RiCE: Research in Chemical Engineering
Volume 5. No 1, 2026
Journal homepage: https://ejournal.ump.ac.id/index.php/rice

The Effect of Combining Coffee Grounds Charcoal on The Quality of Rice Husk Briquettes with Varying Amounts of Molasses Adhesive

Mochammad Agung Indra Iswara[1], Susanto[1*], Sigit Hadiantoro[1]
[1]Chemical Engineering of Department, Politeknik Negeri Malang, Malang, Indonesia, 65141
*Corresponding author: susanto.s@polinema.ac.id

Article Info

Submitted:
14 January 2026

Revised:
10 February 2026

Accepted:
07 March 2026

ABSTRACT

Energy demands are increasing although fossil fuel resources are decreasing. Charcoal briquettes are used as an alternative renewable energy source, producing heat from biomass derived from agricultural waste. This study is aimed at a) determine the composition ratio of a waste combination including coffee grounds and rice husk charcoal as a carbon source, and b) evaluate the amount of molasses applied as an adhesive in briquette production to yield briquettes of optimal quality. The briquette production process consists of three stages: the preparation of materials by drying, followed by carbonization, then briquetting, and finally, the analytical testing of the resulting briquette products. The best briquettes produced in accordance with SNI standards from this study contain 3% adhesive, comprising 40 grams of coffee grounds charcoal and 60 grams of rice husk charcoal, with an ash content of 0.18%, a moisture content of 5%, a density of 0.97 g/cm³, and a calorific value of 5335.80 Cal/gram.

Keywords: Alternative renewable energy sources, Briquettes, Coffee grounds, Molasses, Rice husk

1. INTRODUCTION

Energy demands persistently increase; however, the availability of fossil raw resources is limited. Diverse initiatives and regulations are implemented to ensure the continual fulfillment of energy requirements. It is essential to identify and regulate alternate energy sources, particularly renewable ones. Alternative energy must be abundant, sustainable, and environmentally friendly. Indonesia is a tropical nation with substantial agricultural yield; of its potential energy capacity of 50,000 MW, only 320 MW is now exploited [1]. Biomass is a primary resource that can be converted into alternative energy. Briquettes, a regularly utilized biomass for alternative energy, are produced from processed organic waste and serve as an alternative fuel for both industrial and dwelling uses [2]. The production of briquettes is straightforward, facilitated by the Indonesian geographical conditions that yield abundant agricultural organic waste, including rice husks and coffee grounds. Research indicates that rice husks converted into briquettes provide fewer emissions of CO, NO, and SO compared to the combustion of rice husks that are only chopped [3].

Rice husk is a primary component in the production of widely utilized briquettes, consisting of 42.2% cellulose, 18.47% hemicellulose, and 19.4% lignin [4]. The chemical composition of rice husk includes an ash content of approximately 55.7% and a silica concentration of around 51% [5]. Increased amounts of cellulose and lignin can affect the calorific value and moisture content, specifically resulting in a high calorific value and low moisture content [6].

Coffee grounds are used as complementary raw materials, with the large consumption of coffee beverages in Indonesia leading to an ample supply of coffee grounds. Unprocessed coffee grounds, when burned contribute to air and soil pollution [7]; therefore, it is essential to reuse coffee grounds by combining them with rice husks to produce briquettes.

The cellulose content of coffee grounds is around 12.4%, lignin 23.9%, hemicellulose 39.1%, and ash content 1.3% [8]. Compared to rice husk, coffee grounds have a relatively low ash level. If combined, the briquette will exhibit a relatively low ash level. The calorific value of coffee grounds is substantial, specifically 20.9 MJ/kg in dry conditions and 14.6 MJ/kg in wet ones [9]. When combined with rice husks, which possess a calorific value of 1.167 MJ/kg [10], it is anticipated that briquettes will be produced that meet SNI criteria.

