The Effect of Percentage Variation of Ketapang Fruit Biobrickets on Health Value and Combustion Rate

Himmi Raudatul Fadilah[1], Sukainil Ahzan[2]*, Dwi Pangga[3], Habibi[4], and Muhammad Roil Bilad[5]
[1,2,3] Department of Physics Education, Faculty of Applied Science and Engineering, Universitas Pendidikan Mandalika, Indonesia
[4] Department of Physics Education, Faculty of Mathematics and Natural Sciences, Surabaya State University, Indonesia
[5]Faculty of Integrated Technologies, Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei Darussalam
Email: sukainilahzan@undikma.ac.id

Article Info

Article History
Received: Aug 14, 2023
Revision: Nov 21, 2023
Accepted: Dec 29, 2023

Keywords:
Bio briquette
Burning rate
Calorific value
Ketapang fruit

ABSTRACT

This study aims to determine the effect of variations in the percentage of Ketapang fruit (KF) bio briquette on calorific value and burning rate. This research is experimental in a physics laboratory with a literature review carried out in three stages, namely the preparation stage, the bio briquette manufacturing stage, and the bio briquette testing stage. The main ingredient used in the manufacture of bio briquettes is Ketapang fruit. The adhesive materials used were tapioca flour and sago flour with percentages of 10%, 12.5% and 15%. The results showed that the calorific value of the following bio briquettes using the tapioca predicate included 5,139.45 Cal, 5,540.97 Cal, 5,922.42 Cal, and those using the sago predicate including 2,409.12 Cal, 3,653.83 Cal, 3,894.74 cal. The highest calorific value was in bio briquettes with tapioca adhesive type in the sample at 85%:15%. The burning rate of bio briquettes using tapioca glue included 1.98 gr/minute, 1.76 gr/minute, 1.62 gr/minute and those using sago glue included 2.62 gr/minute, 2.50 gr/minute, 2.31 gr/minute. The lowest burning rate value was in bio briquettes with the type of sago glue in the sample at 85%:15%. Based on the test results, it is known that the lower the percentage of keta pang fruit in the bio briquettes, the lower the burning rate, and the resulting calorific value increases.

To cite this article:
H. R. Fadilah, S. Ahzan, D. Pangga, Habibi, and M. R. Bilad, "The Effect of Percentage Variation of Ketapang Fruit Biobrickets on Health Value and Combustion Rate," *Indones. Rev. Phys.*, vol. 6, no. 2, pp. 92-98, 2023, doi: 10.12928/irip.v6i2.8871.

I. Introduction

Alternative energy is a renewable and efficient energy source that is needed by the community, one of which is briquettes [1]. Briquettes are solid fuels that can be made from carbon-containing biomass with high calorific value and can burn for a long time [2]. Biomass itself is organic material produced through the process of photosynthesis, both in the form of products and waste such as plants, grass, trees, agricultural waste, organic waste, and livestock manure [3].

Various solutions have been sought by scientists to overcome dependence on non-renewable energy sources. One such solution is the utilisation of renewable energy such as biomass [4]. Biomass energy by briquetting method is converting solid raw materials into a more usable form through the compaction process [5]. Biomass can also be used directly without prior coagulation [6]. However, the direct use of biomass as fuel is less efficient so it needs to be converted into chemical energy first, for example converted into biobriquettes and biochar, which have a higher fuel value than biomass [7].

Research conducted [8] used rice husk as the base material with tapioca adhesive. The calorific value of the resulting briquettes ranged from 4,793.94 calories to 5,266.52 calories with burning rates ranging from 2.2212 grams/minute to 2.4363 grams/minute. Research conducted by Ramdani et al. [9] used water hyacinth as the base material with tapioca adhesive, flour, and cement. The resulting calorific value ranged from 2,984,520 calories to 4,476,780 calories with combustion rates ranging from 0.029543 g/s to 0.042431 g/s. The research by Aljarwi met the SNI for calorific value in the 30 PSI and 40 PSI samples, while the research by Ramdani did not meet the SNI for calorific value. Both studies produced poor briquettes due to low calorific value and high burning rate. Good quality bio briquettes are those that produce high calorific value and low burning rate [10].

Using biobriquettes as fuel is an alternative approach to conserving fossil fuels. Their sustainable usage can help mitigate carbon emissions [11]. An alternative base material that can be used to make briquettes is biomass material. One of the biomass materials that can be used in the Lombok area is ketapang fruit.

Utilisation of ketapang fruit waste can be used as an alternative fuel source so that in addition to reducing waste it can also save fuel consumption [12]. The results of this waste utilisation can be marketed so that it has a higher selling value and can help reduce the use of fuel and gas.

