Effect of Composition of Coconut Shell Charcoal and Char Gasification on the Quality of Biobriquettes

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Abstract. The increasing use of coal fuel has an impact on environmental emissions, in an effort to reduce the impact, the application of clean coal is sought, one of which is through coal gasification. Coal gasification is a pilot project at PT Bukit Asam, in the coal gasification process it will produce a by-product in the form of char. The results of previous studies showed that charcoal has increased calorific value and decreased sulfur content significantly, this is the basis for research on the use of charcoal as a raw material for biobriquettes which is more environmentally friendly and can be an alternative energy resource [1]. The parameters of this research that were studied were the effect of composition and size on the quality and flame of biobriquettes. From the results of the study, it was found that the quality of biobriquettes met the SNI briquette quality standards, while the ignition time became shorter with the addition of coconut shell charcoal. So as a recommendation, the best biobriquettes that can be used as solid fuels based on their ignition properties are biobriquettes with a size of 100 mesh or 60 mesh. With a composition of 100% coconut shell charcoal.

Keywords: Coal · Char · Biobriquettes · Coconut Shell Charcoal

1 Introduction

Indonesia's proven coal reserves for anthracite and bituminous types are 23,141 million tons and for subbituminous and lignite types amounting to 11,728 million tons [1]. At the world level coal reserves are 753,639 million tons. The total coal reserves in Indonesia are estimated at around 39.9 billion tons [2]. In addition to coal reserves, there are also coal resources recorded at 143.7 billion tons. This is according to the National Energy Council website of the Ministry of Energy and Mineral Resources. All over the archipelago are coal reserves, with Kalimantan having the most at 14.9 billion tons, followed by Sumatra (11.2 billion) and Sulawesi (0.12 million).). In Kalimantan, the largest reserves are in East Kalimantan, with 7.5 billion tons; South Kalimantan, with 4.2 billion tons and Central Kalimantan, with 2.1 billion tons. In the meantime, South Sumatra is the region with the most coal reserves in Sumatra, with 8.9 billion tons, followed by Jambi with 1.1 billion tons, so the development of coal energy sources

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will continue to be a priority by the National Energy Policy, which will minimize coal consumption until 2050. One of the other policies in implementing clean energy is to change the conventional way of using coal as fuel for power plants. electricity by making coal as a raw material in the gasification process. The pilot project in the use of clean coal in the national gasification process was carried out at as a state-owned company, PT Bukit Asam [3].

The thermochemical process of gasification transforms solid coal into combustible gas. Syngas is the primary end product sought after in the gasification process. [4]. By heating in the gasifier, the biomass/coal feedstock will decompose into hydrogen gas, methane, carbon monoxide, carbon dioxide, nitrogen, pollutants and ash. The combustible gases hydrogen, methane, and carbon monoxide, which make up syngas, can be utilized to generate energy. While the syngas is a non-flammable gas made up of CO2, N2, and O2In terms of the product produced, processing coal through gasification will be more profitable than processing through direct combustion because gasification allows for the more flexible conversion of coal processing products into industrial raw materials or gas fuel, both of which are obviously more valuable to sell. The consequence of this gasification process will be char, a material that, if not recycled, is quite likely to end up in the waste stream.. The accumulation of char waste in the future will become a burden on the industry in this case PT Bukit Asam, because the accumulation of solid materials for a certain period of time will have a negative impact on the environment [5].

When one or more crushed materials are combined into solid compression materials under pressure, a binder like cassava is usually used as a binding agent. These substances may consist of sawdust, palm oil, peanut shells, rice husks, corn cobs, bamboo, coconut husks, and other combustible substances. Fiber [6]. The Minister of Energy and Mineral Resources' regulation No. 047 of 2006 governs the quality of coal briquettes in Indonesia. The table of quality requirements for coal-based briquettes is provided below [7] (Table 1).