Adhesives are crucial in influencing the quality of briquettes, because they facilitate the binding of biomass charcoal particles, resulting in solid briquettes that are homogeneous, without voids, and durable to hardness [11]. Adhesives typically integrate flour to bond biomass charcoal; in addition to flour, they can additionally use other high-viscosity substances such as molasses and wood sap. The selection of adhesive affects the quality of briquettes, including calorific value, moisture content, and ash content. The formulation of flour-based adhesives consistently incorporates moisture to create a viscous gel; when used as a briquette adhesive, it elevates the moisture content despite subsequent drying procedures.

Molasses adhesives, with a moisture level of approximately 20% [12], will increase the moisture content somewhat, approaching the number of flour-based adhesives [13]. In contrast to wood SAP glue, despite its minimal moisture content, combustion will generate significant smoke and a strong stench [11].

The combination of rice husks and coffee grounds into briquettes using molasses as an adhesive not only reduces environmental waste but is also expected to serve as an alternative solid fuel with comparable calorific value to other solid fuels. This study evaluates the impact of varying ratios of waste coffee grounds and rice husk charcoal as carbon sources (20%:80%; 30%:70%; 40%:60%; 50%:50%) and evaluates the influence of molasses as an adhesive (3% and 5%) on the quality of the produced briquettes.

2. MATERIALS AND METHODS

2.1 Materials

The investigation into the production of briquettes from a blend of coffee grounds and rice husks conducted on a small scale encompasses the computation of the proportions of raw materials and the ratio of molasses binder to charcoal. This study employs several tools: a carbonization furnace for the carbonization of raw materials at 200 ℃, a disc mill for reducing charcoal size, a sieve shaker to ensure uniform particle size, a digital balance for weighing raw materials and products, printing equipment for briquette formation and compaction, a bomb calorimeter for calorific value measurement, a desiccator for sample cooling, and an oven for evaporating moisture from briquettes. The raw materials utilized include rice husks, coffee ground waste, and molasses glue.

2.2 Experimental procedure

The initial phase involves the preparation of raw materials. Biomass waste, specifically rice husks and coffee grounds, is subjected to drying in an oven at 105° for 2 hours to diminish the moisture content in the coffee grounds and the moisture content in the rice husks. Following oven drying, rice husks and coffee grounds are incinerated in a carbonation furnace. The carbonation process occurs independently; rice husks are incinerated at 200 °C for 2 hours, whilst coffee grounds are incinerated at 200 °C for 1 h. Subsequently, rice husk charcoal and coffee grinds are subjected to sieving through a 60-mesh screen.

The second stage involves the production of briquettes, utilizing a mixture of rice husk charcoal and sifted coffee grounds in varying proportions, resulting in a total mass of 100 grams of briquettes. The composition ratios of coffee grounds to rice husks are 20:80, 30:70, 40:60, and 50:50. The raw material mixture is combined with a molasses adhesive, comprising 3% to 5% of the molasses mass per 100 g of raw material. The dough is subsequently printed and compressed with a tool to increase the briquette's density, followed by drying in an oven at 105 °C for 2 hours.

2.3 Methods of analysis

According to SNI 01-6235-2000, briquette testing, which includes assessing moisture content, ash content, and calorific value, is essential for determining the quality and efficiency of briquettes as a fuel source. The analysis of ash content involves drying a porcelain cup at 105 ℃ for 1 h, followed by cooling it in a desiccator for 15 min, after which the mass of the porcelain cup is recorded. The porcelain cup and the sample were subjected to a furnace at 600 ℃ for 3 h, after which they were weighed to determine ash concentration.

$$\text{ash content (\%)} = \frac{m_3 - m_1}{m_2 - m_1} \times 100\% \qquad (1)$$

The subsequent study pertains to the moisture content, utilizing porcelain cup apparatus and same procedure to ascertain the mass of the empty cup. Moreover, the dishes and samples were placed in the oven at 105 ℃ for 3 h and thereafter transferred to a desiccator for 15 min to determine the moisture content.

$$\text{moisture content (\%)} = \frac{m_2 - m_4}{m_2 - m_1} \times 100\% \qquad (2)$$

