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Characteristics of Briquettes Made from Plastic Waste, Plastic-Coconut Shell Blends, and Plastic-Corn Cob Composites

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Abstract: Recycling plastic waste holds considerable potential as a fuel source, especially when combined with agricultural waste. This study aims to evaluate the physical characteristics of charcoal briquettes - moisture content, ash content, volatile matter, calorific value, and fixed carbon content - produced from a mixture of plastic waste and organic waste. Three composition variations were tested: pure Low Density Polyethylene (LDPE) plastic waste (100%) as the first treatment (S1), a combination of coconut shells and plastic waste in a 50%:50% ratio as the second treatment (S2), and a combination of corn cobs and plastic waste in the same 50%:50% ratio as the third treatment (S3). Testing was conducted according to SNI 01-6235-2000 standards. The results showed that all treatments produced charcoal briquettes with moisture content and calorific value that met SNI standards. Among the treatments, briquettes made entirely from plastic waste (S1) achieved the highest calorific value at 5921 cal/g, followed by the plastic-coconut shell mixture (S2) at 5574 cal/g and the plastic-corn cob mixture (S3) at 5100 cal/g. These findings indicate that plastic waste and agricultural waste have significant potential as fuel sources for power generation, supporting energy mix targets, and contributing to waste management and sustainable energy production. However, the study also identified areas for improvement. The ash content across all treatments failed to meet SNI standards, and the volatile matter content in S1 was below the acceptable range. These shortcomings highlight the need for further optimization in material formulation and manufacturing processes to enhance briquette quality. Future research should prioritize refining material combinations, improving ash content and volatile matter characteristics, and assessing the environmental impacts of using plastic-based briquettes. With continued innovation, this approach could play a pivotal role in achieving energy mix targets and addressing the challenges of plastic and agricultural waste, offering a sustainable and practical solution for energy generation.

Keywords: Agricultural Waste; Charcoal Briquettes; LDPE; Physical Properties; Plastic Waste.

Introduction

In 2020, 38% of municipal solid waste (810 million tonnes) was either dumped in the environment or openly burned [1]. By 2050, global waste generation is expected to surge by 70%, rising from 2.01 billion tonnes in 2016 to 3.40 billion tonnes annually, making solid waste management a critical issue that affects every individual worldwide, as it will contribute to climate change, pollution, and adverse health effects [1-3]. Plastics are especially problematic, as improper collection and management can lead to contamination of waterways and ecosystems for centuries [1, 4-6].

In Indonesia, waste management remains a significant challenge, with waste production reaching 18.3 million tonnes in 2024, averaging approximately 50,000 tonnes per day, and an alarming 41.32% of this waste remaining unmanaged [7]. The Indonesian Long-Term Development Plan (RPJP) 2025–2045 has set ambitious goals to achieve 'No Landfill' and minimal residue targets by 2045 [8]. However, significant barriers hinder progress toward these objectives. Indonesia's waste management system still relies heavily on the collect-transport-dispose approach, resulting in a substantial volume of waste ending up in landfills [8]. Of this, 60% is managed through the open dumping method, while only 10% is handled using sanitary landfill practices [9]. The average capacity of national landfill sites is projected to reach full capacity by 2028 or earlier, worsening environmental issues such as declining water and soil quality underscored by the Biological Oxygen Demand (BOD) load, which is estimated to reach 3,000 thousand tons per year, significantly exceeding the maximum allowable limit of 600 thousand tons per year [8]. These projections highlight the urgency of adopting more sustainable and effective waste management practices to mitigate environmental and public health risks.

In West Nusa Tenggara, rapid population growth has led to a significant increase in waste production, which has doubled in just four years, rising from 203,220 tonnes in 2020 to 400,722.99 tonnes in 2024 [7]. The province launched the Zero Waste program in 2020 as a priority initiative, targeting 70% waste management and 30% waste reduction by 2023 [10]. Over the four years of the Zero Waste NTB Gemilang program, approximately 3.9 million

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tonnes of waste have been generated in the province, but only 1.9 million tonnes have been managed or processed in landfills, leaving 2 million tonnes of waste inadequately handled [11]. This highlights the need for enhanced efforts to improve waste management practices and achieve the program's ambitious goals.

Data from the national waste management information system shows that organic waste, including food scraps and biomass waste, accounts for the largest proportion of waste at approximately 39.71%, followed by plastic waste in second place at 19.2% [7]. This pattern is also observed in West Nusa Tenggara province, where the two highest proportions of waste are from food scraps and biomass and plastics, 51.58% and 20.11% respectively [12].