Ketapang (Terminalia cattapa) is a fruit-bearing plant and belongs to the Combretaceae class with the genus Terminalia. The fruit of the ketapang tree is similar to an almond, with a size between 4 to 5.5 cm [13]. The ketapang fruit is green in colour but when ripe it will turn red-brown. The outer skin of the seeds is smooth and covered by fibres that surround the seeds. This plant is easy to grow and develop [14]. Usually, this plant is widely planted in office areas or roadside and coastal areas, besides that this plant does not require special care and can grow and produce a lot of fruit. However, the high production of ketapang fruit is not matched by optimal utilisation. Ripe and dark brown ketapang fruits just fall to the ground and become waste or garbage.

Based on the above problems, the community has not utilised ketapang fruit waste optimally and has not used bioenergy on a household scale because it still uses fuel oil which is increasingly depleting [15]. Ketapang plants or trees are easily found on the side of the road and the fallen ketapang fruit will scatter on the road so that it becomes waste or garbage that is not environmentally friendly or makes the environment dirty. Based on this, the author aims to process ketapang fruit into briquettes as renewable energy to replace hard-to-find fuels, anticipate the scarcity of energy sources, and reduce waste in the community.

This research contributes by exploring variations in the percentage of ketapang fruit briquettes and their impact on health value and burning rate. Thus, this research not only provides a solution to the problem of ketapang fruit waste, but also offers a more environmentally friendly and sustainable fuel alternative. The results of this research are expected to be a reference in the development of renewable energy as well as providing economic and environmental benefits to the community.

II. Theory

Briquettes

Briquettes are solid fuels that serve as an alternative energy source to replace petroleum, which is made through a carbonisation process, then formed with a certain pressure, either with or without adhesives or other additives [2]. The characteristics of quality briquettes are that the surface is smooth and does not leave black marks on the hands. In addition, briquettes as fuel must fulfil the following standards: easy to ignite, does not produce smoke when ignited, the gas produced from combustion is non-toxic, and does not easily mould if stored for a long time [16]. Raw materials used in making briquettes include sawdust, coconut shells, corn cobs, rice husks, water hyacinth, and others. The quality of briquettes based on SNI can be seen in Table 1.

(a) (b)

Figure 1. a) cylinder briquettes, b) cube or block briquettes

Table 1. Quality of Briquettes Based on SNI

Parameter	SNI Briket No. 01-6235-2000
Water content	≤ 8%
Evaporation level	≤ 15%
Ash content	≤ 8%
Calorific value	5000 calories/gr

Ketapang Fruit (KF)

Terminalia catappa L. is a coastal plant with a wide distribution area. It originated in the tropics of India, then spread to Southeast Asia. Ketapang trees are often found in green open spaces. This plant generally does not require special care, is widely planted in office areas, and produces a lot of fruit. Ketapang fruit is green in colour but will turn red-brown when ripe, and the old fruit will fall by itself.

Ketapang leaf and fruit waste is a source of organic carbon because it contains chemical compounds such as cellulose, hemicellulose, and lignin [17]. According to Yuniarti [18], the composition of chemical compounds in ketapang seed coat is 16.60% cellulose, 24.70% hemicellulose, and 43.46% lignin. Lignocellulosic organic waste can be carbonised into biochar which can then be

p-ISSN: 2621-3761
e-ISSN: 2621-2889

used in the biosorption process or as fuel for briquettes [19].

III. Method

This type of research is experimental research conducted in the UNDIKMA physics laboratory. The tools used in this research include oven, sieve, stove, mould, measuring cup, stopwatch, digital scale, container (basin), pounder, thermometer, iron clamp, and pot. The materials used were ketapang fruit, tapioca flour, sago flour, cooking oil, and water.

This study used variations in the percentage of tapioca flour and sago flour as much as 10%, 12.5%, and 15% with the percentage of ketapang fruit as much as 85%, 87.5%, and 90%. The process of making briquettes goes through several stages, namely: (1) preparation of tools and materials, (2) making briquettes consisting of drying the base material, carbonising (burning) the base material, making powder and sieving the material, mixing the base material and adhesive, printing the briquettes, and drying the briquettes, and (3) testing the briquettes which include testing density, moisture content, ash content, calorific value, and burning rate.

IV. Results and Discussion

In the study entitled "Effect of Variation in Percentage of Ketapang Fruit (KF) Biobriquettes on Calorific Value and Burning Rate", the basic ingredients of ketapang fruit, tapioca starch, and sago starch were used with variations in the percentage of adhesive of 10%, 12.5%, and 15%. The shape of ketapang fruit briquettes can be seen in Figures 2 and 3.