Focusing solely on boosting calorific value is insufficient when trying to raise the added value of coal by converting it into solid fuel through briquettes because, in addition to its high proportion of solid carbon, coal also has a low volatile matter content. High ignition temperatures are a result of these circumstances [9, 10]. Therefore, to anticipate this problem, coal briquettes will be added with biomass (agricultural/plantation waste). This is due to the biomass's high volatile matter concentration, which enables ignition at low temperatures and reduces the time and energy needed for ignition [11]. [12]. Biobriquettes are attempts to create briquettes by combining coal with biomass. Due to its calorific value being on par with or even higher than coal, coconut shell was chosen as an additive to increase the fuel value of biobriquettes [13]. Therefore, coconut shell will be chosen as the biomass in this study's supporting material, taking into account that it has strong thermal diffusion capabilities and can produce heat at a rate of about 6500–7600 kcal/kg [14]. The following is the ultimate analysis table for various types of biomass (Table 2).

Table 1. Coal Briquette Quality Standards

Types of Coal Briquettes	Moisture (%)	Volatille Matter (%)	Calorific value (Kcal/Kg)	Total Sulfur (%)
Lignite type carbonized coal briquettes	Max 20	Max 15	Min 4000	Max 1
Coal briquette carbonized coal type but not lignite	Max 7.5	Max 15	Min 5500	Max 1
Egg-type non-carbonized coal briquettes	Max 12	According to the original coal	Min 4400	Max 1
Honeycomb type non-carbonized coal briquettes	Max 12	According to the original coal	Min 4400	Max 1
Bio-coal briquettes	Max 15	According to the original coal	Min 4400	Max 1

Table 2. Biomass materials Ultimate analysis

Biomass	Ash	C	H	O	N	S
Wheat Straw	6.53	48.53	5.53	39.08	0.28	0.05
Barley Straw	4.30	45.67	6.15	38.26	0.43	0.11
Maize Straw	5.77	47.09	5.54	39.79	0.81	0.12
Rice Straw	17.40	41.44	5.04	39.94	0.67	0.13
Sugarcane Bagasse	3.90	46.95	6.10	42.65	0.30	0.10
Coconut Shell	1.80	51.05	5.70	41.00	0.35	0.10
Potato Stalks	12.92	42.26	5.17	37.25	1.10	0.21
Beet Leaves		40.72	5.46	39.59	2.28	0.21
Wheat Chaff	7.57	47.31	5.12	39.35	1.36	0.14
Barley Chaff	5.43	46.77	5.94	39.98	1.45	0.15

Sumber: [13].

2 Material and Methods

The coal utilized comes from PT Bukit Asam Tan-jung Enim's Muara Tiga Besar Mine in South Sumatra. Channel sampling, also known as front sampling, was used to sample coal along the mining front at coordinates 3o43′16,315"LS, 103o42′30,463. Exposed coal seams, such as walls or floors in mines, are sampled for coal composition. Coal sampling uses an in situ model devoid of scales or a manual sampling method employing humans as collectors with geological hammers, shovels, and plastic bags. While the charcoal used is Coconut Shell Charcoal, obtained from charcoal traditional market waste from Palembang, South Sumatra, where the charcoal has gone through the process tobe continues for packaging where on the written packaging label, while for the adhesive material for making briquettes, wheat flour and water are used without special specifications.

The coal from the Muara Tiga Besar Mine will then go through a gasification process using the Underground Coal Gasification prototype [15]. The Char from this gasification will then be used as the main raw material for making biobriquettes.

3 Result and Discussion

3.1 Characterization of Material

A Each coal sample is first examined for coal content using proximate analysis and ultimate analysis in order to identify the character and composition of the coal that will be used in the gasification process. This study of coal was performed at PT Bukit Asam's coal laboratory. The results of the proximate and ultimate analysis of each seam are provided in the following Table 3.

In order to examine the potential of char as a raw material for producing biobriquettes, char and coconut shell charcoal composites are analyzed after gasification and the by-products in the form of char are obtained. Tables 4 and 5 below are the proximate and ultimate analysis results for Char Gasification and Coconut Shell Charcoal.

Following the study's results [18], Char Gasification is ideal for use as briquette fuel. This is because the char's water, sulfur, and calorific value are all extremely significant as a solid fuel, as determined by the analysis of the char's quality. Characteristic results of char Gasification of coal states that the water content of char has decreased to 10%, the calorific value is 7.1830 kcal, and the sulfur content is only 0.48. This quality has the potential to be used as solid fuel [19].

