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ANALYSIS OF CHARACTERISTICS OF RICE HUSK BRIQUETTES USING STARCH ADHESIVE WITH VARYING ADHESIVE PERCENTAGES

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ABSTRAK

Peningkatan kebutuhan energi saat ini sedang dialami oleh banyak negara, termasuk Indonesia. Biomassa memiliki potensi besar sebagai sumber energi alternatif yang dapat menggantikan bahan bakar fosil yang saat ini banyak digunakan. Biomassa juga tersedia dalam jumlah yang melimpah. Salah satu metode yang dapat digunakan untuk memanfaatkan energi dari biomassa adalah melalui pembriketan. Briket adalah bahan padat yang dapat digunakan sebagai bahan bakar selama periode waktu tertentu. Biomassa yang digunakan adalah sekam padi, sekam padi dapat menjadi sumber bahan baku briket sebagai salah satu energi alternatif pengganti bahan bakar fosil. Metode penelitian ini menggunakan bahan sekam padi dan tepung kanji sebagai perekat serta pengepresan menggunakan tekanan sebesar 40 kg/cm^2, proses pengeringan dilakukan pada temperatur 100oC selama 3 jam, dengan memvariasikan persentase perekat. Variasi perbandingan sekam padi ditambah perekat yaitu sebesar 70% + 30%, 60% + 40%, 50% + 50%. Berdasarkan hasil pengujian yang telah dilakukan didapatkan variasi yang terbaik yaitu briket dengan persentase 50%+50% dengan nilai untuk kadar air sebesar 4,84%, nilai kalor sebesar 26728,61 kal/gr, kadar abu sebesar 28,78825%, kadar karbon sebesar 50,427 %, kadar zat terbang sebesar 33,919 % dan laju pembakaran sebesar 0,45662 g/menit.

Kata kunci: Biomassa, briket, sekam padi, perekat, SNI

ABSTRACT

The increasing energy demand is currently being experienced by many countries, including Indonesia. Biomass holds significant potential as an alternative energy source that can replace the widely used fossil fuels. Biomass is also available in abundant quantities. One method to harness energy from biomass is through briquetting. Briquettes are solid materials that can be used as fuel for a specified period. In this research, rice husk biomass is used as the primary material for creating briquettes. Tapioca flour is used as the binder, and the briquettes are formed under a pressure of 40 kg/cm^2. The drying process is carried out at a temperature of 100°C for 3 hours, with variations in the percentage of the binder. The binder-to-rice husk ratios tested are 70% + 30%, 60% + 40%, and 50% + 50%. Based on the conducted tests, the most favorable variation is the briquette with a 50% + 50% adhesive-to-rice husk ratio. This variation exhibits a moisture content of 4.84%, a calorific value of 26,728.61 cal/g, an ash content of 28.78825%, a carbon content of 50.427%, a *volatile matter content of 33.919%, and a combustion rate of 0.45662 g/minute.*

Keywords: *Biomass, briquette, rice husk, adhesive, Indonesian National Standard (SNI)*

1. INTRODUCTION

Economic growth has increased energy use in many areas of life. As a result, much progress is needed to stop the development of the energy crisis [1]. The environment needs energy to fulfill its needs. Demand for energy increases as the population grows over time, but getting enough energy to meet basic needs is becoming increasingly difficult. The continuous provision of energy depends on the availability of renewable energy sources [2].

Energy consumption and demand are increasing along with global population growth and rising living standards. Fuel oil is the main energy source used for production and consumption, especially in Indonesia, leading to energy scarcity. One way to reduce the worst impacts of fossil fuel consumption is to develop renewable energy sources, especially in Indonesia which has a variety of potential new renewable energy potential but has not been maximally developed [3].

Future energy shortages will be much more severe, but the signs of an imbalance between supply and demand are already there. Due to its non-renewable nature, oil will continue to become scarce and more expensive. This needs to be immediately balanced with the availability of alternative energy sources that are cheap, abundant and renewable so that they can be reached by the wider community [4].

Agricultural waste has the potential to be used as waste, but this potential has not been fully realized. Utilizing biomass will maximize the use of this waste potential. Biomass energy can be an alternative energy source to fossil fuels due to some of its favourable characteristics such as its ability to be used sustainably as it is renewable, its relative lack of sulphur so it does not contribute to air pollution, and its ability to maximize the use of forestry and agricultural resources, hence biomass energy can be used to replace fossil fuels (petroleum) as an alternative energy source [5].

Some biomasses with considerable potential are wood waste, rice husk, straw. Bagasse, coconut shells, palm kernel shells, livestock manure, and municipal solid waste. There are several methods of utilizing biomass energy such as briquetting, pelletizing, etc. Pellets are usually used to heat small and medium-sized rooms, while briquetting is the conversion of solid raw materials into a compacted form that is easier to use. Briquettes are an alternative fuel source that can be used sustainably to reduce the impact of fossil fuel use and carbon emissions [6].