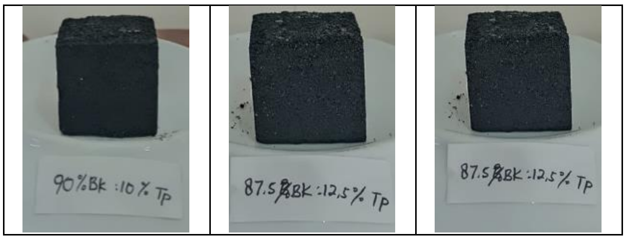

Figure 2. Biobriquettes made from ketapang fruit with variations in the percentage of tapioca paste

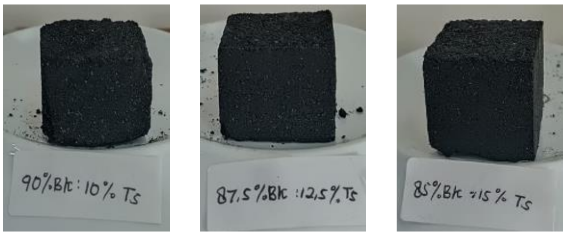

Figure 3. Biobriquettes made from ketapang fruit with variations in the percentage of sago paste

Good quality briquettes must meet the SNI standards that have been set. To determine the quality of ketapang fruit briquettes produced, it is necessary to conduct tests such as density, moisture content, ash content, calorific value, and burning rate. The following are the results of testing ketapang fruit briquettes that have been carried out.

Briquettes Density Analysis

Density is a measure of the concentration of a substance expressed in mass per unit volume. Density has a significant influence on the burning rate of briquettes, so it can determine the quality of a briquette [20]. The density values of ketapang fruit briquettes can be seen in Table 2 and Figure 3.

Table 2. Briquettes Density Testing

Percentage of Biobriquette Material (%)	Density (gr/cm³) Tapioca Adhesive	Sago Adhesive
90%KF:10%	0.67	0.68
87.5%KF:12.5%	0.69	0.71
85%KF:15%	0.74	0.79

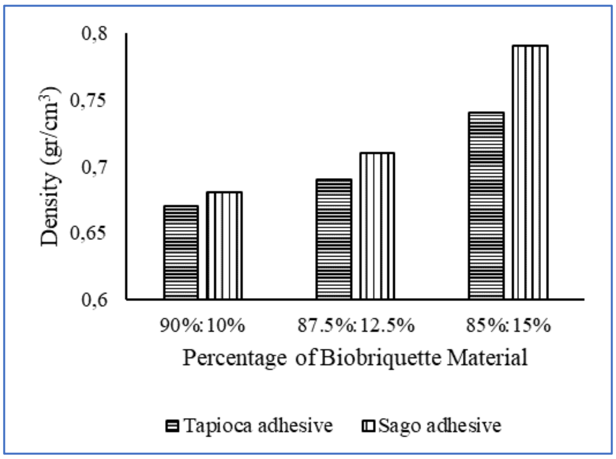

Figure 3. Briquettes Density Testing Chart

Based on Figure 3, it can be seen that the type and percentage of biobriquette materials have different effects on the density of briquettes. Ketapang fruit briquettes with varying percentages of biobriquetting materials show that the lowest density value is 0.67 gr/cm³ in samples using tapioca adhesive with a percentage of 90%:10%. Meanwhile, the highest density value was 0.79 gr/cm³ in the sample using sago adhesive with a percentage of 85%:15%. The density value of biobriquettes produced in this study shows that the higher the density value of biobriquettes along with the greater percentage of adhesive used. This is in line with the research of Iriany et al. [21] who stated that the higher the addition of adhesive, the higher the density of the briquettes, which resulted in the adhesive entering into the pores of the briquettes. In addition, Kholil's research [22] also states that the characteristic fineness of the base material is influenced by the level of sieving or refining used in briquette moulding.

Briquettes Water Content Analysis

Water content is the amount of water content contained in a briquette [23]. The moisture content in a briquette is inversely proportional to the calorific value produced. Briquettes that contain high water content will make the combustion process slow and the resulting calorific value will be low [24]. The drying process in making biobriquettes aims to reduce the water content contained. The results of the water content test of ketapang fruit briquettes that have been dried in the sun for 4-5 days can be seen in Table 3 and Figure 4.