Plastics are composed of polymer compounds, primarily made of carbon and hydrogen [3]. One of the raw materials for plastic production is naphtha, derived from petroleum or natural gas refining [13]. Plastics generally exhibit properties such as corrosion resistance, low density, ductility, strength, and resistance to low temperatures [14]. These characteristics make plastic waste difficult to decompose, contributing to environmental issues and potential human health risks. Improper waste disposal can pollute the air through open burning of waste, releasing harmful pollutants such as methane, dioxins and furans [15].

There has been a global paradigm shift from viewing waste as waste material to becoming a resource, including as an energy source [16, 17]. Conventional recycling methods for plastic waste, such as crafting or textile production, have a limited impact [18]. Studies have explored the use of plastic waste as an additive in briquette production, which, when combined with agricultural waste, is believed to enhance calorific value [19-22]. The primary criterion when using biomass as a fuel source is its calorific value [23].

In addition to biomass, converting plastic into briquettes is a promising step toward reducing reliance on non-renewable energy sources. Additionally, organic waste holds potential as an energy source. Plastic waste can serve as a high-calorific-value additive for alternative fuel production [19-21]. Thus, optimizing the management of both organic and plastic waste by converting them into charcoal briquettes is essential. Previous studies have demonstrated the potential of this approach. For instance, [24] reported that adding 80% plastic yielded the highest calorific value of approximately 9,055 kcal/kg. Similarly, [25] found that a combination of biomass waste, used cooking oil, and 30% plastic achieved a high calorific value of 33.56 MJ/kg.

Recycling plastic waste into alternative energy sources, such as charcoal briquettes, has emerged as a promising strategy to address these challenges while contributing to renewable energy production. When combined with agricultural by-products, plastic waste can be transformed into briquettes with enhanced energy potential, offering a sustainable approach to waste management and energy generation. Utilizing organic and plastic waste as renewable energy feedstock not only addresses environmental issues but also provides a sustainable energy alternative.

In the RPJP 2025–2045, Indonesia has committed to reducing waste generation and increasing the use of new and renewable energy sources. According to the Ministry of Energy and Mineral Resources (ESDM), the realization of the primary energy mix from renewable energy sources reached 13.1% by the end of 2023. Impressively, the renewable energy mix in West Nusa Tenggara (NTB) has already achieved 22.43%, surpassing the province's 2023 target of 19%. The NTB 100% Renewable Energy Roadmap identifies waste-related renewable energy potential, including municipal waste, biogas from corn waste, rice husks, straw, and coconut residues [26].

This highlights the potential of plastic waste and biomass as alternative renewable energy sources. Considering this, the study investigates the characteristics of charcoal briquettes made from combinations of plastic waste and organic materials, with a focus on their compliance with the Indonesian National Standard (SNI 01-6235-2000). Specifically, the study examines pure plastic waste, a combination of plastic and coconut shells, and a combination of plastic and corn cobs. By evaluating key parameters such as moisture content, ash content, volatile matter, calorific value, and fixed carbon content, this research provides valuable insights into the feasibility of plastic-biomass briquettes as a fuel source while identifying areas for improving their formulation and production processes.

Research Methods

This research was conducted over a period of 2 months at the Forest Product Technology Laboratory, Faculty of Agriculture, and the Structure and Materials Laboratory, Faculty of Engineering, University of Mataram. The tools used in this research include a briquette press, bomb calorimeter, desiccator, drum kiln, furnace, hydraulic press, binder mixer, sieves of 40 mesh, 60 mesh, and 80 mesh, oven, and scale. The materials used are coconut shells, corn cobs, plastic waste (LDPE), and a 25% molasses binder.

Three treatments of material compositions were tested to evaluate their characteristics: 100% pure plastic waste (LDPE), or called S1; a 50:50 mixture of coconut shells and plastic waste, or called S2; and a 50:50 mixture of corn cobs and plastic waste, or called S3. Each treatment was repeated three times, resulting in a total of nine test samples.

The production of charcoal briquettes began with carbonizing raw materials such as plastic waste, coconut shells, and corn cobs, which were dried in air and carbonized alternately using a drum kiln for 4 hours, except for plastic waste, which was carbonized for 2 hours. The charcoal was then ground and sieved to a size of 40-60 mesh. The charcoal powder was then mixed with a binder in the form of molasses [27]. After mixing, the material was pressed using a hydraulic press at a compaction pressure of 240 N/cm^2.

Charcoal briquette testing was conducted according to SNI 01-6235-2000 standards. The properties tested include proximate analysis, which consists of moisture content, ash content, volatile matter, calorific value, and fixed carbon content. Analysis of variance (ANOVA) was performed using R Studio 4.1 software. If the results show a p-value < 0.05, it means that the factors used caused significant differences in the characteristics (quality) of the charcoal briquettes, and further tests using Duncan's test were conducted at a 95% confidence level ($\alpha = 0.05$) [28].