Briquettes are lumps of burnable material used as fuel to ignite and sustain a flame over a long period of time. By changing the physical form of biomass by briquetting which aims to create a fuel that can be used for all sectors as a substitute energy source, scientists have proposed to increase the utilization of renewable energy from biomass which has its own energy efficiency. Powder particles, carbonization temperature and molding pressure, and formula incorporation are factors that affect briquetting properties [7].

As most Indonesians are farmers, rice husk is chosen as the main raw material for briquettes. Rice husk, which is the outer shell of the rice grain itself, is often wasted and ends up in the trash. When used, rice husks are only allowed to be burned on land close to paddy fields or as a low soil filler. Even rice husk ash is sold for the mixture used to make lightweight bricks. Only a large proportion of rice husks are burned directly in the fields where rice is grown to be used as a mixture for lightweight bricks [8].

Based on several previous studies, the title "analysis of bio characteristics of rice husk briquettes using starch adhesive with variations in adhesive percentage" was raised. This study aims to determine the most appropriate adhesive composition for the determination of calorific value test, moisture content test, carbon test, ash content test, fly content test and combustion rate. By using starch as an adhesive with adhesive percentages of 30%, 40% and 50%. And compare the quality of rice husk briquettes based on SNI standards.

2. RESEARCH METHODOLOGY

The process of briquette making involves several key steps. To begin, the rice husk experiences a dehydration stage aimed at significantly reducing its moisture content. Following the moisture removal, carbonization is initiated by heating up the rice husk feedstock in a metal container. An LPG gas burner serves as the heating source, providing continuous heat at high temperature with negligible smoke as compared to wood burning. The rice husk is heated at the average temperature of 250 oC (+/- 30 oC) for 1 hour with stirring from time to time during the process to ensure uniform heating exposure throughout the volume. After successful carbonization, the material undergoes a pulverization phase using a mortar and is subsequently sifted through a 40-mesh screen to acquire finely powdered charcoal.

The last step involves the meticulous blending of the charcoal powder with adhesive substances in specified proportions. For instance, one mixture combines 3 grams of water with 10 grams of adhesive, while another utilizes 4 grams of adhesive with 10 grams of water, and a third blend incorporates 5 grams of adhesive with 10 grams of water. The blending process is carried out at the average temperature of 30°C (+/- 2°C) and 85% relative humidity. These conditions are in accordance with the typical daytime atmospheric condition in Lampung, which also reflects the typical climate in low elevation regions in Indonesia. That being said, the method will apply for Indonesian regions in general. This thorough process guarantees the production of top-quality briquettes, as illustrated in Figure 1.

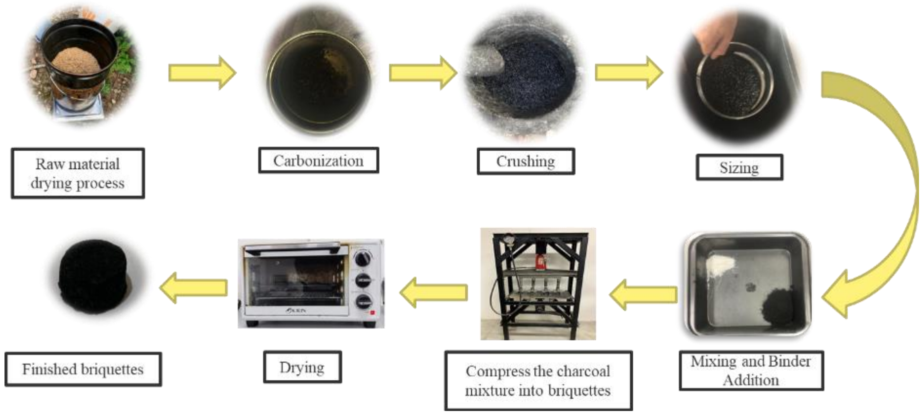

Figure 1. Briquette making process

The tests conducted in this study included: briquette moisture content, briquette ash content, briquette carbon content, briquette calorific value, and briquette volatile matter content. Moisture content is measured by means of a moisture analyzer Mettler-Toledo HE73. A calorimeter (PARR Plain Jacket Bomb Calorimeter 1341) is used for measuring the calorific value. Volatile matters content is measured with a Vulcan A550. For the measurement of ash content, a Heraus M110 is used for the heating and an Ohaus PX323E precision balance for weighing the specimen before and after heating.

