% \quad (5)$$

The ash content is determined by weighing the complete combustion residue from the sample under standard conditions. Calculate the ash content with the formula [16] :

$$\textbf{Ash content} = \frac{\textbf{initial mass} - \textbf{final mass}}{\textbf{initial mass}} \times \mathbf{100}\% \tag{6}$$

During the briquette-making process, the quality is assessed against the Indonesian National Standard, as specified in SNI No. 1/6235/2000. Various factors, including the composition of the mixture between the main base material and filler, can influence the briquette's characteristics. The quality standards outlined in SNI No. 1/6235/2000 are provided in Table 1 below for reference.

**Table 1.** SNI briquettes [17]

| No | Parameter | SNI |
|---|---|---|
| 1 | Moisture content (%) | ≤ 8 |
| 2 | Calorific value (cal/g) | ≥ 5000 |
| 3 | Volatile matter content (%) | ≤ 15 |
| 4 | Ash content (%) | ≤ 8 |

## 3. Results and discussion

This study tested biomass briquettes made from bagasse (AT) using tapioca flour (TT) as an adhesive. The author has experimented with various compositions and discovered that employing a broader range of adhesives yields superior results. The ratio between bagasse and adhesive is 8 grams to 12 grams. Despite the lesser mass of sugarcane bagasse, visually, they both appear to be nearly equivalent. This observation is further reinforced by research conducted by Rofiq et al., which demonstrates that utilizing a greater amount of adhesive can decrease the water content in the briquettes' quality [18]. The manufacturing process involved mixing bagasse charcoal (AT) and tapioca flour (AT) in a ratio of 2:3, followed by the addition of 14 ml of water. The mixture was then compacted under a pressure of 50 kgf/cm$^2$ using a manual hydraulic press. These briquettes were subsequently dried in an oven with three temperature variations (TP): 100°C, 150°C, and 200°C, each for 1 hour. The purpose of drying was to reduce the moisture content in the briquettes.

There were observable differences in color and texture between the TP100, TP150, and TP200 briquettes. TP100 briquettes exhibited a grayish-black color, while TP150 briquettes had a grayish-black color with a hint of brownish tones. TP200 briquettes displayed a grayish-black color with darker brown tones. Regarding texture, TP100 briquettes crumbled easily, TP150 had a slightly firmer texture, and TP200 had the firmest texture of the three. The results of the variations in drying temperature are depicted in Figure 2.

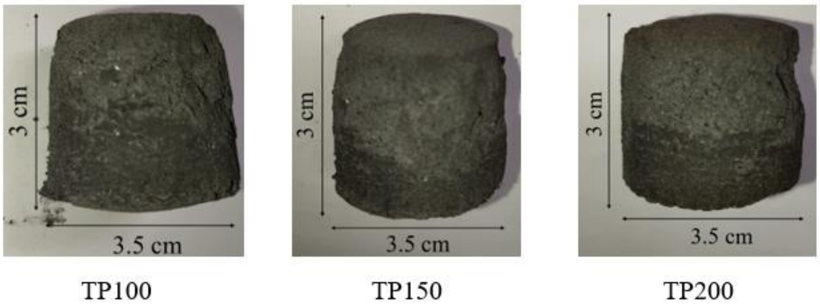


**Figure 2.** Charcoal briquettes with variations in drying temperature (TP)

### 3.1. Moisture Content

Testing the water content is a method used to determine the amount of water present in charcoal briquettes. This measurement is conducted using a device called a moisture analyzer to obtain precise data. In this study, there were three sample variations with different drying temperatures, namely TP100, TP150, and TP200. Each briquette sample was refined to form charcoal powder, simplifying the data collection process. The samples were then weighed to determine their mass. During the water content testing, several pieces of information were collected, including the moisture content of the briquettes, test duration, and test temperature.

