Utilization of a Mixture of Peuyeumization Market Waste-Derived RDF (Refuse-Derived Fuel) and Coconut Shell Charcoal (CSC) into Bio-Briquettes with Coal-Calorific Value

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Abstract

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The accumulation of market waste and coconut shells poses a significant environmental challenge, necessitating effective management strategies by both local governments and academic institutions. This study explores the conversion of organic market waste into Refuse-Derived Fuel (RDF) through a dry fermentation (peuyeumization) process using 5% EM4 bio-activator over a 21-day incubation period. Concurrently, coconut shells were carbonized to produce high-carbon Coconut Shell Charcoal (CSC). Both RDF and CSC, ground to a 100-mesh particle size, were utilized to produce cylindrical bio-briquettes (7 cm height, 3.6 cm outer diameter, 1.6 cm inner diameter) using a compaction method. Various RDF:CSC ratios (0:100, 25:75, 50:50, 75:25, and 100:0) were tested with three concentrations of tapioca starch adhesive (6%, 8%, and 10%). The quality of the resulting briquettes was evaluated based on the Indonesian National Standard (SNI 01-6235-2000), assessing parameters such as moisture content, ash content, density, fixed carbon content, and calorific value. Combustion characteristics were further examined through ignition time and combustion rate measurements. The optimal briquette was produced at a 25:75 RDF:CSC ratio with 6% adhesive, achieving a weight of 30 g, density of 0.46 g/mL, fixed carbon content of 75.51%, moisture content of 5.25%, ash content of 5.91%, calorific value of 6117.38 cal/g, ignition time of 63.78 minutes, and combustion rate of 1.55 g/min. These findings indicate that the bio-briquettes meet the calorific standard of young coal, supporting their potential use as an environmentally friendly alternative fuel.

***Keywords**:*
biobriquette;
young coal;
calorific value;
waste peuyeumization;
RDF:CSC ratio.

1. Introduction

Environmental pollution caused by market waste and coconut shells requires proper management and is an urgent issue that must be addressed. With the increasing rate of population growth, the volume of waste generation continues to rise, necessitating more environmentally friendly and economically valuable waste treatment solutions. One of the emerging waste treatment technologies is *peuyeumization*[1]. *Peuyeumization* is a biological drying (biodrying) method that involves the fermentation of organic waste through anaerobic bacterial activity during an incubation period. The end product, known as RDF (Refuse-Derived Fuel), is a high-carbon dry material derived from segregated waste [2, 3]. RDF can be mixed with a binder and molded into pellets called bio-briquettes, with a calorific value ranging from 2,500–4,000 cal/g [3]. Mixing RDF with 7% tapioca binder has been reported to produce bio-briquettes with a calorific value of 4,439 cal/g [4].

Meanwhile, coconut shells represent a productive biomass that can be carbonized via pyrolysis. Coconut Shell Charcoal (CSC), when crushed and blended with a binder and compacted using appropriate technology, can be converted into high-calorific briquettes. Several studies have reported that coconut shell charcoal briquettes yield calorific values of 6,878.5 cal/g [5] and 7,652.64 cal/g with 7% binder [6].

Bio-briquettes are solid biomass-based pellets formed by compressing loose biomass materials into a denser solid form [7, 8]. They possess higher energy content than their raw materials by maximizing carbon content through proper physical, chemical, or biological processes [9, 10]. Bio-briquettes are easily combustible in the presence of oxygen, and the heat generated during combustion is defined as the fuel's calorific value. The quality standard for bio-briquettes is defined by SNI 01-6235-2000 [5], with a maximum moisture content of 8% and calorific values of 4,000–5,000 cal/g, comparable to young coal. Coal, a non-renewable fossil energy source obtained through mining, may be economically beneficial but poses serious environmental and health concerns [11, 12].

Numerous studies have been conducted on bio-briquette production from agricultural waste, such as coconut shells, corn cobs, palm kernel shells, rice husks, and others. These studies employed various carbonization methods to produce charcoal as the main briquette material, combined with binders. The state of the art of previous research is summarized in Table 1.