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

Parameter	*SNI Standards*
Water content (%)	≤8
Volatile matter (%)	≤15
Ash content (%)	≤8
Calorific value (kal/g)	≥5000

3. RESULTS AND DISCUSSION

This study analyzes the quality of biomass charcoal briquettes made from rice husks using starch as an adhesive material. Three different samples were prepared by varying the percentage of starch adhesive (TK): specifically, 30%, 40%, and 50%, as shown in Figure 2. Each sample was created using a mass of raw rice husks totaling 10 grams. The briquettes were formed using a hydraulic press and subsequently dried in an oven for 3 hours at a temperature of 100°C. The purpose of this drying process is to reduce the water content in the briquettes.

The quality analysis conducted in this study includes assessing moisture content, calorific value, combustion rate, ash content, carbon content, and fly content. The research data obtained will be analyzed to evaluate the quality of charcoal briquettes made from rice husk base material using starch adhesive. The results indicate that the briquettes meet the standards outlined in SNI briquette standard No. 01-6235-2000. The figure below illustrates the briquette molding products using variations in adhesive percentages of 30%, 40%, and 50%.

3.1 *Burning Rate*

The combustion rate analysis aims to assess the efficiency of briquette fuel made from rice husks using starch as an adhesive. This analysis helps determine whether these briquettes are suitable for testing or use as fuel. Additionally, the author conducted combustion rate tests to identify the briquette with the longest and fastest burning times among three samples, each with a different adhesive percentage: 30%, 40%, and 50%.

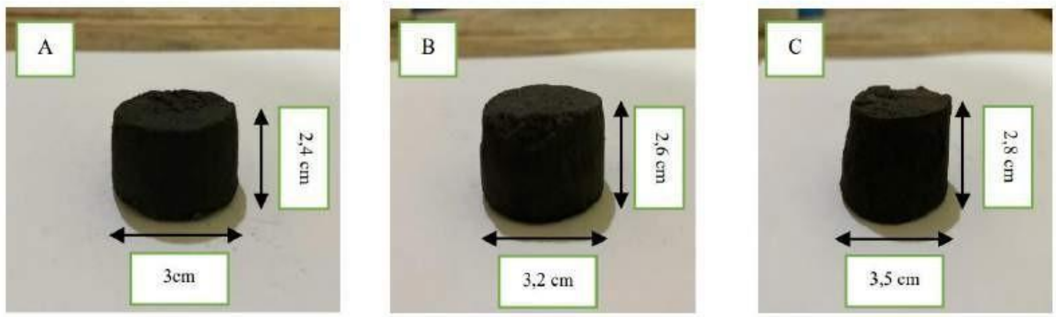

Figure 2. Briquettes with Varying Percentage of Adhesive a) 30%, b) 40% and c) 50%

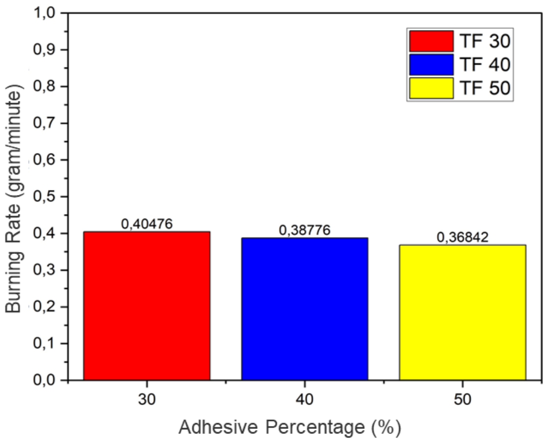

Figure 3. Burning Rate of Briquettes with Varying Percentage of Adhesive

The Figure 3 shows that the highest combustion rate is achieved in briquettes with a 30% adhesive content, at 0.40476 grams per minute, while the lowest rate is observed in briquettes with a 50% adhesive content, at 0.36482 grams per minute. Briquettes with a 40% adhesive content exhibit a combustion rate of 0.38776 grams per minute. Increasing the adhesive content results in more durable briquettes due to the greater amount of adhesive, which enhances the briquette's structural integrity, resulting in longer burn times. A study conducted by Dimas Ryan Nofanhadi et al. on variations in adhesive content of rice husk charcoal briquettes demonstrated the lowest burning rate, supporting the conclusion that higher adhesive content contributes to more durable briquettes and longer burn times [18]. This finding aligns with the author's research. Table 2 displays the burning conditions of the briquettes throughout the entire combustion process, from start to finish.