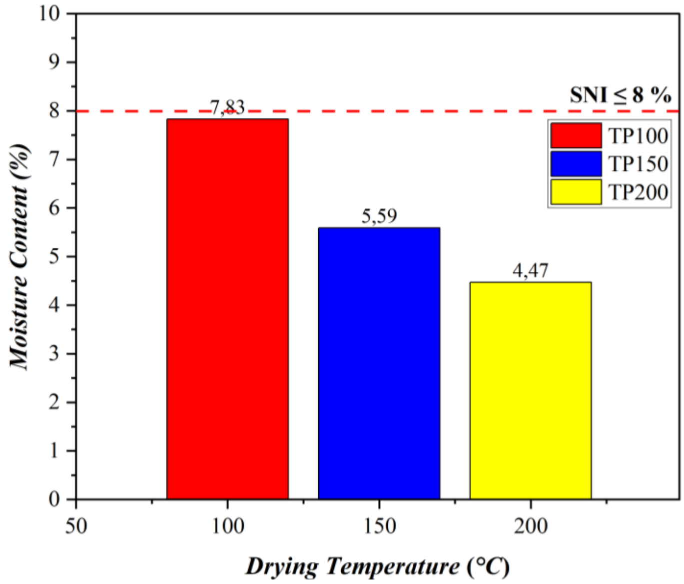


**Figure 3.** Moisture content chart

According to Figure 3, the water content in bagasse briquettes decreased as the drying temperature increased. It's evident that the lowest water content was recorded at TP200, which was 4.47%, while the highest water content was at TP100, at 7.83%. TP150 had a water content of 5.59%. Referring to SNI 01-6235-2000, briquettes are considered good if their maximum moisture content is ≤ 8%. Therefore, it can be concluded that bagasse briquettes with drying temperature variations of TP100°C, TP150°C, and TP200°C met these standards, with sequential water content levels of 7.83%, 5.59%, and 4.47%. The authors' research results indicate that a drying temperature of 200°C resulted in the lowest moisture content, while a drying temperature of 100°C produced the highest moisture content.

In a study conducted by Ristianingsih, moisture content tests were conducted using various drying temperatures. The test results indicated that the lowest moisture content was achieved at a highest drying temperature with a drying time of 2 hours. Meanwhile, the highest moisture content, occurred at a lowest drying temperature with the same drying time [19]. In Alabi's research on moisture content testing parameters, drying temperature variations were utilized [20]. The lowest water content test results were obtained using 15% adhesive with a drying temperature of 120°C, while the highest water content test results were obtained using 20% adhesive with a drying temperature of 80°C.

### 3.2. Calorific Value

The significance of calorific value in briquette manufacturing lies in the fact that briquettes must undergo a combustion process to determine the amount of heat they produce. Heating value is a key quality factor for briquettes used as fuel. Additionally, calorific value is influenced by the water and ash content in charcoal briquettes. Lower water and ash content in charcoal briquettes result in a higher calorific value. Calorific value testing employs a bomb calorimeter to collect essential data. Each sample tested with the bomb calorimeter requires 20 minutes. In this test, bagasse briquettes were subjected to three drying temperature variations: TP100, TP150, and TP200. Temperature data for calorific value testing of the briquettes was collected from the 1st to the 20th minute.

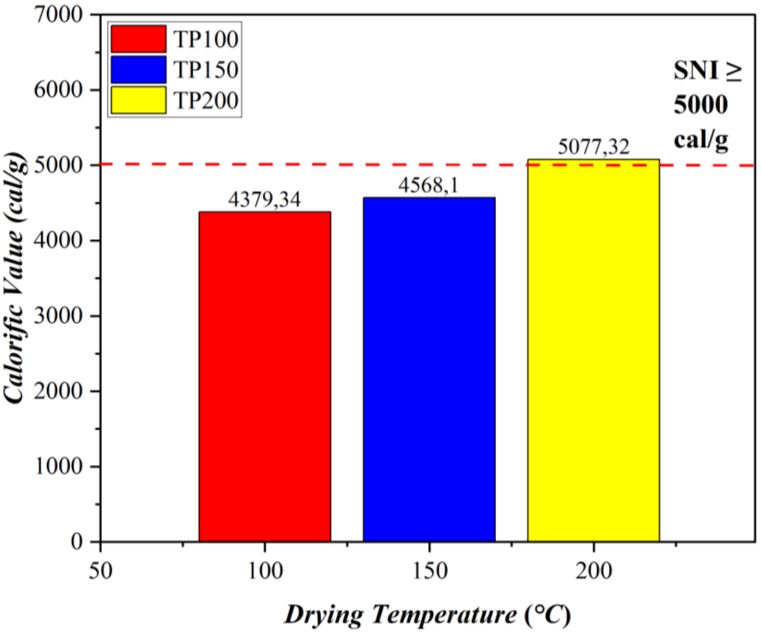


**Figure 4.** Calorific value chart

As illustrated in Figure 4, bagasse briquettes exhibited an increase in calorific value at each temperature variation. This increase was particularly notable when the heating value significantly rose from TP150 to TP200. At TP150, the calorific value reached 4568.1 cal/g, while TP200 yielded a calorific value of 5077.32 cal/g. In contrast, TP100 resulted in a calorific value of 4379.34 cal/g. Consequently, TP100 exhibited the lowest calorific value, while TP200 demonstrated the highest among the temperature variations used. According to SNI 01-6235-2000, the minimum calorific value for a briquette is ≥ 5000 cal/g. Consequently, it can be inferred that bagasse briquettes TP100 and TP150 do not meet SNI standards, possibly due to less efficient carbonization processes. In contrast, TP200 meets SNI standards.