Results and Discussion

Moisture Content

Moisture content is a crucial factor in determining the quality of charcoal briquettes, as it directly affects ease of combustion, burning efficiency, calorific value, and the amount of smoke generated during burning [29]. Lower moisture content typically enhances ignition and heat output, contributing to cleaner and more efficient combustion, while higher moisture levels can reduce calorific value and increase smoke production [30].

The results of this study indicate that there is no significant difference in moisture content among the three treatments (S1, S2, and S3). The specific moisture content values for each treatment are presented in Table 1.

The moisture content of charcoal briquettes based on composition and material variations ranges between 0.31% and 0.52%. The lowest moisture content is produced by the combination of plastic waste and coconut shells (S2R1), approximately 0.31%, while the highest value is found in briquettes made from pure plastic waste, around 0.52% (Table 1). Plastic can enhance adhesion and compactness, contributing to higher density and lower moisture content [25]. The results of this study show that the average moisture content of briquettes made from plastic waste (LDPE) is relatively low, at 0.39%. This average is lower compared to the moisture content of briquettes made from a mixture of plastic bottles (PET) with teak sawdust and coconut shells, which has been reported at 5.18% [31]. The material variation factor does not significantly affect moisture content. Analysis of variance ($\alpha = 0.05$) indicates no significant difference in moisture content across all treatments (p-value> 0.05) (Table 1).

Table 1. Moisture Content Value for Each Treatment (%)

Treatment	Replication			Average
	R1	R2	R3	
S1	0.38	0.31	0.52	0.39 ^{ns}
S2	0.31	0.38	0.37	0.35 ^{ns}
S3	0.35	0.46	0.41	0.41 ^{ns}

Remarks: S1, plastic waste (100%); S2, plastic waste and coconut shells (50:50%); S3, plastic waste and corn cobs (50:50); ns, no significant difference among the treatments based on the Least Significant Difference (LSD) test at α= 0.05.

However, all briquettes produced meet the moisture content requirements outlined in the SNI 01-6235-2000 standard. This suggests that the combination of plastic waste with agricultural residues such as coconut shells and corn cobs does not adversely affect the moisture content of the briquettes.

Ash Content

Ash is the residue left after combustion [32]. The primary component of ash is silica minerals, which negatively impact the calorific value produced [33]. The higher the ash content, the lower the quality of the briquette [34]. High ash content is caused by the mineral content in materials such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) [35]. Briquettes with high ash content can lead to problems in combustion systems and cause scaling on the equipment used [36]. This is triggered by the deposition of volatile minerals that can adhere to the equipment walls [33]. The ash content of charcoal briquettes made from plastic waste and different material variations is presented in Table 2.

Tabel 2. Ash Content Value for Each Treatment (%)

Treatment	Replication			Average
	R1	R2	R3	
S1	18.78	18.69	24.24	20.57 ^{a}
S2	11.11	10.69	12.3	11.37 ^{b}
S3	12.83	11.8	12.41	12.35 ^{b}

Remarks: S1, plastic waste (100%); S2, plastic waste and coconut shells (50:50%); S3, plastic waste and corn cobs (50:50); a,b, significant difference among the treatments based on LSD test at α= 0.05.

Variance analysis indicates that the ash content of treatment S1 (pure plastic waste) is significantly different from both S2 and S3, while no significant difference is observed between S2 and S3. The highest ash content was recorded in treatment S1R3 (pure plastic waste, LDPE), while the lowest ash content was found in treatment S2R2, a combination of plastic waste and coconut shells (50:50). Compared to previous studies, the average ash content of the plastic waste charcoal briquettes in this research is notably higher. For instance, a mixture of fruit waste, plastic waste, and coconut shells yielded an ash content of 0.77% [14], plastic bottle caps recorded 6.9% [37], and a combination of plastic bottles (PET) with teak sawdust and coconut shells resulted in 3.55% [31]. The ash content is influenced by the chemical compounds present in the raw materials. Inorganic compounds in the briquette raw materials can affect the ash content during the carbonization process [18, 38]. High ash content is also attributed to raw materials with high levels of carbonate salts, potassium, calcium, magnesium, and silicates [39]. Higher silicate content leads to higher ash content because silicates do not combust [33].

Volatile Matter

Volatile matter in charcoal briquettes refers to the combustible volatile components composed of CO, H_2, and CO_2 compounds [40]. A higher volatile matter content results in faster ignition of the briquettes, but also leads to shorter burn times [41]. The volatile matter content of plastic waste, charcoal briquettes, and their variations is presented in Table 3.