Table 2. Briquette Combustion Process

Adhesive Percentage	***Initial Combustion***	***Final Combustion***
30 %		
40 %		
50 %		

3.2 *Calorific Value Analysis*

When testing the heat value using a bomb calorimeter, various components were obtained to calculate the heat value. Initially, a preliminary test using the bomb calorimeter was conducted for each sample, lasting 20 minutes and involving a sample mass of approximately 0.3 grams, to determine the temperature of the test material before and after the ignition process. The temperature readings were recorded for the first five minutes prior to ignition and from 5 minutes and 45 seconds to 20 minutes during the briquette testing process. The briquettes used in the tests exhibited varying adhesive percentages of 30%, 40%, and 50%, with rice husk as the primary ingredient and starch as the adhesive.

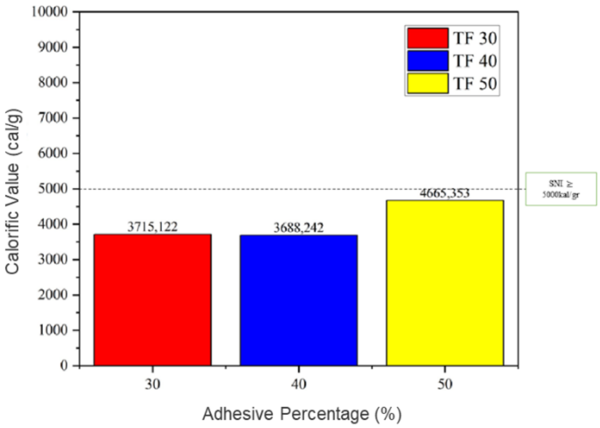

Figure 4. Calorific Value of Briquettes with Varying Percentage of Adhesive

Based on the 20-minute bomb calorimeter test data, it can be observed that the highest heating value is achieved with a 50% adhesive percentage, which measures 4665.353 cal/g, while the lowest heating value is found at a 40% adhesive percentage, measuring 3688.242 cal/g. A higher calorific value enhances the quality of briquettes by reducing smoke production and maximizing burn time. Adhesive composition also influences heating value; higher adhesive concentrations result in lower heating values and suboptimal burn times.

In a study conducted by Sabitah et al. on the experimental testing of charcoal briquette characteristics using Siam and Pandak rice husk waste, the calorific value of briquettes from Siam and Pandak rice husk types, with their respective variations, ranged from 4481.0454 to 5063.6187 cal/gram. This study's results indicate that only one type of pandak rice husk, with the lowest adhesive percentage variation, meets the SNI briquette standard No.1/6235/2000 for wood charcoal briquettes, with a calorific value of ≥ 5000 kcal [15].

Sabitah et al.'s research findings align with the author's work, particularly with specimen of 50% adhesive percentage. Our results is higher than Sabitah's Siam rice husk but lower than the Pandak one. The major cause of this intermediate value is due to the use of randomly mixed rice husk feedstock used in our specimen. Despite its randomness in composition, all those different rice husks types are sourced from the fields in South Lampung region. Therefore, the results can be considered as the case of a variety mix composition of rice husks in Lampung. That simplifies the sourcing of feedstock, simply because there is no need to exclusively select a specific rice variety. One specific variety may not be always available over years as the farmers may change the variety they cultivate from season to season. Thus, the mix of varieties taken in this work is proven beneficial from the supply chain perspective. Admittedly, an improvement is needed for our specimen to achieve the required standard, where currently is still short by 6%.

A higher calorific value improves briquette quality by reducing smoke production and maximizing burn time. Adhesive composition also influences heating value, with higher adhesive concentrations resulting in lower heating values and suboptimal burn times. Conversely, higher adhesive concentrations lead to increased water content, ash content, and fly substance content [21]. Based on the existing Indonesian standards, specifically SNI briquettes No.1/6235/2000, a good briquette is defined as having a calorific value ≥ 5000 cal/g. However, none of the three adhesive percentage variations tested, namely 30%, 40%, and 50%, meet these applicable SNI briquette standards, measuring 3715.122 cal/g, 3688.242 cal/g, and 4665.353 cal/g, respectively.

3.3 *Moisture Content Analysis*

Moisture content testing is conducted to determine the moisture content present in charcoal briquettes. A moisture analyzer is utilized for this purpose. Prior to testing, intact briquettes are initially crushed into a powder form. The powdered briquettes are then weighed, with an average sample mass of 2 grams. During the moisture content testing, the time and temperature are monitored to ensure that the water content remains constant. Subsequently, data analysis is performed, and the results are presented in Figure 5.