Table 3. Caratisization of Coal

Proximate Analysis	Coal
Volatile Matter (%, adb)	40.6
Ash Content (%, adb)	1.3
Fixed Carbon (%, adb)	42.00
Inheren Moisture (%, adb)	18.1
Total Sulphur (%, adb)	1.18
Gross Calorific Value (Cal/gr)	5,804

Table 4. Analysis of Char Gasification

Proximate Analysis	Char
Ash Content (%, adb)	0.70
Moisture Content (%)	10.00
Volatile Matter (%, adb)	42.00
Fixed Carbon (%, adb)	47.30
Total Sulphur (%, adb)	0.48
Gross Calorific Value (Cal/gr)	7,1830

Table 5. Analysis of Carcoal Coconut Shell

Proximate Analysis	Shell Charcoal
Moisture (%)	6.9
Volatile Matter (%)	17.2
Ash Content (%)	2.1
Total Sulfur (%)	0.04
Fixed Karbon (%)	74.85
Calorific Value (cal/gr)	6,275

3.2 Biobriquette Characteristics

The results of the biobriquettes obtained were carried out with characteristic analysis, namely proximate analysis, the results of the analysis can be seen in the Table 6.

Characteristic analysis of the quality of the Bio Briquettes produced, it can be said that from each variable test composition carried out, it can be said that the quality of the bio Briquettes meets the good quality standards according to Ministerial regulations 047 of 2006 or Japanese, British, American and Indonesian coal briquettes standards SNI 01 -6235-200. For the analysis of the water content of all test samples, based on the Ministry of Regulation No. 047 of 2006, the requirement for water content in coal briquettes is 15%, while in SNI 8%, the test results for each sample range from 6–3%., while the quality standards for American, Japanese and British briquettes state that the water content ranges from 15–24%. For the analysis of volatile matter levels, both from ministry regulations and American, Japanese and British standards are not regulated. So in this case the volatile matter content of each biobriquette sample can be said to meet the requirements, for the analysis of each sample for ash content it also meets the quality requirements. Bio briquettes. The sulfur content of each sample, as determined by the bio-briquette test, complies with Ministerial Regulation 047 of 2006, which sets the maximum sulfur content at 1%. SNI01-6235-2000 does not control the amount of total sulfur. Furthermore, the minimum value for the fixed carbon value based on the

Table 6. Proximate Analysis Biobriquete

No	Variasi Sample	Characterization Parameters					
		Moisture (%)	*Volatile Matter (%)*	*Ash Content (%)*	*Total Sulfur (%)*	*Fixed Carbon (%)*	*Kalori (Cal/gr)*
1	AV1	6,61	16,6	7,2	0,81	69,59	6.321
2	AV2	6,62	17,7	5	0,47	70,68	6.587
3	AV3	4,92	17,5	4,3	0,38	73,28	6.818
4	AV4	4,90	17,9	6,1	0,48	71,10	6.517
5	AV5	5,09	19,3	2	0,19	73,61	7.007
6	BV1	5,92	23,8	10	0,69	60,28	5.830
7	BV2	6,86	21,3	5,1	0,61	66,74	6.288
8	BV3	6,18	18,6	4,8	0,53	70,42	6.630
9	BV4	4,26	19,6	2,8	0,27	73,34	6.878
10	BV5	4,85	20,1	1,4	0,19	73,65	7.076
11	CV1	7,35	24,5	7,1	0,77	61,05	5.896
12	CV2	6,14	22,3	8,3	0,69	63,26	6.016
13	CV3	6,26	20,8	7,7	0,53	65,24	6.244
14	CV4	5,32	22,4	5,9	0,38	66,38	6.457
15	CV5	3,58	22	4,1	0,24	70,32	6.710

SNI 01-6235-2000 qualification is set at 77%, although there is no regulation for the fixed carbon value in Permen 047 of 2006. Therefore, based on the requirements of SNI 01-6235-2000, the overall sample did not fulfill these standards, with the selection made up entirely of coconut shells having the highest fixed carbon value (73.61%). These samples have complied with the requirement since the fixed carbon qualifying value is at least 60% [21]. For the caloric value, based on Ministerial Regulation 047 of 2006, the desired caloric value is a minimum of 4000 kcal/kg and based on SNI 01-623-2000 the qualification of the caloric value is a minimum of 5000 kcal/kg, the results obtained from all samples range from 5000–6700 k cal.