Table 3. Volatile Matter Value for Each Treatment (%)

Treatment	Replication			Average
	R1	R2	R3	
S1	13.55	14.17	14.33	14.02 ^{a}
S2	4.66	6.84	8.82	6.77 ^{b}
S3	5.36	5.59	5.98	5.64 ^{b}

Remarks: S1, plastic waste (100%); S2, plastic waste and coconut shells (50:50%); S3, plastic waste and corn cobs (50:50); a,b, significant difference among the treatments based on the LSD test at α= 0.05.

The results of the study show that the volatile matter content of the charcoal briquettes ranges from 4.66% to 14.33%. The highest volatile matter content was obtained from treatment S1R3, while the lowest was from treatment S2R1. The average volatile matter content of these charcoal briquettes is lower compared to a previous study on briquettes made from a mixture of coconut shells and corn cobs, which reported a volatile matter content of 27.4% [42], but higher than briquettes made solely from coconut shells, which had a volatile matter content of 3.65% [43].The volatile matter values in this study meet the requirements of the SNI 01-6235-2000 standard, which specifies a maximum of 15%. The variation in material composition significantly affected the volatile matter content. Variance analysis (α = 0.05) showed that among the three treatments, S2 and S3 share similar notations, indicating no significant difference in volatile matter content quality between these two treatments (Table 3). However, S1 has a distinct notation, signifying a difference in volatile matter content quality compared to S2 and S3.

Fixed Carbon Content

Fixed carbon content is a key parameter representing the combustible portion of biomass remaining in solid fuels after the removal of volatile matter [44]. A higher fixed carbon content indicates superior quality in charcoal briquettes, as it is directly associated with higher energy output during combustion [45]. The fixed carbon content and calorific value of plastic waste-based charcoal briquettes, along with variations in composition, are presented in Table 4.

Table 4. Fixed Carbon Content Value for Each Treatment (%)

Treatment	Replication			Average
	R1	R2	R3	
S1	67.33	66.83	51.92	62.03 [a]
S2	83.9	82.08	78.53	81.50 [b]
S3	80.43	82.14	81.18	81.25 [b]

Remarks: S1, plastic waste (100%); S2, plastic waste and coconut shells (50:50%); S3, plastic waste and corn cobs (50:50); a,b, significant difference among the treatments based on the LSD test at α= 0.05.

The findings reveal that the fixed carbon content of the charcoal briquettes ranged from 51.92% to 83.9%. The highest fixed carbon content was observed in treatment S2R1, while the lowest was recorded in treatment S1R3. Fixed carbon content is closely influenced by ash content, with lower ash levels generally associated with reduced fixed carbon content [46]. This observation aligns with the study conducted by [47], which reported a positive correlation between ash content and fixed carbon, highlighting that lower ash levels can lead to diminished fixed carbon output.

The composition variations significantly affected the fixed carbon content. Analysis of Variance (α = 0.05) identified statistically significant differences in fixed carbon content across all treatments, as indicated by distinct notations ($p < 0.05$) (Table 5). Treatments S2 and S3 were statistically distinct from treatment S1, reflecting differences in the quality of fixed carbon content. However, no significant difference was observed between treatments S2 and S3. Conversely, treatment S3 exhibited a notably different fixed carbon content profile compared to the other treatments.

Calorific Value

The quality of the calorific value of briquettes depends on their chemical composition, moisture content, ash content, and volatile matter [33, 48]. The calorific value testing was conducted using an Oxygen Bomb Calorimeter with the serial number IKA C5003 Control. The calorific values of plastic waste, charcoal briquettes, and variations by type are presented in Table 5.

Table 5. Calorific Value for Each Treatment (Cal/gram)

Treatment	Replication			Average
	R1	R2	R3	
S1	5813	5994	5955	5921 [a]
S2	5507	5406	5809	5574 [b]
S3	5212	5141	4946	5100 [c]

Remarks: S1, plastic waste (100%); S2, plastic waste and coconut shells (50:50%); S3, plastic waste and corn cobs (50:50)a,b,c significant difference among the treatments based on the LSD test at α=0.05.

The study results indicate that the calorific value of these charcoal briquettes ranges from 4946 cal/g to 5994 cal/g.The highest calorific value was obtained from the S1R2 treatment, while the lowest was observed in the S3R3 treatment. On average, the calorific value of this charcoal is higher compared to previous studies, such as briquettes made from fruit waste, which reported around 4549 cal/g [14]. The calorific value obtained in this study is also higher compared to a previous study that produced charcoal briquettes from plastic waste using pyrolysis technology, which reported an average calorific value of approximately 4,962–5,391 cal/g [49]. However, it is lower compared to charcoal briquettes made from plastic bottle caps, which reached approximately 9982 cal/g [37].