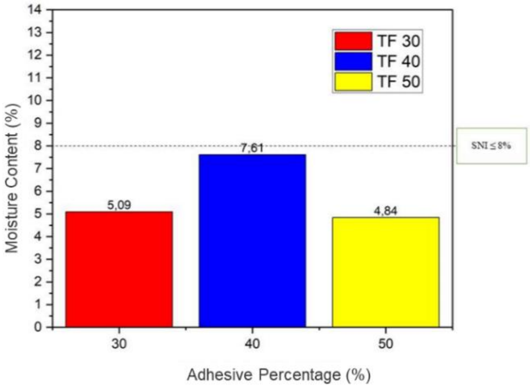

Figure 5. Moisture Content of Briquettes with Varying Percentage of Adhesive

Based on Figure 5 above, the water content values for different adhesive percentages are as follows. At a 30% adhesive percentage, the water content is 5.09%, measured for 1 minute and 26 seconds at 103°C. The sample mass before testing is 1.392 grams, and after testing, it is 1.335 grams. For a 40% adhesive percentage, the moisture content value is 7.61%, measured for 1 minute and 20 seconds at 105°C. The sample mass before testing is 0.882 grams, and after testing, it is 0.856 grams. At a 50% adhesive percentage, the moisture content value is 4.84%, measured for 1 minute and 29 seconds at 103°C. The sample mass before testing is 2.586 grams, and after testing, it is 2.169 grams.

In research conducted by Nuryati et al. on the effect of adhesive addition and particle size on briquettes from pyrolysis of rice husks, it was found that the highest water content value was observed in briquette samples with the lowest adhesive percentage, while the best water content value was observed in those with the highest adhesive percentage [2]. This finding aligns with the author's research. Moisture content plays a crucial role in determining the quality of briquette fuel. Higher moisture content can lead to a decrease in briquette quality, particularly affecting calorific value and making the briquettes more challenging to ignite [15].

Based on the existing standards in Indonesia, specifically SNI briquettes No.1/6235/2000, good briquettes are those with a moisture content value of ≤ 8%. In this study, all three variations in adhesive percentage (30%, 40%, and 50%) meet the applicable SNI briquette standards with moisture content values of 5.09%, 7.61%, and 4.84%, respectively.

3.4 *Carbon Content Analysis*

The carbon content reveals the proportion that remains after the combustion of biomass charcoal briquettes made from rice husks, utilizing starch as an adhesive, with variations in adhesive percentages of 30%, 40%, and 50%. A furnace is employed as the instrument for carbon content testing. Carbon content significantly influences the quality of the briquette.

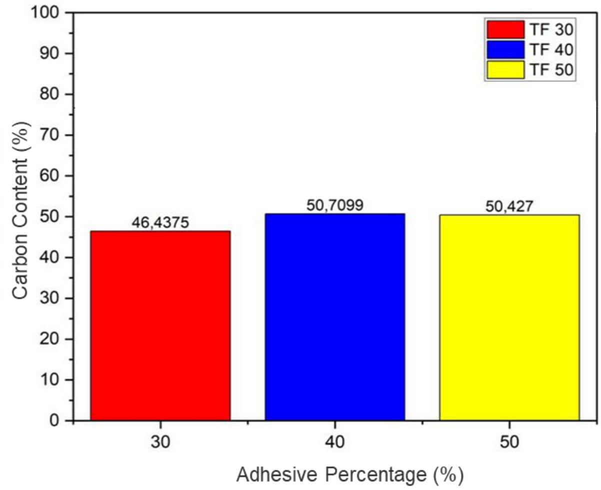

Figure 6. Carbon content of briquettes with varying percentage of adhesive

Figure 6 illustrates the carbon content percentages for various adhesive percentages in rice husk-based biomass charcoal briquettes, using starch as an adhesive material. At a 30% adhesive percentage, the carbon content is 46.4375%, while the 40% adhesive percentage exhibits a carbon content of 50.7099%. For a 50% adhesive percentage, the carbon content reaches 50.427%. The figure indicates that the highest carbon content is observed at the 40% adhesive percentage, while the lowest is found at the 30% adhesive percentage.

In a study conducted by A'yan Tsabitah et al. on experimental tests of charcoal briquette characteristics made from Siamese and pandak rice husk waste, carbon content values ranged from 25.9261% to 29.4934%. Additionally, research by Rizka W Putri et al. regarding the utilization of rice husks for the production of biobriquettes with varying tapioca flour binders revealed that the lowest carbon content was in the rice husk briquette sample with a 3:1 adhesive ratio (10%), while the highest flying substance content was in the rice husk briquette sample with a 1:3 adhesive ratio (11%). High carbon content is a desirable characteristic in a quality charcoal briquette. Carbon content tends to be high when the ash and fly substance content in the charcoal briquettes are low [24].

3.5 *Ash Content Analysis*

The ash content value indicates the proportion that remains after the combustion of biomass charcoal briquettes made from rice husk using starch as an adhesive. The test employs a furnace as the measuring instrument. Higher ash content in charcoal briquettes typically indicates lower quality. Below, you will find a graph displaying the results of the ash content analysis for briquettes with adhesive percentages of 30%, 40%, and 50%, as shown in Figure 7.