Additionally, the last analysis involves determining the calorific value; 1 g of briquette samples are placed into the bomb calorimeter, and the calorific value is then displayed on the device. The calorific value was determined using the ASTM D-2015 technique.

$$\text{calorific value} = \frac{\Delta\text{T} \times \text{W} - (\text{CVT} + \text{CVW})}{M} \qquad (3)$$

3. RESULTS AND DISCUSSION

3.1. The effect of adding charcoal derived from coffee grounds on moisture levels

The results of the briquette moisture content test, concerning the variations in the addition of coffee peel charcoal and the quantity of adhesive, are shown in Figure 1. The moisture content in briquettes impacts their calorific value and density. A decreased moisture content in the briquette correlates with an increased calorific value and density. If the moisture content increases, a significant amount of energy is utilized to evaporate the moisture, resulting in a decreased calorific value [14-16].

The test findings in Figure 1 indicate an increase in moisture content with the addition of adhesives and charcoal coffee grounds. The percentage of adhesive significantly affects the moisture content produced in briquettes [17-19]. The addition of a higher amount of adhesive causes the moisture contained in the adhesive will enter and bind in the pores of the charcoal. The larger the surface area of the coffee grounds powder particles cause many pores in the briquettes that easily bind moisture present in the air [20].

Figure 1 indicates that an increase in adhesive content correlates with a rise in moisture content, as the adhesive, in the form of molasses, possesses a high moisture content. The data presented by standard SNI 01-6235-2000 consists entirely of briquettes with adhesive concentrations of 3% or 5%, except for those containing 50% coffee grounds and 50% rice husk.

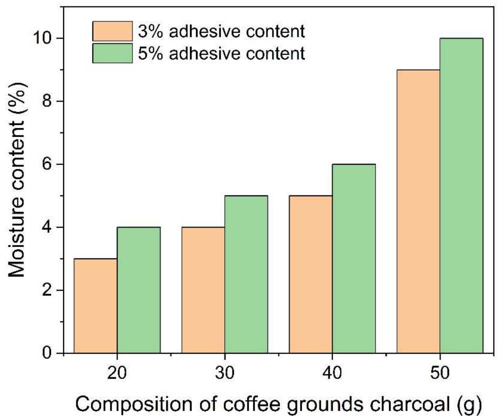

Figure 1. The effect of adding coffee grounds charcoal on the moisture content at adhesive concentrations of 3% and 5% at briquettes

3.2. The Effect of Adding Coffee Grounds Charcoal on Ash Content

The ash content value, according to SNI, is a maximum of 8. Ash content values over 8 are deemed indicative of inferior briquette quality. All samples of briquette already comply with the Indonesian national standard 01-6235-2000. Figure 2 indicates that the highest ash level was observed in briquettes composed of 5% adhesive and the greatest proportion of rice husk. An increase in the adhesive content of a briquette correlates with a rise in ash content and a decrease in calorific value [17-19].

The adhesive content in briquettes is challenging to ignite due to its lack of carbon. Carbon is derived from raw materials subjected to pyrolysis. Briquettes that have transformed into ashes because of charcoal combustion. The study's results indicate that ash content is inversely correlated with calorific value; hence, a lower ash content corresponds to a higher calorific value. Increased ash content correlates with a decreasing calorific value [17][18][21-23].

The brewing process of coffee grounds can lead to the dissolution of minerals such as calcium and magnesium into the solution, resulting in a lower ash content value for coffee compared to rice husks. The lower the ash content, the greater the proportion of charcoal in coffee grounds, as coffee grounds possess higher organic constituents that result in waste characterized by low mineral content [24].

The addition of the number of coffee grounds charcoal was also accompanied by a drop in the quantity of rice husk charcoal so that the ash content value that fell could not be established from the addition of the amount of coffee grounds charcoal. Figure 2 demonstrates that there is an increase in ash content in the addition of adhesive in the form of molasses. The adhesive % significantly affects the ash content of the briquette, as molasses possesses a high moisture content that increases moisture levels, causing increased ash production [25][26].