In Ahmad's research, the calorific value of briquettes was examined at various drying temperatures, including 70°C, 80°C, and 90°C. The findings revealed that the highest calorific value, 4643 cal/g, was attained at a drying temperature of 90°C, while the lowest, 4313 cal/g, occurred at 70°C. The study analyzed the calorific values of briquettes using drying temperatures of 100°C, 150°C, and 200°C. The results indicated that the lowest calorific value of the briquettes was 2843.634 cal/g at 80°C, whereas the highest calorific value was 3814.751 cal/g at 120°C [21].

### 3.3. Combustion Rate

The combustion rate is used to determine the quality of a briquette, optimize its formulation, or compare it with other solid fuels. In this study, the combustion rate of briquettes made from bagasse biomass with tapioca adhesive was tested. Three samples were prepared with different drying temperature variations, namely TP100, TP150, and TP200. The combustion rate test was carried out by igniting the briquettes and recording the duration until they burned out. Calculations were then performed to determine the combustion rate of each briquette.

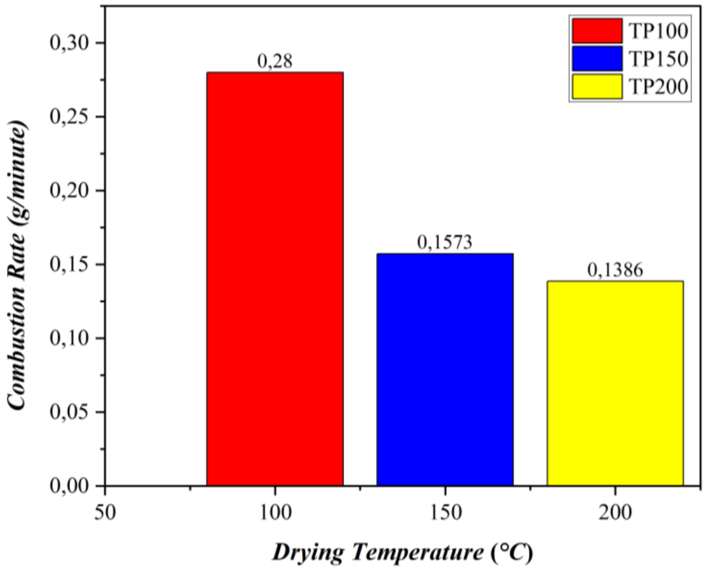


**Figure 5.** Combustion rate chart

Based on Figure 5, the results of the combustion rate graph indicate a decrease in combustion rate. At TP100, the highest combustion rate obtained was 0.28 g/minute, while at TP200, the lowest combustion rate obtained was 0.1386 g/minute. Meanwhile, at TP150, the combustion rate was 0.1573 g/minute. The author suggests that the drying temperatures of TP100, TP150, and TP200 used to dry the briquettes can affect the combustion rate test, which is consistent with the author's research showing differences in results with different briquette drying temperature variations.

Ikelle's research focused on the influence of drying temperature variations using temperatures of 80°C, 100°C, and 120°C. The highest combustion rate was observed at a drying temperature of 80°C, which was 0.21 g/minute, while the lowest combustion rate was recorded at a drying temperature of 120°C, which was 0.4 g/minute [22]. Table 2 displays a visual representation of the average combustion temperatures of briquettes at both the initial and final combustion conditions.

**Table 2.** The process of briquette combustion

| Variation of Drying Temperature (TP) | Initial Combustion | Final Combustion | Briquette Flame Temperature Average (°C) |
|---|---|---|---|
| TP100 |  |  | 137,5 |

| Variation of Drying Temperature (TP) | Initial Combustion | Final Combustion | Briquette Flame Temperature Average (°C) |
|---|---|---|---|
| TP150 |  |  | 148,2 |
| TP200 |  |  | 153,9 |

3.4. Carbon Content

Testing for carbon content was conducted on three variations of drying temperature samples, namely TP100, TP150, and TP200. Each sample was made from the same materials, namely bagasse and tapioca sugarcane adhesive. The tool used for carbon testing was the Furnace. As shown in Figure 6, TP200 produced the highest carbon content at 22.833%, while TP100 yielded the lowest carbon content at 21.0479%. TP150 had a carbon content of 21.283%. The carbon content of these bagasse briquettes did not meet the SNI 01-6235-2000 standard, which requires a minimum of 77%, for all three drying temperature variations. Several reasons contribute to this, including the conventional carbonization process, which fails to reach the ideal temperature.