Table 3. Briquttes Water Content Testing

Percentage of Biobriquette Material (%)	Water Content (%)	
	Tapioca Adhesive	Sago Adhesive
90%KF:10%	7%	8%
87.5%KF:12.5%	5%	7%
85%KF:15%	5%	5%

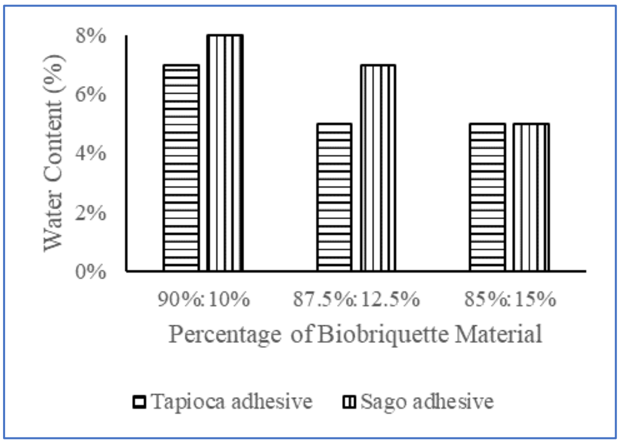

Figure 4. Briquettes Water Content Chart

Based on Figure 4, it can be seen that the results of water content with varying percentages of biobriquette materials, namely the lowest water content value, which is 5% in samples using tapioca adhesive with a percentage of 87.5%: 12.5% and 85%: 15%. While the highest water content value is 8% in samples using sago adhesive with a percentage of 90%: 10%. According to SNI standard No. 01-6235-2000, good quality biobriquettes have a moisture content of <8%, so when compared to the SNI standard, all biobriquettes produced in this study have met the standard.

Water content will affect the ease of briquettes to burn [5]. The higher the moisture content, the more difficult it is for the briquettes to burn. In this study, the more adhesive mixed in the briquettes, the lower the moisture content of the briquettes. This is in line with research [25] which states that the use of adhesives with a higher composition gives a lower moisture content value. This is because the higher amount of adhesive causes the adhesive strength between the components to be higher.

In addition to affecting flammability, moisture content will also affect the calorific value that will be produced. The lower the moisture content of the briquettes, the higher the calorific value. This is in line with research [26] which states that the lower the moisture content, the less heat is needed to evaporate the water, so the remaining heat energy in the briquette becomes greater.

Briquettes Ash Content Analysis

Ash content is the remaining part of the combustion products. The ash content of a briquette affects its calorific value. The higher the ash content, the lower the quality of the briquette, so that the calorific value produced also decreases [27]. The ash content test results can be seen in Table 4 and Figure 5.

Tabel 4. Briquettes Ash Content Testing

Percentage of Biobriquette Material (%)	Ash content (%)	
	Tapioca Adhesive	Sago Adhesive
90%KF:10%	8%	14%
87.5%KF:12.5%	7%	10%
85%KF:15%	6%	9%

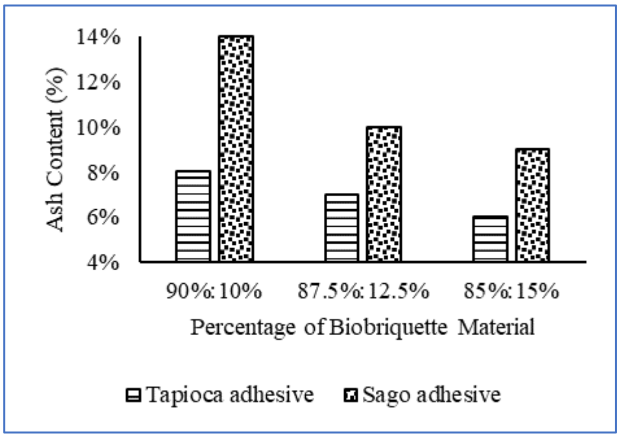

Figure 5. Briquettes Ash Content Chart

Based on Figure 5, the ash content of ketapang fruit briquettes with varying percentages of biobriquette materials has a different influence on the heating value produced. The percentage of ash content produced ranges from 6% - 14%. The lowest ash content is found in the 85%:15% sample using tapioca starch adhesive, which is 6%. Meanwhile, the highest ash content was found in the 90%:10% sample using sago starch adhesive, which was 14%. According to SNI standard No. 01-6235-2000, good quality biobriquettes have ash content <8%. In this study, biobriquettes using tapioca starch were used to fulfil the SNI standard regarding ash content.

High ash content greatly affects the quality of briquettes because it will produce briquettes that form crusts, thus causing the low quality of briquettes because

p-ISSN: 2621-3761
e-ISSN: 2621-2889

high ash content can cause a decrease in the resulting calorific value. This is consistent with research [28] which states that ash content greatly affects the calorific value, this is because ash content has silica elements that have a negative impact on the briquette ignition process. The higher the ash content, the lower the quality of the briquettes produced.

Briquettes Calorific Value Analysis

The calorific value is the maximum amount of heat energy that a fuel releases during a complete combustion reaction per unit of mass or volume of the fuel [29]. Calorific value testing of ketapang fruit briquettes can be seen in Table 5 and Figure 6.