3.3 The Impact of Varying the Amount of Coconut Shell Charcoal Used and the Biobriquette Size as to Ingnition Time and Burning Time

Biobriquettes that have been characterized are tested for their flammability by observing the length of ignition time. Combustion time and combustion temperature.

3.3.1 Ignition Time

A good biobriquette is one that burns quickly or has a short ignition time. In the bio-briquettes produced, the calculation of the time required for ignition is relatively short with the fastest time being 24 s on the BV5 sample or 60 mesh size with 100% coconut shell charcoal, while the longest ignition time is 76 s or 1 min more on the CV1 sample or size 100 mesh with 100% char, as can be seen in the table (Fig. 1).

From the graph it can be seen that in the same grain size group, the more coconut charcoal composites are added, the faster the biobriquettes will ignite, this is very likely related to the volatile content contained in coconut charcoal [22] and also the decreasing water content. Along with the increasing addition of coconut shell charcoal [17, 23]. The burner temperature of the bio-briquettes is affected by the water and volatile matter content, where the higher the volatile matter content of the bio-briquettes, the higher the volatile matter content, the faster the burning time of the bio-briquettes [17, 24].

Meanwhile, when compared in grain size, it can be seen that the 60 mesh size is the faster burning grain size, followed by the 20 mesh size and finally the 100 mesh size, this may be due to the use of adhesives, small particle size, low porosity and bond strength of the briquettes. High [25]. Where the use of flour as an adhesive will show a higher water content [24], in this study the use of adhesives was not taken into account in detail. Meanwhile, the higher the water content value, the more difficult it is for ignition to occur, because the high water content will cause the calorific value produced by the briquettes to decrease, this is because the energy produced will be absorbed a lot to evaporate water [26, 27]. This makes the briquettes more difficult to burn. In addition, the presence of inorganic content in the adhesive can increase the ash content so that it can become an impurity and slow down the combustion flame [28].

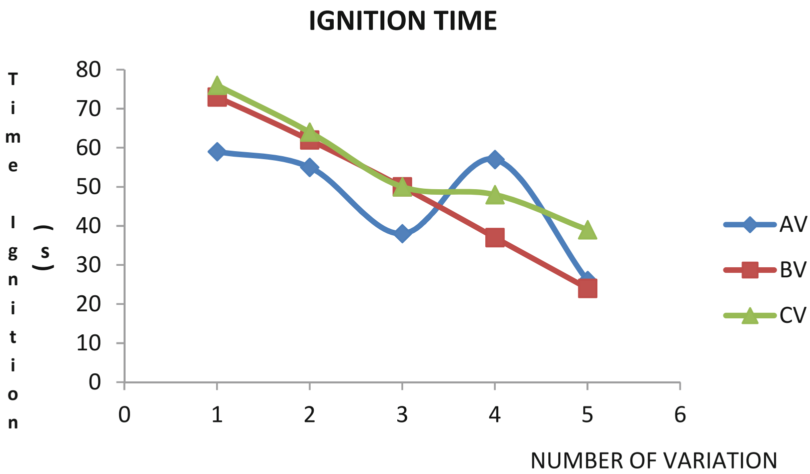

Fig. 1. Relationships between Variation of Biobriquete and Ignitions Time

3.3.2 Burning Time

A good biobriquette is a biobriquette that has a long enough combustion time, so it can save energy use effectively and efficiently. As for the burning time of the resulting biobriquettes, the biobriquette with the longest burning time is 1894 s or equivalent to 31.5 min and the fastest burning is 1440 s or 24 min before the biobriquettes run out to ashes (Fig. 2).