Compared to the Indonesian National Standard (SNI 01-6235-2000), the calorific values in this study meet the required standard of ≥5000 cal/g. The high calorific value of these briquettes is attributed to the material content in plastic, particularly the carbon chains, which are highly flammable [14]. Plastic, being a polymer, influences the calorific value of the briquettes and inherently possesses a high calorific value [24, 50].

The variation in types significantly affects the calorific value. The variance test results (α = 0.05) indicate significant differences in calorific values across all treatments, as marked by distinct notations (p-value < 0.05) (Table 5). These differing notations show that treatments S1, S2, and S3 exhibit varying calorific quality.

Briquettes Qualities based on the Indonesian National Standard

The diversification of plastic utilization into briquette production serves as an alternative approach to optimizing the use of plastic waste [22]. The quality of the waste briquettes was assessed based on the Indonesian National Standard (SNI 01-6235-2000). Overall, the test results indicated that the briquettes met the SNI 01-6235-2000 standards in terms of moisture content, volatile matter content, and calorific value. However, the ash content of the charcoal briquettes did not meet the required standards (Table 6). As for fixed carbon content, no standard is specified in the SNI. The highest fixed carbon content was observed in the briquettes made from a mix of plastic waste and coconut shells.

The findings of this study present significant implications for future research and practical applications. Firstly, the failure of the briquettes to meet the ash content standard highlights the necessity for further investigation into methods to reduce ash production. Future studies could examine alternative combinations of plastic waste with other materials or implement pre-treatment techniques to enhance the ash content properties.

Table 6. Briquettes Characteristics

Physical characteristics	Laboratory results		
	S1	S2	S3
Moisture content (%)	0.39*	0.35*	0.41*
Ash content (%)	20.57	11.37	12.69
Volatile matter (%)	17.01	6.78*	5.65*
Calorific value (cal/gr)	5921*	5574*	5100*
Fixed carbon content	62.03	81.50	81.25

*Meet requirements from SNI 01-6235-2000

Secondly, although fixed carbon content is not explicitly addressed in the SNI, its critical role in determining the combustion efficiency of briquettes cannot be underestimated. The elevated fixed carbon content observed in briquettes composed of plastic waste and coconut shells suggests the potential of such material combinations. This finding warrants further exploration of their properties and performance across diverse applications. Thirdly, the results emphasize the importance of advancing research into mixed-material briquettes to identify optimal blends that maximize quality while adhering to established standards. This could involve incorporating a broader range of agricultural or industrial by-products to improve the overall characteristics of the briquettes. Lastly, the study underscores the viability of utilizing plastic waste in energy production as a dual-purpose solution for waste management and energy generation. Nevertheless, future research must also address the environmental implications of burning plastic-based briquettes, particularly with respect to emissions and long-term sustainability. These considerations are essential to ensure the broader applicability and environmental compatibility of plastic-based briquette technologies.

Conclusion

This study highlights the potential of utilizing plastic waste, both in pure form and in combination with agricultural waste, as a viable source of fuel. The findings demonstrate that all tested briquette compositions met SNI 01-6235-2000 standards for moisture content and calorific value, with pure plastic briquettes (S1) yielding the highest calorific value. The combination of plastic waste with coconut shells (S2) and corn cobs (S3) also exhibited promising calorific properties, supporting the use of these materials in energy production. Despite these promising results, the ash content across all treatments and the volatile matter content in the pure plastic briquettes (S1) did not meet SNI standards. These shortcomings underline the need for further optimization of briquette formulations and manufacturing processes to ensure compliance with quality standards. The study underscores the dual benefits of this approach, contributing to sustainable waste management and advancing renewable energy goals. Future research should focus on refining material combinations, improving ash content characteristics, and evaluating the environmental impacts of using plastic-based briquettes. With continued development, this approach could support energy mix targets and offer a sustainable solution to plastic and agricultural waste challenges.

Author's Contributions

Wiwin Iswandi Djola: draft writing; Dhimas Mardyanto Prasetyo: performed ANOVA analysis, prepared samples and laboratory analysis; Nandita Pasya Salsabila: prepared samples and laboratory analysis; Muhammad Sadir: draft writing; Eni Hidayati: draft writing and editing.

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References

[1] UNEP, "Global Waste Management Outlook 2024 Executive summary: Beyond an age of waste – Turning rubbish into a resource.," Nairobi, 2024. [Online]. Available: https:// wedocs.unep.org/20.500.11822/44992

[2] K. Silpa, L. C. Yao, P. Bhada-Tata, and F. Van Woerden, "What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050," The World Bank, Washington DC, 2018.