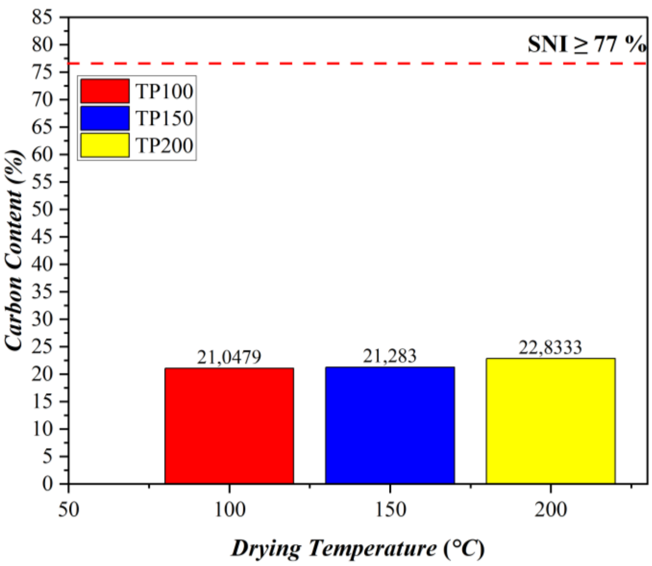


**Figure 6.** Carbon content chart

Ristianingsih's study examined parameters for testing carbon content at drying temperatures of 300°C, 350°C, 400°C, 450°C, and 500°C. At 400°C, the briquette mixture consisting of 85% charcoal and 15% starch adhesive achieved the lowest carbon content at 26.85%. Conversely, at a temperature of 500°C, the composition of the briquettes consisting of 90% charcoal and 10% starch adhesive achieved the highest carbon content at 54.5% [19]. According to Utami's research on carbon content testing with variations in carbonization temperature at 200°C, 250°C, and 300°C, the highest bonded carbon value was obtained at a carbonization temperature of 300°C and a coking time of 60 minutes, resulting in 25.71%. The lowest bonded carbon value was recorded at an influencing temperature of 200°C and a carbonization time of 30 minutes, yielding 15.03% .

3.5. Volatile Matter Content

Tests for volatile matter content were conducted on briquettes with variations in drying temperature, specifically TP100, TP150, and TP200. The tool used for measuring the levels of volatile matter was the furnace. The volatile matter content of each sample is depicted in Figure 7.

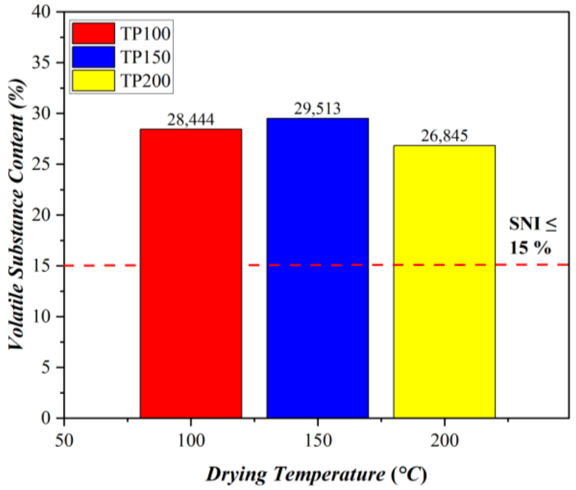


**Figure 7.** Volatile substance content chart

Figure 7 illustrates that bagasse briquettes had the highest volatile matter content at 29.513% for TP150 and the lowest volatile matter content at 26.845% for TP200. In TP100, the volatile matter content was 28.444%. The volatile matter content in the bagasse briquettes did not meet the SNI 01-6235-2000 standard, which specifies a maximum of 15%. This discrepancy can be attributed to the processing temperature during the coagulation or carbonization process, which was not sufficiently high.

Based on research conducted by Utami, the volatile matter content varied with drying temperatures of 200°C, 250°C, and 300°C. The lowest volatile matter content was achieved at a carbonization temperature of 300°C with a carbonization time of 60 minutes, resulting in 81.51%, while the highest volatile matter value was recorded at a carbonization temperature of 200°C with a carbonization time of 30 minutes, yielding 89.91%. It is noteworthy that higher drying temperatures correlated with higher volatile matter content [23].