From the graph above, it can be seen that the longest burning time is in the BV5 sample or biobriquette with a grain size of 60 mesh and 100% coconut shell charcoal, while the fastest is in the AV4 sample or grain size of 20 mesh and 75% coconut shell charcoal. And from the graph it can be seen that in the same size group, in general, the burning time of biobriquettes is not much different, the addition of coconut shell charcoal significantly extends the burning time, while the grain size, especially at the grain size of 60 mesh and 100 mesh, tends to burn longer than the one used size 20 mesh. This is very likely related to particle size and porosity in biobriquette samples, where the smaller the particles, the greater the porosity so that they can hold oxygen more effectively [29].

Meanwhile, the addition of coconut shell charcoal in general increases the burning time because coconut shell charcoal is more compact so it can heat up longer [23]. Volatile matter content in coconut shell charcoal also affects the combustion of briquettes [26]. The volatile matter content affects the rate of combustion and the intensity of the flame. The rate of combustion depends on the ratio or ratio between the carbon content and volatile matter, which is called the fuel ratio by increasing the value of the fuel ratio will reduce the amount of carbon burned in biobriquettes.. If the fuel ratio is more than 1.2, then the combustion process of solid fuel (bio briquettes) is not perfect so that the combustion rate will also decrease. According to Segun [22] the fixed carbon content in

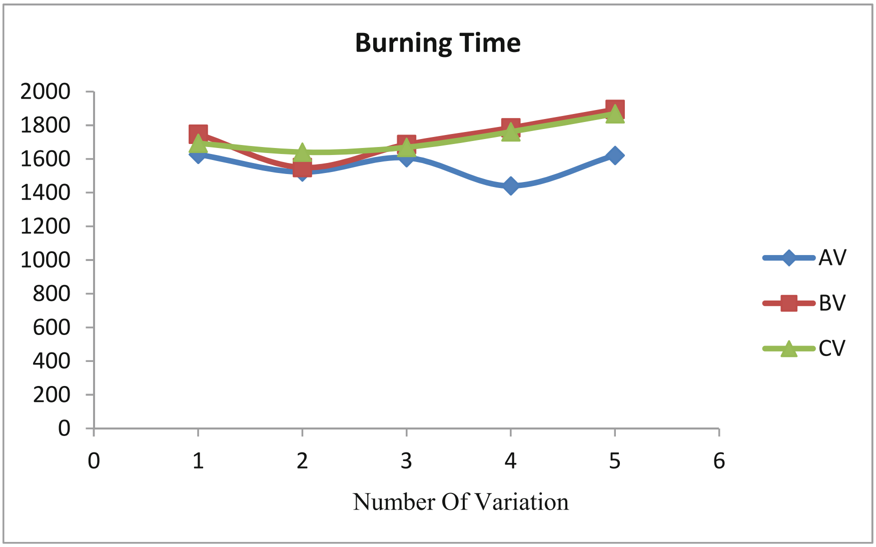

Fig. 2. Relationships between Variation of Biobriquete and Burnings Time

the biobriquette material affects the duration of combustion, this is because the amount of heat released during combustion depends on the carbon in the raw material. In addition, the ash content also affects the burning time, high ash content can cause problems during combustion [24] because the ash will slow down the combustion rate, because it has silica which is not good for the combustion and ignition process [28].

4 Conclusions

Following the study's results, it was found that adding coconut shell charcoal has a good impact on the ignition properties of bio briquettes made from coal char gasification. This can be seen in the ignition time in the combustion of bio briquettes. It was found that the ignition time with the fastest time was 24 s in the sample BV5, or the size of 60 mesh with 100% coconut shell charcoal, while the longest ignition time was 76 s or 1 min more on the CV1 sample or the size of 100 mesh with 100% char. Meanwhile, the longest burning time was in the BV5 piece or bio briquette with a grain size of 60 mesh and 100% coconut shell charcoal, which was 1894 s or equivalent to 31.5 min, while the fastest way in the AV4 sample or grain size of 20 mesh and 75% shell charcoal. Coconut is 1440 s or 24 min. And for the maximum temperature of all samples obtained in the second 4 min, then decreased, for the highest maximum temperature was found in the sample BV5 or size 60 mesh with 100% coconut shell charcoal, which was 532.80C, but in general, the initial temperature of combustion was up to After the completion of the briquette burning, all samples followed a pattern that was not much different, the deviation occurred at CV3 or 100 mesh with a variation of 50% char and coconut shell charcoal. The best grain size variation is in the grain size of 60 mesh and 100 mesh. The smaller grain size will increase the ignition time and bind oxygen to maintain more efficient combustion.