Based on Figure 7, which presents the ash content of rice husk briquettes using starch adhesive, it is evident that the highest ash content is observed in the 40% adhesive percentage, measuring 32.015009%. Following closely is the 50% adhesive percentage with an ash content value of 28.788248%. The lowest ash content, on the other hand, is found in the 30% adhesive percentage, with a value of 26.104247%. Consequently, it can be concluded that the bio briquettes with the most favorable ash content are those with a 40% adhesive percentage.

In a study conducted by Masriyandi Pratama on the analysis of rice husk briquettes with tapioca starch adhesive, varying composition percentages (20%, 25%, 30%, 35%) revealed that the highest ash content in the experiment was 33.52% in the 35% composition. This outcome can be attributed to the fact that tapioca starch adhesives tend to reduce the combustion quality of rice husk briquettes, with higher adhesive material usage resulting in greater ash content [11]. This finding aligns with the author's research.

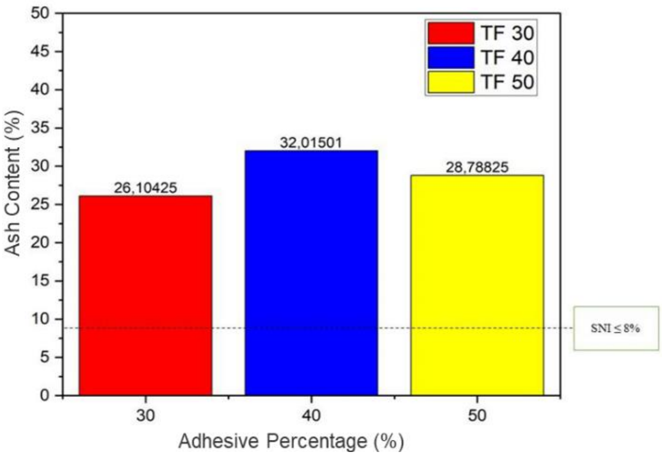

Figure 7. Ash Content of Briquettes with Varying Percentage of Adhesive

The ash content in a briquette significantly impacts its combustion efficiency when used. All briquettes contain inorganic substances that remain after complete combustion, referred to as ash. Briquettes with high ash content are undesirable because they can lead to scale formation [23]. In accordance with Indonesian standards, specifically SNI briquettes No.1/6235/2000, good briquettes are defined as those with a moisture content value of ≤ 8%. However, in this study, all three adhesive percentage variations tested (30%, 40%, and 50%) fail to meet the applicable SNI briquette standards, recording ash content percentages of 26.104247%, 32.015009%, and 28.788248%, respectively.

This discrepancy is due to the influence of starch adhesive proportions used in the briquette production process. As evidenced by the findings in Figure 7 and supported by Masriyandi Pratama's research, higher adhesive percentages tend to result in increased ash content. While this may impact the adherence to SNI standards, it's essential to consider the trade-off between ash content and other briquette qualities, such as structural integrity and combustion properties. In practical terms, high ash content can lead to decreased combustion efficiency and potentially more residue when briquettes are used as fuel. Therefore, while the ash content may not meet SNI standards, it's essential to evaluate briquettes holistically, taking into account their overall performance in various applications.

This high ash content, which is currently does not conform with SNI, is caused by several factors that subject to our further works. The first aspect to scrutinize is the presence of impurities in the rice husk feedstocks, or in a simple terms, the cleanliness of the raw materials from contaminants like soil, minerals or other foreign matters. The other factor is the moisture content that should be further decreased. Another improvement is also to be made in terms of the quality of binder or adhesive, since the quantity of binder material may affect the resulting ash content of the end product, hence a high quality but low quantity is expected.

3.6 *Volatile Matters Analysis*

The level of flying or vaporized substances is a substance that can evaporate as the level of volatile or vaporized substances refers to compounds that can evaporate during the decomposition of materials present in charcoal or briquettes, apart from water. Elevated levels of volatile substances often result from an incomplete carbonization process, which can be influenced by the duration of rice husk charring. The instrument employed for this test is a Furnace, and the results are presented in Figure 8 after data analysis.

Based on Figure 8, it can be concluded that rice husk-based briquettes using starch as an adhesive, with various adhesive ratios, exhibit the highest content of volatile substances in the variation with a 50% adhesive ratio, measuring 36.481%. The second-highest volatile substance content is found in the variation with a 30% adhesive ratio, at 36.381%, while the lowest volatile substance content is observed in the 40% adhesive ratio, measuring 33.919%.