Table 5. Briquettes Calorific Value Testing

Percentage of Biobriquette Material (%)	Calorific Value (cal)	
	Tapioca Adhesive	Sago Adhesive
90%KF:10%	5,139.45	2,409.12
87.5%KF:12.5%	5,540.97	3,653.83
85%KF:15%	5,922.42	3,894.74

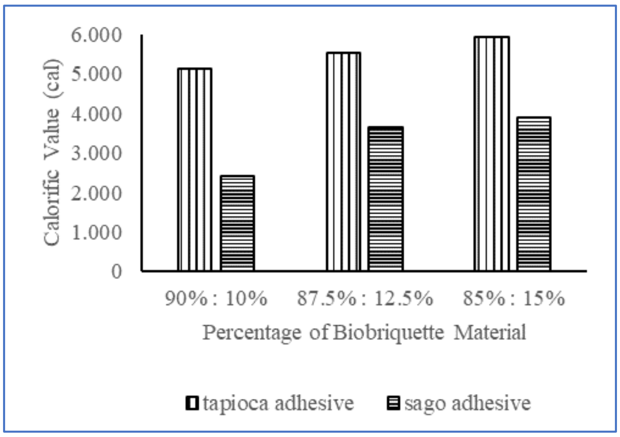

Figure 6. Briquettes Calorific Value Chart

Based on Figure 6, the calorific value of ketapang fruit briquettes with varying percentages of biobriquette materials has a different influence on the calorific value produced. The calorific value of ketapang fruit briquettes ranges from 2,409.12 - 5,922.42 calories. The briquettes with the lowest calorific value used sago adhesive type in the 90%:10% sample. Meanwhile, the highest calorific value is using tapioca adhesive type in the 85%:15% sample. According to SNI standard No. 01-6235-2000, good quality biobriquettes have a calorific value of not less than 5000 cal/gr. In this study, biobriquettes using tapioca adhesive were used to fulfil the SNI standard for calorific value.

The calorific value in Figure 6 can be seen that the higher the percentage of biobriquette material in tapioca adhesive and sago adhesive, the lower the calorific value produced. The briquettes that have the highest calorific value are the biobriquettes with tapioca adhesive. The high calorific value of biobriquettes with tapioca starch compared to sago adhesive in each sample is due to the influence of water content contained in the briquettes. Biobriquettes with tapioca starch adhesive produce lower moisture content than briquettes with sago adhesive. This is influenced by the increase in the amount of adhesive, the resulting calorific value will increase because tapioca starch and sago starch can form a gel [28]. This is in accordance with research [30] which states that the quality of the calorific value of briquettes will increase with the addition of adhesives in briquettes.

Briquettes Burning Rate Analysis

Burning rate is the speed at which a briquette burns out [31]. The greater the burning rate value of a briquette, the faster the briquette will burn out. The results of the burning rate test can be seen in Table 6 and Figure 7.

Table 6. Briquettes Burning Rate Testing

Percentage of Biobriquette Material (%)	Burning rate (gr/min)	
	Tapioca Adhesive	Sago Adhesive
90%KF:10%	1.98	2.62
87.5%KF:12.5%	1.76	2.50
85%KF:15%	1.62	2.31

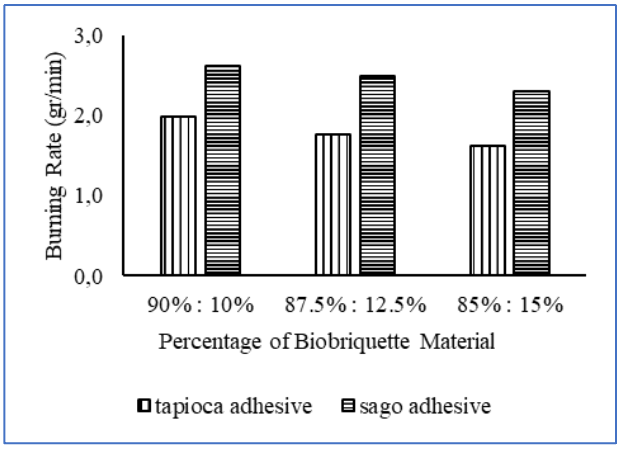

Figure 7. Briquettes Burning Rate Chart

Based on Figure 7, it can be seen that the value of the burning rate of ketapang fruit briquettes with variations in biobriquetting materials, namely the type and composition of adhesive materials, can affect the resulting burning rate. The burning rate of ketapang fruit briquettes ranged from 1.62 - 2.62 gr/min. The briquettes with the highest burning rate were those with sago adhesive in the 85%:15% sample. While the lowest burning rate is the briquette with tapioca adhesive at 85%:15% sample.

The burning rate in Figure 7 shows that the higher the percentage of biobriquettes in tapioca starch and sago starch adhesive, the higher the burning rate. The burning rate of biobriquettes using tapioca starch adhesive is lower than that of sago starch adhesive because the higher water content in sago starch adhesive can inhibit the burning rate.

p-ISSN: 2621-3761
e-ISSN: 2621-2889

This is consistent with research [32] which states that the burning rate is affected by the moisture content contained in each type of adhesive used. Biobriquettes using tapioca starch adhesive have a faster burning rate due to the higher calorific value produced.