[3] A. Torres-Agullo, A. Karanasiou, T. Moreno, and S. Lacorte, "Overview on the occurrence of microplastics in air and implications form the use of face masks during the COVID-19 pandemic," *Science of the Total Environment*, vol. 800, no. 149555, 2021, doi: https://doi.org/10.1016/j.scitotenv.2021.149555.

[4] S. B. Borrelle *et al.*, "Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution," *Science*, vol. 369, pp. 1515-1518, 2020.

[5] E. S. Germanov *et al.*, "Microplastics on the menu: Plastics pollute Indonesian Manta Ray and Whale Shark feeding grounds," *Frontiers in Marine Science*, vol. 6, no. 679, pp. 1-21, 2019, doi: https://doi.org/10.3389/fmars.2019.00679.

[6] S. M. Mintenig, M. G. J. Löder, S. Primpke, and G. Gerdts, "Low numbers of microplastics detected in drinking water from ground water sources," *Sci. Toral Environ.*, vol. 648, pp. 631-635, 2019, doi: https://doi.org/https://doi.org/10.1016/j.scitotenv.2018.08.178.

[7] MoEF. "Timbulan Sampah." Sistem Informasi Pengelolaan Sampah Nasional (SIPSN). https://sipsn.menlhk.go.id/sipsn/public/data/timbulan (accessed 11 January, 2024).

[8] Undang-Undang Republik Indonesia Nomor 59 Tahun 2024 tentang Rencana Pembangunan Jangka Panjang Nasional Tahun 2025-2045, 2024.

[9] P. Damayanti, S. S. Moersidik, and J. T. Haryanto, "Waste to energy in Sunter, Jakarta, Indonesia: Plans and Challenges," *IOP Conference Series: Earth and*