3.6. Ash Content

Ash content testing was conducted on briquettes with variations in drying temperature, specifically TP100, TP150, and TP200. Each sample was made from the same material, namely bagasse and tapioca sugarcane adhesive. The furnace was used for testing ash content. As depicted in Figure 8, it is evident that the ash content of bagasse briquettes is relatively low. TP150 yielded the highest ash content at 3.4288%, TP200 at 3.8323%, and TP100 produced an ash content of 2.8972%. This indicates that higher drying temperatures result in lower ash content in the briquettes, while lower drying temperatures lead to higher ash content.

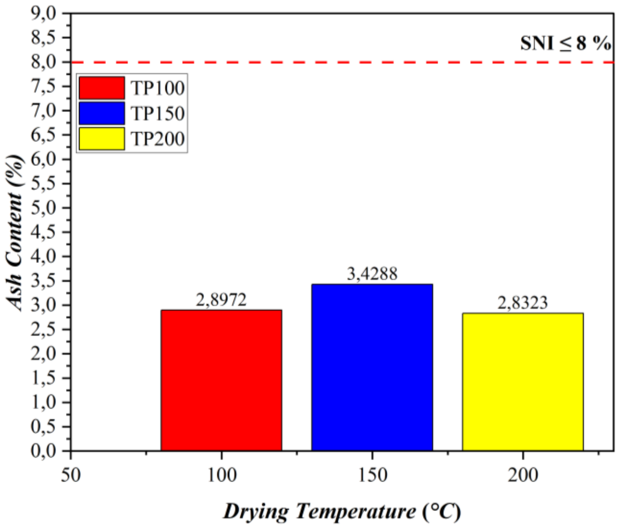


**Figure 8.** Ash Content

In research conducted by Wahida on testing the ash content of briquettes with drying temperature variations of 70°C, 80°C, and 90°C, it was observed that the lowest ash content was 0.26 % at 90°C with a drying time of 2 hours, while the highest ash content was 0.81% at 70°C with 2 hours of drying time [7]. According to the Indonesian National Standard (SNI) 01-6235-2000, the ash content of briquettes should not exceed 8%. It can be concluded that bagasse briquettes with variations in drying temperature, namely TP100, TP150, and TP200, have met these standards, with ash content of 2.8972%, 3.4288%, and 2.8233%, respectively.

The Indonesian National Standard (SNI) for briquettes is intended to ensure that briquettes produced and sold in Indonesia meet specific quality, safety, and performance standards. This standard encompasses parameters such as moisture content, ash content, volatile matter content, carbon content, and heating value. A comparison table between SNI briquettes and the author's research findings is available in Table 3.

**Table 3.** Comparison of SNI briquettes with the results of the author's research

| Variables | SNI Briquettes | Drying Temperature Variations | | |
|---|---|---|---|---|
| | | 100°C | 150°C | 200°C |
| Moisture Content | ≤ 8 | 7.83 | 5.59 | 4.47 |
| Calorific Value | ≥ 5000 | 4379.34 | 4568.1 | 5077.32 |
| Carbon Content | - | 21.0479 | 21.283 | 22.8333 |
| Volatile Substance Content | ≤ 15 | 28.444 | 29.513 | 26.845 |
| Ash Content | ≤ 8 | 2.8972 | 3.4288 | 2.8323 |

Based on Table 3, five parameters are used to determine the quality of briquettes. These parameters consist of moisture content, calorific value, carbon content, volatile matter content, and ash content. Upon reviewing the table, it becomes apparent that two out of the five parameters for briquette testing do not conform to SNI briquette standards. The incorrect test parameters for SNI briquettes include carbon content yielding less than 77% and volatile matter content yielding more than 15%. Several factors contribute to these parameters being inconsistent with SNI briquette standards, notably the conventional carbonization process, which fails to achieve the ideal temperature.

## 4. Conclusion

In conclusion, the research on bagasse briquettes encompassed a series of tests exploring water content, carbon content, volatile matter content, ash content, and combustion characteristics. Findings revealed that among variations in drying temperature (TP100, TP150, and TP200), the most favorable results were achieved at TP200, exhibiting optimal moisture content (4.47%), high calorific value (5077.32 cal/g), low burning rate (0.1386 g/minute), significant carbon content (22.833%), volatile substance content (26.845%), and ash content (2.8323%). While meeting Indonesian National Standard (SNI) criteria for moisture, ash, and calorific value, carbon and volatile substance content fell short, likely due to conventional carbonization processes failing to reach necessary temperatures. This highlights the need for refining carbonization techniques to ensure compliance with quality standards, thus enhancing bagasse briquette production efficiency.

**Acknowlegements**

The authors would like to express their gratitude to all the laboratory staff and facilities at Institut Teknologi Sumatera for their invaluable assistance in completing this research.

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