The burning rate does not have a standard to determine the quality of briquettes, good briquettes are briquettes that have high durability. In other words, the smaller the burning rate of a briquette, the better the quality of the briquette [33]. The tapioca starch adhesive type has the lowest burning rate compared to the sago starch adhesive type. This is because tapioca starch has good gel strength properties, high solution purity, and has high adhesion [34].

V. Conclusion

Based on the results of the data analysis, it can be concluded that the calorific value increases with higher amounts of adhesive used, which aligns with the SNI standard for tapioca adhesive. Additionally, the proportion of bio-briquette ingredients significantly influences both the calorific value and burning rate of the briquettes. Decreasing the proportion of these ingredients reduces the burning rate while increasing the calorific value. Data analysis shows that briquettes with lower burning rates indicate higher quality due to lower density, which results in larger air cavities. Consequently, more material can be burned compared to denser briquettes.

This study titled "Effect of Varying Percentage of Ketapang Fruit Biobriquettes on Health Value and Burning Rate" presents significant findings but acknowledges some limitations. The main focus was on the use of ketapang fruit as biomass and tapioca starch and sago starch as adhesives, without exploring alternative biomass and adhesive combinations. The research was conducted under controlled laboratory conditions, which may limit its application in real environments with diverse environmental factors. To overcome this limitation, future studies are recommended to diversify biomass sources and adhesive composition, conduct field experiments to evaluate performance under various conditions, and evaluate economic feasibility and scalability for wider implementation. These efforts will improve the understanding and utilisation of ketapang fruit biobriquettes as a sustainable alternative fuel, contributing to environmental conservation and energy sustainability.

References

[1] W. Wirandika, “Karaktristik Proses Gasifikasi Campuran Limbah Kayu Merawan dan Tempurung Kelapa dengan Sistem Downdraft Kontinyu,” Politeknik Negeri Sriwijaya Palembang, 2016.
[2] R. Rifdah, N. Herawati, and F. Dubron, “Pembuatan Biobriket dari Limbah Tongkol Jagung Pedagang Jagung Rebus dan Rumah Tangga sebagai Bahan Bakar Energi Terbarukan dengan Proses Karbonisasi,” *J. Distilasi*, vol. 2, no. 2, pp. 39–46, Nov. 2018, doi: 10.32502/jd.v2i2.1202.
[3] H. Haberl, “The Growing Role of Biomass for Future Resource Supply—Prospects and Pitfalls,” in *Sustainability Assessment of Renewables-Based Products*, Wiley, 2015, pp. 1–18. doi: 10.1002/9781118933916.ch1.
[4] S. Ahzan, D. Pangga, D. S. B. Prasetya, and A. H. P. Wijaya, “Pengembangan Briket Berbahan Dasar Eceng Gondok dan Abu Sekam Padi sebagai Alternatif Bahan Bakar Oven Tembakau,” *ORBITA J. Kajian, Inov. dan Apl. Pendidik. Fis.*, vol. 7, no. 1, p. 98, May 2021, doi: 10.31764/orbita.v7i1.3444.
[5] L. Sulistyaningkarti and B. Utami, “Making Charcoal Briquettes from Corncobs Organic Waste Using Variation of Type and Percentage of Adhesives,” *JKPK (Jurnal Kim. dan Pendidik. Kim.*, vol. 2, no. 1, p. 43, May 2017, doi: 10.20961/jkpk.v2i1.8518.
[6] L. Maulinda, H. Mardinata, and J. Jalaluddin, “Optimasi Pembuatan Briket Berbasis Limbah Ampas Tebu Menggunakan Metode Rsm (Response Surface Methodology),” *J. Teknol. Kim. Unimal*, vol. 8, no. 1, pp. 1–25, Jan. 2020, doi: 10.29103/jtku.v8i1.2222.
[7] L. Parinduri and T. Parinduri, “Konversi Biomassa Sebagai Sumber Energi Terbarukan,” *JET (Journal Electr. Technol.*, vol. 5, no. 2, pp. 88–92, 2020, [Online]. Available: https://jurnal.uisu.ac.id/index.php/jet/article/view/2885
[8] M. A. Aljarwi, D. Pangga, and S. Ahzan, “Uji Laju Pembakaran dan Nilai Kalor Briket Wafer Sekam Padi dengan Variasi Tekanan,” *ORBITA J. Kajian, Inov. dan Apl. Pendidik. Fis.*, vol. 6, no. 2, p. 200, Nov. 2020, doi: 10.31764/orbita.v6i2.2645.
[9] L. M. A. Ramdani, S. Ahzan, and D. S. B. Prasetya, “The Effect of the Type and Composition of the Adhesive on the Physical Properties and the Rate of Combustion Hyacinth Biobriquettes,” *Lensa J. Kependidikan Fis.*, vol. 8, no. 2, p. 85, Dec. 2020, doi: 10.33394/j-lkf.v8i2.2786.
[10] I. Qistina, D. Sukandar, and T. Trilaksono, “Kajian Kualitas Briket Biomassa dari Sekam Padi dan Tempurung Kelapa,” *J. Kim. Val.*, vol. 2, no. 2, pp. 136–142, Dec. 2016, doi: 10.15408/jkv.v2i2.4054.
[11] N. Supatata, J. Buates, and P. Hariyanont, “Characterization of Fuel Briquettes Made from Sewage Sludge Mixed with Water Hyacinth and Sewage Sludge Mixed with Sedge,” *Int. J. Environ. Sci. Dev.*, vol. 4, no. 2, pp. 179–181, 2013, doi: 10.7763/IJESD.2013.V4.330.
[12] S. C. Hutagalung, E. Erwin, and A. S. Panggabean, “Pembuatan Briket Arang Dengan Memanfaatkan Limbah Dari Tempurung Biji Ketapang (Terminalia Catappa) Dan Tempurung Biji Kemiri (Aleurites Molucanna L. Willd.),” in *Prosiding Seminar Nasional Kimia*, 2017, pp. 164–169. [Online]. Available: https://jurnal.kimia.fmipa.unmul.ac.id/index.php/prosiding/article/view/567
[13] N. Hidayah, I. Astarinugrahini, and Lulu Maklunah, “‘Briket Cattapa’ Alternatif Briket Bioarang Terbarukan Berbahan Buah Ketapang (Terminalia Cattapa) Yang Ramah Lingkungan,” *Pelita*, vol. IX, no. 1, pp. 81–89, 2014, [Online]. Available: https://journal.uny.ac.id/index.php/pelita/article/view/3945
[14] R. Fachrurozi, F. A. Widayah, F. Adifa, and I. W. Widiarti, “Studi Penambahan Polietilen untuk Meningkatkan Kualitas Biobriket Ketapang,” *J. Miner. Energi, dan*