Environmental Science, vol. 940, no. 1, p. 012033, 2021.
[10] I. Muhammad, "NTB Zero Waste, Program Unggulan Pemprov NTB Atasi Sampah," in *Times Indonesia* vol. 2025, ed. Mataram, 2020.
[11] I. Khalid and K. Krisiandi, "Dinas LHK: Selama 4 tahun, 2 juta ton sampah tidak terkelola di NTB," in *Kompas*, ed. Online, 2023.
[12] MOEF (Ministry of Environment and Forestry). "Komposisi Sampah." https://sipsn.menlhk.go.id/sipsn/public/data/komposisi (accessed 5 April, 2025).
[13] U. B. Surono, "Berbagai metode konversi sampah plastik menjadi bahan bakar minyak," *Jurnal Teknik*, vol. 3, no. 1, pp. 32-40, 2013.
[14] Y. Ruslinda, F. Husna, and A. Nabila, "Karakteristik briket dari komposit sampah buah, sampah plastik high density polyethylene (HDPE) dan tempurung kelapa sebagai bahan bakar alternatif di rumah tangga," *Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan*, vol. 14, no. 1, 2017, doi: 10.14710/presipitasi.v14i1.5-14.
[15] E. Erika and E. Gusmira, "Analisis dampak limbah sampah rumah tangga terhubung pencemaran lingkungan hidup," *Profit: Jurnal Manajemen, Bisnis dan Akuntansi*, vol. 3, no. 3, pp. 90-102, 2024.
[16] N. Scarlat, F. Fahl, and J. F. Dallemand, "Status and opportunity for energy recovery from municipal solid waste in Europe," *Waste Biomass Valor*, vol. 10, pp. 2425-2444, 2019, doi: https://doi.org/10.1007/s12649-018-0297-7.
[17] Z. Zhou and L. Zhang, "Sustainable waste management and waste to energy: Valuation of energy potential of MSW in the Greater Bay Area of China," *Energy Policy* vol. 163, no. 112857, 2022, doi: https://doi.org/10.1016/j.enpol.2022.112857.
[18] S. Septhiani and E. Septiani, "Peningkatan Mutu Briket dari Sampah Organik dengan Penambahan Minyak Jelantah dan Plastik High Density Polyethylene (HDPE)," *Jurnal Kimia VALENSI*, vol. 1, no. 2, pp. 91-96, 2015, doi: 10.15408/jkv.v0i0.3567.
[19] S. R. Anggita, R. F. Devarasalya, I. Istikomah, and A. Bawono, "Utilization of LDPE plastic waste, coconut shell and coconut husk as basic material fro briquettes with tapioca starch adhesive," *Jurnal Ilmu Fisika*, vol. 15, no. 2, pp. 81-90, 2023, doi: https://doi.org/10.25077/jif.15.2.81-90.2023.
[20] F. Asip, T. Anggun, and N. Fitri, "Pembuatan briket dari campuran limbah plastik LDPE, tempurung kelapa dan cangkang sawit. ," *Teknik Kimia*, vol. 20, no. 2, 2014, doi: https://doi.org/10.20527/k.v2i1.136.
[21] M. Faizal, A. D. Rifky, and I. Sanjaya, "Pembuatan briket dari campuran limbah plastik LDPE dan kulit buah kapuk sebagai energi alternatif," *Jurnal Teknik Kimia*, vol. 24, no. 1, pp. 8 - 16, 2018, doi: https://doi.org/10.36706/jtk.v24i1.412.
[22] R. E. Fernanda, P. A. Tjahjanti, A. Fahruddin, A. Akbar, and A. F. Iksanudin, "Pengkajian briket dari campuran sampah botol jenis PET dan bahan natural dengan perekat kanji," *JUSTEK: Jurnal Science dan Teknologi*, vol. 5, no. 2, pp. 73-80, 2022.
[23] N. J. Wistara, S. Bahri, and G. Pari, "Biopellet properties of agathis wood fortified with its peeled-off bark," *IOP Conf Ser Mater Sci Eng*, vol. 935, no. 1, p. 012047, 2020, doi: 10.1088/1757-899X/935/1/012047.
[24] R. Riyadi, S. T. Dwiyati, A. Kholil, and A. Ilahi, "Charcoal briquettes characteristics of HDPE mixed with water hyacinth, coconut shell, and bagasse," *International Journal of Energy Engineering*, vol. 6, no. 3, pp. 43-48, 2016.
[25] W. Suwinarti, R. Amirta, and Yuliansyah, "Production of high-calorie energy briquettes from bark waste, plastic and oil," *IOP Conf Ser Earth Environ Sci*, vol. 144, p. 12034, 2018, doi: 10.1088/1755-1315/144/1/012034.
[26] M. E. Wijaya, N. Rospiriandana, P. Anugrah, S. Koiromah, and S. Daroyni, "100% Renewables Roadmap, West Nusa Tenggara, Indonesia," ICLEI – Local Governments for Sustainability e.V. , 2024. [Online]. Available: https://e-library.iclei.org/uploads/WNT_100RE-Roadmap_En_Final.pdf
[27] O. Nurlihal and S. Suryaningsih, "Pengaruh komposisi campuran sabut dan tempurung kelapa terhadap nilai kalor biobriket dengan perekat molase," *Jurnal Ilmu dan Inovasi Fisika*, vol. 2, no. 1, pp. 8-14, 2018.
[28] H. Sahai and M. I. Ageel, *The Analysis of Variance. Fixed, Random and Mixed Models*. Boston: Birkhäuser Boston, MA, 2000, pp. XXXV, 742.
[29] T. Iskandar, "Identifikasi nilai kalor biochar dari bongkol jagung dan sekam padi pada proses pirolisis," *Jurnal Teknik Kimia*, vol. 7, no. 1, pp. 32-35, 2013.
[30] R. Rahman, "Keragaman biopelet dari biomasa limbah sekam padi (Oryza sativa sp.) sebagai bahan bakar alternatif terbarukan. ," Undergraduate, Fakultas Teknologi Pangan, Institut Pertanian Bogor, Bogor, 2011.
[31] D. B. Achmad and Diniyati, "Agroforestry for food estate development: Environmental perspective," *Jurnal Agroforestry Indonesia*, vol. 4, 2021.
[32] R. Armiliandi, "Uji kadar abu pakan ternak daerah Kota Painan dengan metode gravimetri," in *Prosiding SEMNAS BIO 2023*, UIN Raden Fatah Palembang, 2023.
[33] M. Yayi, P. Setyono, and Y. S. Purnomo, "Analisis kadar air dan kadar abu briket lumpur IPAL dan fly ash dengan penambahan serbuk gergaji kayu," *INSOLOGI: Jurnal Sains dan Teknologi*, vol. 1, no. 6, pp. 696-703, 2022, doi: https://doi.org/10.55123/insologi.v1i6.1047.
[34] A. Kahariayadi, D. Setyawati, Nurhaida, F. Diba, and E. Roslinda, "Kualitas arang briket berdasarkan persentase arang batang kelapa sawit (*Elaeis guineensis* Jacq) dan arang kayu laban (*Vitex pubescens* Vahl)," *Jurnal Hutan Lestari*, vol. 3, no. 4, pp. 561-568, 2015.
[35] N. A. Christanty, D. Hermawan, and G. Pari, "Biopelet cangkang dan tandan kosong kelapa sawit sebagai sumber energi alternatif terbarukan," Undegraduate, Faculty of Forestry and Environment, IPB University, Bogor, 2014. [Online]. Available: http://repository.ipb.ac.id/handle/123456789/72654
[36] R. Sudradjat, D. Setiawan, and H. Roliadi, "Teknik Pembuatan dan Sifat Briket Arang dari Tempurung dan Kayu Tanaman Jarak Pagar (*Jatropha curcas* L.)," *Jurnal Pendidikan Hasil Hutan*, vol. 24, no. 3, pp. 227-240, 2006.