References

1. National Energy Council, "Indonesia Energy Outlook 2019," 2019.
2. IESR (Institute for Essential Services Reform), "Indonesia Energy Transition Outlook 2021," 2021.
3. Undang Undang Republik Indonesia No 3 Tahun 2020, "Tentang Perubahan Atas Undang - Undang Nomor 4 Tahun 2009," 2020.
4. J. Lesmana, A. Hasan, and A. Syarief, "Syngas Underground Coal Gasification (UCG) Testing of Fracture Type Subbituminous Coal in Laboratory Scale," *Int. J. Res. Vocat. Stud.*, vol. 1, no. 2, 2021
5. Rusdianasari, S. Arita, E. Ibrahim, and Ngudiantoro, "Characteristic of Coal Stockpile in Lowland and the Effect to Environment," in *Springer Series in Materials Science Vol 204 in Recent Trends in Physics of Material Science and Technology*, 2015, pp. 221–243.
6. O. J. Lawal, T. A. Atanda, S. O. Ayanleye, and E. A. Iyiola, "Production of Biomass Briquettes Using Coconut Husk and Male Inflorescence of Elaeis guineensis," *J. Energy Res. Rev.*, no. July, pp. 1–9, 2019, doi: https://doi.org/10.9734/jenrr/2019/v3i230093.
7. Menteri Energi Dan Sumber Daya Mineral, "Permen ESDM No 047 Tahun 2006," 2006.
8. A. Triono, "Characteristics of charcoal briquettes from a mixture of sawdust of African wood (Maesopsis eminii Engl) and Sengon (Paraserianthes falcataria L. Nielsen) with the addition of Coconut Shell (Cocos Nucifera L)," Institute Pertanian Bogor, 2006.