Research conducted by Rizka W Putri et al. concluded that none of the samples in this study meet the SNI briquette standard No.01-6235-2000, where the maximum allowable fly content is ≤ 15 [24]. These findings align with the author's research. Among the three adhesive percentage variations tested (30%, 40%, and 50%), none meet the applicable SNI briquette standards of 36.381%, 33.919%, and 36.481%. This discrepancy may result from suboptimal charring time and temperature, which can prevent the efficient evaporation of organic substances in rice husks [8].

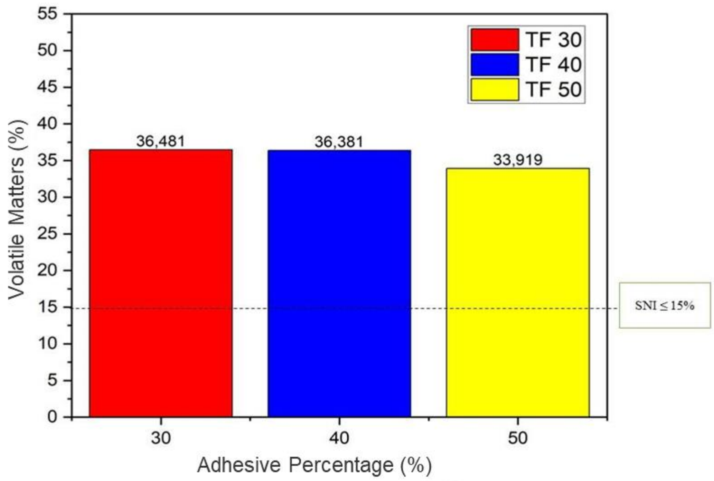

Figure 8. Volatile Matters of Briquettes with Varying Percentages of Adhesive

Standard deviation analysis could not be conducted in this study because testing on each sample was performed using only the best sample from each production process. Therefore, there is insufficient variation data to represent the range and distribution of values produced from multiple samples under each testing condition. The high volatile matter content in briquettes is generally attributed to lower carbonization temperatures. Pyrolysis or carbonization at higher temperatures can produce briquettes with lower volatile matter content. Elevated volatile matter levels can reduce briquette quality by lowering carbon content, which impacts calorific value and increases smoke emissions during combustion. This indicates that temperature control in the carbonization process is a crucial factor in improving the quality of biomass briquettes as a viable alternative energy source [22].

4. CONCLUSIONS

Based on the research findings, it is evident that the percentage of adhesive used in the production of rice husk briquettes was varied, including 30%, 40%, and 50%. The comprehensive test results reveal that briquettes with a 50% adhesive content exhibit the most favorable characteristics, featuring a water content of 4.84%, a calorific value of 4665.353 cal/gr, ash content of 28.78825%, carbon content of 50.427%, volatile matter of 33.919%, and a burning rate of 0.368421 g/min. This illustrates how the quality of briquettes is influenced by the application of varying adhesive percentages. In this study, conducted using rice husk as the raw material and starch adhesive at proportions of 30%, 40%, and 50%, only one parameter aligns with the SNI Briquette No.1/6235/2000 standard, which is the water content parameter. Conversely, three other parameters, including heating value, ash content, and volatile matter content, fall short of meeting the specified standards.This is due to the duration and temperature of the carbonization process.

The implications of these findings suggest promising potential for enhancing the quality and applicability of biomass briquettes as a source of alternative energy. The variation in adhesive content has demonstrated a significant impact on briquette characteristics, particularly in improving calorific value and water retention, which are critical for efficient combustion and storage stability. Although only the water content met the SNI Briquette No.1/6235/2000 standard, the insights gained from this study provide a foundation for optimizing carbonization conditions to better achieve standard requirements in ash content, calorific value, and volatile matter. Developing an optimized adhesive formula and refining carbonization processes could help elevate the performance of rice husk briquettes, making them more suitable for use in larger-scale energy applications and supporting a shift toward more sustainable energy alternatives. This aligns with the broader goals of reducing reliance on fossil fuels, promoting cleaner combustion, and utilizing abundant agricultural waste products to contribute to a circular economy in renewable energy production.

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REFERENCES

[1] D. Firdausa, D. 2017. “Makalah Energi Terbarukan”. *Program Studi DIII teknik Kimia Jurusan Teknik Kimia.*

[2] Aljarwi, M.A. 2020. “Uji Laju Pembakaran dan Nilai Kalor Briket Wafer Sekam Padi dengan Variasi Tekanan”. Program Studi Pendidikan Fisika Fakultas Sains dan Terapan Universitas Pendidikan Mandalika Mataram 6. 2.

[3] Alfian, D.G.C. (2023). Briket Dari Limbah Menjadi Bahan Bakar, Lampung Selatan: Itera Press.