Lingkung., vol. 3, no. 2, p. 83, Dec. 2019, doi: 10.31315/jmel.v3i2.2920.
[15] M. S. Rizaldi, B. Budiman, and S. W. Moonti, "Efektivitas Briket Daun Ketapang Terminalia Catappa Dan Kulit Kakao Theobroma Cacao L Sebagai Bioarang," *J. Kolaboratif Sains*, vol. 2, no. 1, pp. 11–18, 2019, doi: 10.56338/jks.v2i1.752.
[16] S. Miskah, L. Suhirman, and H. R. Ramadhona, "Pembuatan biobriket dari campuran arang kulit kacang tanah dan arang ampas tebu dengan aditif KMnO4," *J. Tek. Kim.*, vol. 20, no. 3, 2014, [Online]. Available: https://www.e-jurnal.com/2015/03/pembuatan-biobriket-dari-campuran-arang.html
[17] Y. Andani, Muhdarina, and T. A. Amri, "Karbonisasi Cangkang Buah Ketapang (Terminalia Catappa) dan Aplikasinya pada Pengolahan Air Gambut," Universitas Riau, 2017.
[18] Yuniarti, "Tinjauan Kinetika Reaksi Pirolis Cangkang Biji Ketapang untuk Menghasilkan Bahan Briket Arang," Universitas Gadjah Mada, 2016.
[19] A. F. Mulyadi, I. A. Dewi, and P. Deoranto, "Utilization of Nypa (Nypa fruticans) Bark for Making Biocharcoal Briquette as Alternative of Energy Sources," *J. Teknol. Pertan.*, vol. 14, no. 1, pp. 65–72, 2013, [Online]. Available: https://jtp.ub.ac.id/index.php/jtp/article/view/393
[20] "Karaktristik Briket dari Limbah Pengolahan Kayu Sengon dengan Metode Cetak Panas," *JMEL J. Mech. Eng. Learn.*, vol. 2, no. 1, pp. 14–21, 2013, [Online]. Available: https://journal.unnes.ac.id/sju/jmel/article/view/1942
[21] Iriany, Meliza, Firman Abednego S. Sibarani, and Irvan, "Pengaruh Perbandingan Massa Eceng Gondok dan Tempurung Kelapa Serta Kadar Perekat Tapioka terhadap Karakteristik Briket," *J. Tek. Kim. USU*, vol. 5, no. 1, pp. 20–26, Mar. 2016, doi: 10.32734/jtk.v5i1.1520.
[22] A. Kholil, "Analisis Fisis Briket Arang Berbahan Alami Kulit Buah Salak dan Pelepah Salak," Universitas Islam Negeri Maulana Malik Ibrahim, 2017.
[23] N. Darun, "Pengaruh Variasi Temperatur Cetakan terhadap Karaktristik Briket Kayu Sengon pada Tekanan Kompaksi 500 Psig," Universitas Negeri Semarang, 2013.
[24] T. F. Prasetyo, A. F. Isdiana, and H. Sujadi, "Implementasi Alat Pendeteksi Kadar Air pada Bahan Pangan Berbasis Internet of Things," *SMARTICS J.*, vol. 5, no. 2, pp. 81–96, Oct. 2019, doi: 10.21067/smartics.v5i2.3700.
[25] H. W. Desgira, "Pengaruh Variasi Perekat terhadap Kualitas Briket dari Serbuk Daun Teh," Universitas Islam Negeri Sumatera Utara, 2020.
[26] H. P. Putra, M. Mokodompit, and A. P. Kuntari, "Study Karaktristik Briket Berbahan Dasar Limbah Bambu dengan Mneggunakan Perekat Nasi," *J. Teknol.*, vol. 6, no. 2, pp. 116–123, 2013, [Online]. Available: https://ejournal.akprind.ac.id/index.php/jurtek/article/view/996