9. S. Jamilatun, "Ignition and Combustion Properties of Biomass Briquettes, Coal Briquettes and Wood Charcoal," *J. Rekayasa Proses*, vol. 2, no. 2, pp. 37–40, 2012, doi: https://doi.org/10.22146/jrekpros.554.
10. Sudding and Jamaluddin, "The Processing Of Coconut Shell Based On Pyrolysis Technology To Produce Reneweable Energy Sources," *Int. Conf. Math. Sci. Technol. Educ. their Appl.*, no. October 2016, pp. 498–510, 2016, [Online]. Available: https://ojs.unm.ac.id/icmstea/article/download/3565/1976.
11. V. Benedetti, F. Patuzzi, and M. Baratieri, "Gasification Char as a Potential Substitute of Activated Carbon in Adsorption Applications," *Energy Procedia*, vol. 105, no. May, pp. 712–717, 2017, doi: https://doi.org/10.1016/j.egypro.2017.03.380.
12. J. Riaza, J. Gibbins, and H. Chalmers, "Ignition and combustion of single particles of coal and biomass," *Fuel*, vol. 202, pp. 650–655, 2017, doi: https://doi.org/10.1016/j.fuel.2017.04.011.
13. M. Yerizam, F. . Faizal.M, M. Marsi, and N. Novia, "Characteristics of Composite Rice Straw and Coconut Shell as Biomass Energy Resources (Briquette)(Case study: Muara Telang Village, Banyuasin of South
14. G. Amoako and P. Mensah-Amoah, "Determination of Calorific Values of Coconut Shells and Coconut Husks," *J. Mater. Sci. Res. Rev.* , vol. 2, no. 2, pp. 1–7, 2018, doi: https://doi.org/10.9734/JMSRR/2019/45639.
15. A. Zulatama, A. Syarif, and M. Yerizam, "Effect of Oxygen Flow Rate on Combustion Time and Temperature of Underground Coal Gasification," *Int. J. Res. Vocat. Stud.*, vol. 1, no. 2, pp. 27–33, 2021.
16. P. Aguko Kabok, D. M. Nyaanga, J. M. Mbugua, and R. Eppinga, "Effect of Shapes, Binders and Densities of Faecal Matter - Sawdust Briquettes on Ignition and Burning Times," *J. Pet. Environ. Biotechnol.*, vol. 09, no. 02, 2018, doi: https://doi.org/10.4172/2157-7463.1000370.
17. N. H. Haryanti, Suryajaya, S. Husain, H. Wardhana, Y. Anggraini, and N. Sofi, "Combustion Properties of Briquette from Halaban (vitex pubescens vahl) Charcoal, Bottom Ash and Fly Ash," *Int. J. ChemTech Res.*, vol. 12, no. 03, pp. 219–226, 2019, doi: https://doi.org/10.20902/ijctr.2019.120328.
18. A. Yopianita, A. Syarif, and M. Yerizam, "The Potential of Charcoal Gasification as an Eco-Friendly Fuel," *Proc. 5th FIRST T1 T2 2021 Int. Conf. (FIRST-T1-T2 2021)*, vol. 9, pp. 130–137, 2022, doi: https://doi.org/10.2991/ahe.k.220205.023.
19. Z. Yin, H. Xu, Y. Chen, and T. Zhao, "Coal char characteristics variation in the gasification process and its influencing factors," *Energy Explor. Exploit.*, vol. 38(5), 2020, doi: https://doi.org/10.1177/0144598720935523.
20. A. Yopianita, A. Syarif, and M. Yerizam, "Biocoal Characterization as an Environmentally Friendly Alternative Energy Innovation Composite Variations of Gasified Char with Coconut Shell Charcoal," no. May, pp. 68–79, 2022, doi: https://doi.org/10.24845/ijfac.v7.i2.68.
21. T. M. Gantina, "The effect of adding coconut shell charcoal to increasing the heating value and burning process of bio-coal briquette," *J. Tek. Energi*, vol. 9, no. November, pp. 31–36, 2019, [Online].Available: https://jurnal.polban.ac.id/energi/article/view/1642%0A. https://jurnal.polban.ac.id/index.php/energi/article/download/1642/1322.
22. S. E. Ibitoye, R. M. Mahamood, T. C. Jen, and E. T. Akinlabi, "Combustion, Physical, and Mechanical Characterization of Composites Fuel Briquettes from Carbonized Banana Stalk and Corncob," *Int. J. Renew. Energy Dev.*, vol. 11, no. 2, pp. 435–447, 2022, doi: https://doi.org/10.14710/ijred.2022.41290.
23. M. N. Sabo, M. M. Aji, A. L. Yaumi, and B. G. Mustafa, "Preparation and Characterization of Biomass Briquettes Produced from Coconut Shell and Corncobs," *Arid. J. Basic Appl. Res.*, vol. 1, no. 1, pp. 47–54, 2022, doi: https://doi.org/10.55639/607enw.

24. S. N. F. S. Adam, J. H. M. Aiman, F. Zainuddin, and Y. Hamdan, "Processing and Characterisation of Charcoal Briquettes Made from Waste Rice Straw as A Renewable Energy Alternative," *J. Phys. Conf. Ser.*, vol. 2080, no. 1, 2021, doi: https://doi.org/10.1088/1742-6596/2080/1/012014.
25. T. Kebede, D. T. Berhe, and Y. Zergaw, "Combustion Characteristics of Briquette Fuel Produced from Biomass Residues and Binding Materials," *J. Energy*, vol. 2022, pp. 1–10, 2022, doi: https://doi.org/10.1155/2022/4222205.
26. Sunardi, Djuanda, and M. A. S. Mandra, "Characteristics of charcoal briquettes from agricultural waste with compaction pressure and particle size variation as alternative fuel," *Int. Energy J.*, vol. 19, no. 3, pp. 139–147, 2019.