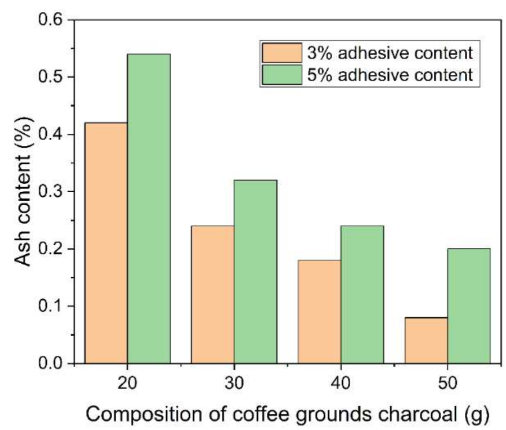

Figure 2. The effect of adding charcoal into the ash content of coffee grounds on the quantity of adhesive at 3% and 5% wt/wt at briquettes

3.3. The Effect of Adding Coffee Grounds Charcoal on Density

The results of the briquette density test relating the variations in the addition of coffee skin charcoal and the quantity of adhesive are illustrated in Figure 2. The density affects the calorific value. The density of the briquette increases with its density; nevertheless, the moisture content also rises, resulting in a larger calorific value [27][28].

This corresponds to Figure 1, which illustrates that density is exactly related to moisture content; as density increases, it also increases moisture content. The results of the briquette density test shown in Figure 3 indicate a consistent increase in density, correlating positively with the rising composition of coffee grounds charcoal and the quantity of adhesive used.

The data indicates that all samples conform to the Indonesian national standard 01-6235-2000. The research data indicate that an increased concentration of adhesive molasses and charcoal coffee grounds in briquettes results in a higher density value. Increased molasses adhesives can result in increased densities. This is attributable to the correlation between increased molasses and increased moisture content.

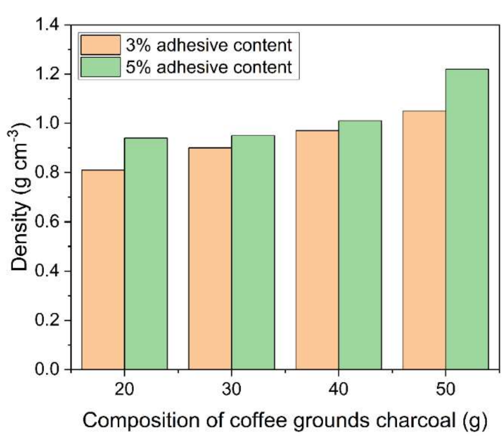

Figure 3. Effect of adding coffee grounds charcoal to the density of the adhesive amount of 3% and 5 % at briquettes

3.4. The Effect of Adding Coffee Grounds on Calorific Value

The result of the briquette ash content test, relating the variations in the addition of coffee skin charcoal and the quantity of adhesive, is shown in Figure 2. The calorific value is the maximum heat energy produced by a briquette during complete combustion per unit mass of the briquette [29][30].

The calorific value data, derived from varying adhesive concentrations and the ratio of coffee grounds to rice husks in charcoal briquettes, indicates a consistent increase in calorific value with a greater percentage of coffee grounds. However, this value decreases with an increase in adhesive quantity.

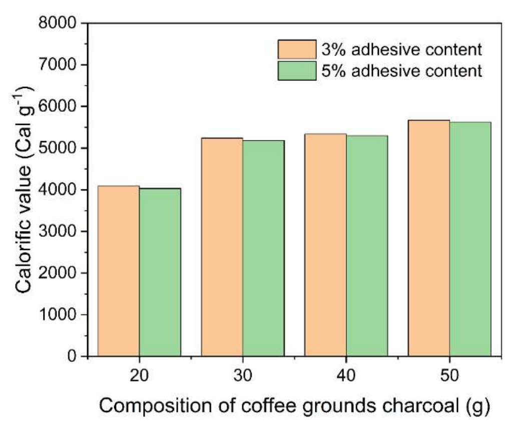

Figure 4. The effect of adding coffee grounds to the calorific value of the amount of adhesive 3% and 5 % at briquettes