[27] O. Nurhilal and S. Suryaningsih, "Pengaruh Komposisi Campuran Sabut dan Tempurung Kelapa terhadap Nilai Kalor Biobriket dengan Perekat Molase," *J. Ilmu dan Inov. Fis.*, vol. 2, no. 1, pp. 8–14, Jan. 2018, doi: 10.24198/jiif.v2i1.15606.
[28] F. Faijah, R. Fadilah, and N. Nurmila, "Perbandingan Tepung Tapioka dan Sagu pada Pembuatan Briket Kulit Buah Nipah (Nypafruticans)," Universitas Negeri Makassar, 2020.
[29] M. A. Almu, S. Syahrul, and Y. A. Padang, "Analisa Nilai Kalor dan Laju Pembakaran pada Briket Campuran Biji Nyamplung (Calophyllm Inophyllum) dan Abu Sekam Padi," *Din. Tek. Mesin*, vol. 4, no. 2, pp. 117–122, Jul. 2014, doi: 10.29303/d.v4i2.61.
[30] A. Ismayana and M. R. Afriyanto, "The Effects of Adhesive Type and Concentration In the Manufacturing of Filter Cake Briquettes As an Alternative Fuel," *J. Teknol. Ind. Pertan.*, vol. 21, no. 3, pp. 186–193, 2011, [Online]. Available: https://journal.ipb.ac.id/index.php/jurnaltin/article/view/4780
[31] A. Trisa, W. Nuriana, and M. Mustafa, "Pengaruh Variasi Tekanan terhadap Densitas, Kadar Air dan Laju Pembakaran pada Briket Pelepah Kelapa," in *Seminar Nasional Sains dan Teknologi Terapan*, 2019, pp. 421–426. [Online]. Available: https://ejurnal.itats.ac.id/sntekpan/article/view/664
[32] M. R. Aziz, A. L. Siregar, A. B. Rantawi, and I. B. Rahardja, "Pengaruh Jenis Perekat Pada Briket Cangkang Kelapa Sawit Terhadap Waktu Bakar," in *Prosiding Semnastek*, 2019. [Online]. Available: https://jurnal.umj.ac.id/index.php/semnastek/article/download/5256/3532
[33] B. L. Jannah, D. Pangga, and S. Ahzan, "Pengaruh Jenis dan Persentase Bahan Perekat Biobriket Berbahan Dasar Kulit Durian terhadap Nilai Kalor dan Laju Pembakaran," *Lensa J. Kependidikan Fis.*, vol. 10, no. 1, p. 16, Jun. 2022, doi: 10.33394/j-lkf.v10i1.5293.
[34] Norhikmah, N. M. Sari, and M. Mahdie, "Pengaruh Persentase Perekat Tapioka terhadap Karaktreristik Briket Arang Tempurung Kelapa," *J. Sylva Sci.*, vol. 4, no. 2, p. 324, Apr. 2021, doi: 10.20527/jss.v4i2.3343.

Declarations

Author contribution	:	Himmi Raudatul Fadilah and Sukainil Ahzan: conceptualization, methodology, project administration, writing–original draft, & writing– reviewing & editing; Dwi Pangga: methodology, formal analysis, writing–original draft, & writing–reviewing & editing; Habibi and Muhammad Roil Bilad: writing–reviewing, editing and investigation.
Funding statement	:	This research did not receive any funding.
Conflict of interest	:	All authors declare that they have no competing interests.
Additional information	:	No additional information is available for this paper.