[4] Suryaningsih, S. 2020.” Analisis Karakteristik briket Tandan Kosong dan Cangkang Kelapa Sawit Dengan Penambahan Limbah Plastik Low Density Polethylene (LDPE) Sebagai Bahan Bakar Alternatif”. Departemen Fisika Universitas Padjadjaran 10. 01.

[5] Syafaat, A. 2014. “Analisa Briket Serabut Tempurung Kelapa dengan Stryofoam Guna Meningkatkan Nilai Kalor”. Teknik Konversi Energi Jurusan Teknik Mesin Politeknik Negeri Jakarta.

[6] Baderan, D. D. W. K. 2016. “Pemanfaatan Sekam Padi Sebagai Bahan Bakar Alternatif dan Pupuk Organik Yang Ramah Lingkungan Di Desa Lakeya Kecamatan Tolanghula Kabupaten Gorontalo”. Jurusan Biologi Program Studi Pendidikan Biologi.

[7] Setiawan, A. 2018. “Pemanfaatan Sekam Padi Untuk Pembuatan Biobriket Menggunakan Metode Pirolisa”. Universitas Punawarman Program Studi Teknik Kimia.

[8] Vegatama, M. R. 2022. “Variasi Komposisi Biobriket Arang Terhadap Karakteristik Termal. Program Studi Pengolahan Minyak dan Gas”. 237-246.

[9] Fachry, H. 2011. “Pengaruh Penambahan Batubara Lignit Terhadap Kualitas Briket Bioarang Dari Campuran Tandan Kosong dan Cangkang Kelapa Sawit”. Jurusan Teknik Kimia.

[10] Nuryati. 2018. “Pengaruh Penambahan Perekat dan Ukuran Partikel Terhadap Biobriket Hasil Pirolisis Sekam Padi” 5.1.

[11] Yuliza, N. 2018. “Pengaruh Briket Bioarang Sekam Padi dan Biji Salak Sebagai Sumber Alternatif”. Universitas Muhammadiyah Palu. 4. 2.

[12] Amalinda, F. 2018. “Formulasi Briket Bioarang Sekam Padi dan Biji Salak sebagai Sumber Energi Alternatif”. Universitas Muhammadiyah Palu 4. 2.

[13] Qistina, I. 2016. “Kajian Kualitas Briket Biomassa Dari Sekam Padi dan Tempurung Kelapa”. Program Studi Kimia Fakultas Sains dan Teknologi UIN Syarif Hidayatullah Jakarta. 136-142.

[14] Allo, J. S. T. 2018. “Pemanfaatan Sekam Padi Untuk Pembuatan Biobriket Menggunakan Metode Pirolisa”. Program Studi Teknik Kimia Fakultas Teknik Universitas Mulawarman 2.1.

[15] Sabitah, A. 2019. “Uji Eksperimental Karakteristik Briket Arang Berbahan Baku Limbah Sekam Padi Siam dan Pandak. Politeknik Unisma Malang 20.1.

[16] Nofanhadi, D. R. 2014. “Uji Variasi Kadar Perekat Briket Arang Sekam Padi,” Laboratorium Instrumental Jurusan Teknik Mesin Politeknik Negeri Jakarta.

[17] Pratama, M. 2021. “Analisis Karakteristik Briket Sekam Padi Dengan Perekat Tepung Tapioka Akibat Variasi Komposisi,” Program Studi Teknik Mesin Fakultas Teknik Universitas Muhammadiyah Sumaterea Utara Medan.

[18] Ferdianti, A. 2022. “Pemanfaatan Sekam Padi Menjadi Briket,” Program Studi Teknologi Hasil Pertanian Politeknik Enjiniring Pertanian Indonesia.

[19] Yanti, R. N. 2022. “Pembuatan Bio Briket dari Produk Pirolisis Biochar Cangkang Kelapa Sawit Sebagai Sumber Energi Alternatif,” Departemen Of Forestry Faculty of forestry Universitas Lancang Kuning.

[20] Fitri, N. 2012. “Uji Karakteristik Briket Tatal Karet Dengan Parameter (kadar air, kadar karbon, dan nilai kalor”. Jurusan Teknik Lingkungan Fakultas Teknik Sipil dan Perancangan Universitas Islam Indonesia.

[21] Arbi, Y. 2019. “Pemanfaatan Limbah Cangkan Kelapa Sawit Menjadi Briket Arang Sebagai Bahan Bakar Alternatif,” Universitas Negeri Padang Sekolah Tinggi Teknologi Padang.

[22] Putri, R.W. “Pemanfaatan Sekam Padi Untuk Produksi Biobriket dengan Variasi Binde Tepung Tapioka dan Bahan Durian,” Jurusan Teknik Kimia Universitas Sriwijaya.