Figure 4 illustrates that briquettes with a 3% adhesive concentration exhibit a higher calorific value relative to those with a 5% adhesive concentration. A briquette with increased adhesive content leads to elevated moisture content, resulting in a decreased calorific value. The addition of coffee grounds charcoal into a rice husk briquette combination enhances the briquettes' heat result, as shown by a rise in the calorific value corresponding to the increasing quantity of coffee grounds charcoal and a decrease in rice husk charcoal content. The calorific value of coffee grounds charcoal is significantly higher than that of rice husks [15][31].

The addition of coffee grounds charcoal is directly proportional to the calorific value, indicating that an increased quantity of coffee grounds charcoal results in a higher calorific value. However, as illustrated in the prior graph, the sample with a 50% coffee grounds mixture exhibits the highest calorific value yet possesses a significant moisture content that surpasses the established SNI standard of a maximum of 8%.

Although the moisture content increases, the calorific value also rises concurrently. The addition of charcoal coffee grounds is important because it can absorb moisture, leading to a high moisture content, and it also has a high calorific value of 7550 Cal/gram.

4. CONCLUSION

The addition of coffee ground charcoal is directly related to the moisture content, density, and calorific value of rice husk briquettes. An increase in the proportion of coffee ground charcoal in briquettes correlates with increased moisture content, density, and calorific value; nevertheless, the quantity of coffee grounds is inversely related to ash content, such that a greater amount of coffee grounds results in reduced ash content in the briquettes.

The quantity of adhesive added is directly correlated to the ash concentration, moisture content, and density. The increased use of adhesives results in higher moisture content, ash content, and density. The quantity of adhesives is inversely related to the calorific value, as the adhesive content increases, the calorific value of the briquette decreases.

The highest quality briquettes produced by SNI standards from this study consist of 3% adhesive, comprising 40 grams of coffee grounds charcoal and 60 grams of rice husk charcoal, with an ash content of 0.18%, moisture content of 5%, density of 0.97 g/cm³, and a calorific value of 5335.80 Cal/gram.

ACKNOWLEDGMENT

The author would like to express gratitude to Ananda Suci Wulandari and Muhammad Abdul Rohim for completing this research in the Basic Chemistry Laboratory of the Department of Chemical Engineering, POLINEMA.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Mochammad Agung Indra Iswara: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing. Susanto: Methodology, Investigation, Formal Analysis , Data Curation, Writing – Review & Editing. Sigit Hadiantoro: Supervision, Conceptualization, Validation, Writing – Review & Editing.

REFERENCES

[1] W. Nuriana, N. Anisa, and Martana, “Synthesis preliminary studies durian peel bio briquettes as an alternative fuels,” *Energy Procedia*, vol. 47, pp. 295–302, 2014, doi: 10.1016/j.egypro.2014.01.228.

[2] M. A. I. Iswara, A. Mustain, M. Mufid, and P. Prayitno, “Studi Literatur Karakteristik Briket Dengan Perbedaan Rasio Campuran Arang Tempurung Kelapa Dan Biomassa Lainnya,” *DISTILAT J. Teknol. Separasi*, vol. 10, no. 1, pp. 56–69, 2024, doi: 10.33795/distilat.v10i1.4466.

[3] A. Narzary, J. Brahma, and A. K. Das, “Utilization of waste rice straw for charcoal briquette production using three different binder,” *Clean. Energy Syst.*, vol. 5, no. May, 2023, doi: 10.1016/j.cles.2023.100072.

[4] S. Banerjee *et al.*, "Evaluation of wet air oxidation as a pretreatment strategy for bioethanol production from rice husk and process optimization," *Biomass and Bioenergy*, vol. 33, no. 12, pp. 1680–1686, 2009, doi: 10.1016/j.biombioe.2009.09.001.