[37] E. Ningsih, K. Udyani, A. Budianto, Hamidah, and S. Afifa, "Pengaruh ukuran partikel arang dari limbah tutup botol plastik terhadap kualitas briket," *Majalah Kulit, Karet, dan Plastik*, vol. 36, no. 2, 2020, doi: 10.20543/mkkp.v36i2.6140.
[38] N. Yuliza, N. Nazir, and M. Djalal, "Pengaruh komposisi arang sekam padi dan arang kulit biji jarak pagar terhadap mutu briket arang," *Jurnal Litbang Industri*, vol. 3, no. 1, 2013, doi: 10.24960/jli.v3i1.617.21-30.
[39] F. Fatriani, S. Sunardi, and A. Arfianti, "Kadar air, kerapatan dan kadar abu wood pellet serbuk gergaji kayu galam (*Melaleuca cajuputi Roxb*) dan kayu akasia (*Acacia mangium Wild*)," *EnviroScienteae*, vol. 14, no. 1, pp. 77-81, 2018.
[40] D. Purwanto, "Pembuatan balok dan papan dari limbah industri kayu," *Indonesian Journal of Industrial Research*, vol. 5, no. 1, pp. 13-20, 2011.
[41] S. Jamilatun, "Sifat-sifat penyalaan dan pembakaran briket biomassa, briket batubara dan arang kayu," *Jurnal Rekayasa Proses*, vol. 2, no. 2, pp. 37-41, 2008.
[42] M. F. Abdillah and I. H. Siregar, "Variasi Konsentrasi Perekat Tepung Tapioka Terhadap Karakteristik Biobriket Campuran Arang Tempurung Kelapa dan Janggel Jagung," *Jurnal Teknik Mesin*, vol. 12, no. 2, pp. 89-100, 2024.
[43] M. Maryono, S. Sudding, and R. Rahmawati, "Pembuatan dan analisis mutu briket arang cangkang kelapa ditinjau dari kadar kanji," *Chemica*, vol. 14, pp. 74-83, 2013.
[44] S. Putro, M. Musabbikhah, and S. Suranto, "Variasi temperatur dan waktu karbonisasi untuk meningkatkan nilai kalor dan memperbaiki sifat proximate biomassa sebagai bahan pembuat briket yang berkualitas," in *Simposium Nas. RAPI XIV* 2015: FT UMS, pp. 282-288.
[45] N. Kongpraset, P. Wangpanich, and A. Jutilarptavorn, "Charcoal briquettes from madan wood waste as an alternative energy in Thailand," *Procedia Manuf*, vol. 30, no. 1, pp. 128-135, 2019.
[46] S. Huda, R. D. Ratnani, and L. Kurniasari, "Karakterisasi karbon akrif dari bambu ori (Bambusa arundinacea) yang diaktivasi menggunakan asam klorida (HCl)," *Inovasi Teknik Kimia*, vol. 5, no. 1, pp. 22-27, 2020.
[47] Z. Zulfan, F. Diba, D. Setyawati, Nurhaida, and E. Roslinda, "Kualitas biopelet dari limbah batang kelapa sawit pada berbagai ukuran serbuk dan jenis perekat. ," *Jurnal Hutan Lestasi*, vol. 3, no. 2, 2015.
[48] A. Syarief, M. A. Satria, and A. Nugraha, "Pengaruh ukuran partikel dan variasi komposisi briket pada campuran limbah arang kayu alaban dengan sekam padi terhadap karakteristik briket dan pembakaran," *Jurnal Mesin dan Otomotif*, vol. 1, no. 2, pp. 1-11, 2020.
[49] H. E. Malo, T. Iskandar, S. K. Wandal, and D. T. Diah, "Optimalisasi proses karbonisasi limbah plastik menggunakan teknologi pyrolisis menjadi briket arang *(briqueete charcoal)*," *Reka Buana : Jurnal Ilmiah Teknik Sipil dan Teknik Kimia*, vol. 3, no. 2, pp. 128 - 136, 2018, doi: https://doi.org/10.33366/rekabuana.v3i2.1019.
[50] M. C. Bhoumick, N. C. Sarker, M. M. Hasan, and B. K. Roy, "Conversion of waste plastic into solid briquette in combination with biomass: Bangladesh perspective," *International Advanced Research Journal In Science, Engineering and Technology*, vol. 3, no. 3, pp. 142-146, 2016.