[5] Solihudin and Haryono, "Pemanfaatan Arang Sekam Padi Sebagai Sumber Silika pada Sintesis Forsterit dalam Medium Udara," 2021.

[6] V. A. Lestari and T. B. Priambodo, "'Kajian Komposisi Lignin dan Selulosa dari Limbah Kayu Sisa Dekortikasi Rami dan Cangkakng Kulit Kopi Untuk Proses Gasifikasi Downdraft'. Jurnal Energi dan Lingkungan Vol 16.," *J. Energi dan Lingkung.*, vol. 16, no. 1, pp. 1–8, 2020.

[7] R. Hachicha *et al.*, "Chemosphere Co-composting of spent coffee ground with olive mill wastewater sludge and poultry manure and effect of Trametes versicolor inoculation on the compost maturity," *Chemosphere*, vol. 88, no. 6, pp. 677–682, 2012, doi: 10.1016/j.chemosphere.2012.03.053.

[8] L. F. Ballesteros, J. A. Teixeira, and S. I. Mussatto, "Chemical, Functional, and Structural Properties of Spent Coffee Grounds and Coffee Silverskin," *Food Bioprocess Technol.*, vol. 7, no. 12, pp. 3493–3503, 2014, doi: 10.1007/s11947-014-1349-z.

[9] G. A. Romeiro, E. C. Salgado, R. V. S. Silva, M. K. Figueiredo, P. A. Pinto, and R. N. Damasceno, "A study of pyrolysis oil from soluble coffee ground using low temperature conversion (LTC) process," *J. Anal. Appl. Pyrolysis*, vol. 93, pp. 47–51, 2012, doi: 10.1016/j.jaap.2011.09.006.

[10] A. Maryoto and G. Heri Sudibyo, "Rice husk as an alternative energy for cement production and its effect on the chemical properties of cement," in *MATEC Web of Conferences*, 2018, pp. 0–7. doi: 10.1051/matecconf/201819501009.

[11] V. D. Pratiwi and I. Mukhaimin, "Pengaruh Suhu dan Jenis Perekat Terhadap Kualitas Biobriket dari Ampas Kopi dengan Metode Torefaksi," *CHEESA Chem. Eng. Res. Artic.*, vol. 4, no. 1, p. 39, 2021, doi: 10.25273/cheesa.v4i1.7697.39-50.

[12] H. Olbrich, *The Molasses*. 2006. [Online]. Available: http://www.biotechnologie-kempe.de/Molasses_OLBRICH.pdf

[13] A. A. Mufti, M. Akram, Y. Lisafitri, and E. Kurnianingtyas, "Analisis Variasi Jenis Perekat Tetes Tebu dan Tepung Tapioka Pada Pemanfaatan Limbah Ampas Tebu Menjadi Briket," *Al Ard J. Tek. Lingkung.*, vol. 9, no. 2, pp. 71–77, 2024.

[14] A. Sitogasa, M. Mirwan, F. Rosariawari, and A. M. Rizki, "Analysis of Water and Ash Content in Biomass Briquettes from Durian Fruit Peel Waste and Sawdust," *J. Res. Technol.*, vol. 8, no. 2, pp. 279–288, 2022.

[15] V. D. W. I. Pratiwi, "Effect of Burning Temperature on The Quality of Alternatife Bio-energy from Coffee Waste," *Elkomika*, vol. 8, no. 3, pp. 615–626, 2020.

[16] S. Suryaningsih, O. Nurhilal, Y. Yuliah, and C. Mulyana, "Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels," in *Combustion quality analysis of briquettes from variety of agricultural waste as source of alternative fuels*, 2012.

[17] Rindayatno and A. P. Hutomo, "The Effect of Adhesive Ratio on the Quality of Charcoal Briquettes," vol. 2, no. 10, pp. 1453–1462, 2024.

[18] B. Zaman, A. S. Erga, and H. B. Natalia, "The Utilization of Bottom Ash Coal for Briquette Products by Adding Teak Leaves Charcoal , Coconut Shell Charcoal , and Rice Husk Charcoal," vol. 3, no. April, pp. 14–21, 2015.

[19] I. M. Mara, I. M. Nuarsa, and I. K. Wiratama, "The effect of particle size and adhesive on the ash content and volatile matter of organic waste bio-charcoal briquettes," vol. 20, no. 3, pp. 67–73, 2024.

[20] L. Budiawan, B. Susilo, and Y. Hendrawan, "Pembuatan Dan Karakterisasi Briket Bioarang Dengan Variasi Komposisi Kulit Kopi Preparation and characterization of bio charcoal briquettes from sawdust and coffee shell with variation of composition coffee shell," vol. 2, no. 2, pp. 152–160, 2014.

[21] E. Darus, I. Gauru, F. O. Nitbani, and P. De Rozari, "The Effect of Activated Charcoal Coffee Grounds (Coffea Sp .) as an Adsorbent on the Quality of the Liquid Sugar of Siwalan Pengaruh Adsorben Arang Aktif Ampas Kopi (Coffea Sp .) Terhadap Kualitas Gula Cair Siwalan," vol. 16, no. 1, pp. 49–56, 2022.

[22] K. Johnson, Y. Liu, and M. Lu, "A Review of Recent Advances in Spent Coffee Grounds Upcycle Technologies and Practices," vol. 4, no. April, pp. 1–15, 2022, doi: 10.3389/fceng.2022.838605.

[23] S. Byul, H. Young, J. Jin, and K. Sung, "Characteristics of spent coffee ground as a fuel and combustion test in a small boiler (6 . 5 kW)," *Renew. Energy*, vol. 113, pp. 1208–1214, 2017, doi: 10.1016/j.renene.2017.06.092.

[24] L. Jenicek, B. Tunklova, J. Malatak, M. Neskudla, and J. Velebil, "Use of Spent Coffee Ground as an Alternative Fuel and Possible," *Materials (Basel).*, vol. 15, pp. 1–14, 2022.

[25] C. Pujiastuti, O. Maulidian, P. N. Wahyuni, and A. R. Y. Sunarti, "The Effect of Variation of Raw Materials and Addition of Molasses Adhesive on the Quality of Blotong Bricket," in *3rd International Conference Eco-Innovation in Science, Engineering, and Technology*, 2022, pp. 200–205.

[26] A. Ismayana and D. Moh Rizal Afriyanto, "The Effects of Adhesive Type and Concentration in the Manufacturing of Filter Cake Briquettes As an Alternative Fuel," *J. Tek. Ind. Pert*, vol. 186, no. 3, pp. 186–193, 2011.

[27] S. S. Santi, T. P. Azzahra, D. R. Salfana, and T. Pasang, "Optimization of Particle Size and Addition of Vinasse Waste to Improve Characteristics of Rice Husk Charcoal Briquettes," *CHEESA Chem. Eng. Res. Artic.*, vol. 7, no. 1, pp. 36–46, 2024.

[28] N. V. Avelar, A. A. P. Rezende, A. de C. O. Carneiro, and C. M. Silva, "Evaluation of briquettes made from textile industry solid waste," *Renew. Energy*, vol. 91, pp. 417–424, 2016, [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0960148116300751

[29] A. Anatasya, N. Ayu, K. Umiati, and A. Subagio, "The Effect of Binding Types on the Biomass Briquette Calorific Value from Cow Manure as a Solid Energy Source," in *ICENIS 2019*, 2019, pp. 2–6.

[30] T. N. Azizah and C. Sindhuwati, "EFFECT OF BAGASSE PARTICLE SIZE AND CORNSTARCH COMPOSITION ON BAGASSE BRIQUETTE PRODUCTION AS COOKING FUEL IN SUMBUL VILLAGE," *Distilat, J. Teknol. Separasi*, vol. 8, no. 9, pp. 161–168, 2022.

[31] Fachruzzaki, Halim, and R. Lestari, "PENGARUH CAMPURAN SEKAM PADI PADA BRIKET BATUBARA," *Geosapta*, vol. 8, no. 1, pp. 15–18, 2022.