Table 1. State of the art in briquette research

No	Raw Material	Binder Type	Calorific Value (cal/g)	Reference
1	Palm shell + coconut shell	6% Tapioca	5,448	[13]
2	Coconut shell charcoal	Tapioca	6,878.5	[5]
3	70-mesh coconut shell charcoal	Tapioca	6,710	[14]
4	Bamboo charcoal + coconut shell charcoal	15% Tapioca	6,290.706	[15]
5	Peuyeumized market waste (RDF)	7% Tapioca	4,439	[4]

To optimize the potential of RDF-based bio-briquettes, this study formulates a mixture of RDF and CSC at various composition ratios. The objective is to produce bio-briquettes with calorific values that meet the standard of young coal while being environmentally friendly. Through this approach, environmental issues related to waste and coconut shell disposal can be effectively addressed.

2. Methods

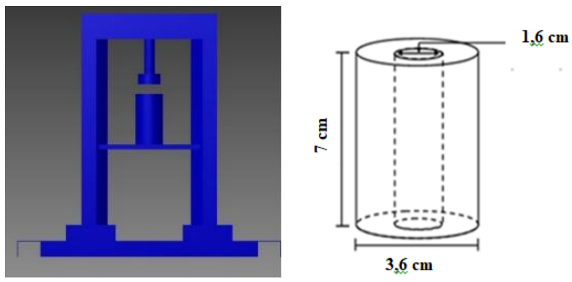
This section provides a detailed explanation of the research conducted.

2.1 Materials

The materials used in this study include coconut shell charcoal, market waste, EM4 bio-activator, tapioca flour, and plastic tarpaulin for the *peuyeumization* process.

2.2 Equipment

The equipment used includes a shredding knife, bamboo container, crusher, sieves, digital balance, oven, briquette mold, hydraulic press machine, bomb calorimeter, moisture analyzer, furnace, and desiccator. The specifications of the briquette mold and briquette specimens is shown in Figures 1.



(a) (b)

Figure 1. 3D design of the briquette mold: (a) front view; (b) dimensions of the cylindrical hollow briquette

2.3 Research Procedure

The research was conducted in two main stages: the *peuyeumization* process of market waste to produce RDF (Refuse-Derived Fuel), the production of coconut shell charcoal (CSC), and the fabrication and molding of bio-briquettes. The block diagram of the *peuyeumization* process is shown in Figure 2, while the block diagram of the bio-briquette production process from varying RDF and CSC mixtures with different binder concentrations is shown in Figure 3.

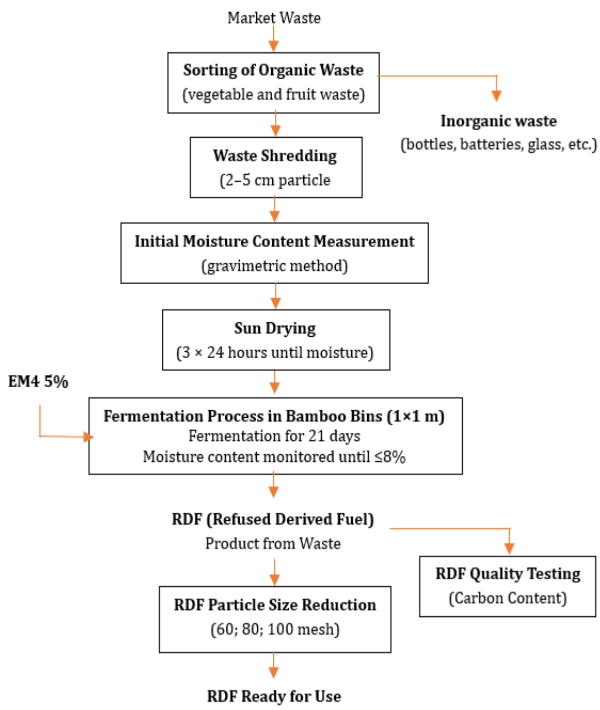


Figure 2. Flow diagram of the *peuyeumization* process for converting organic market waste into RDF

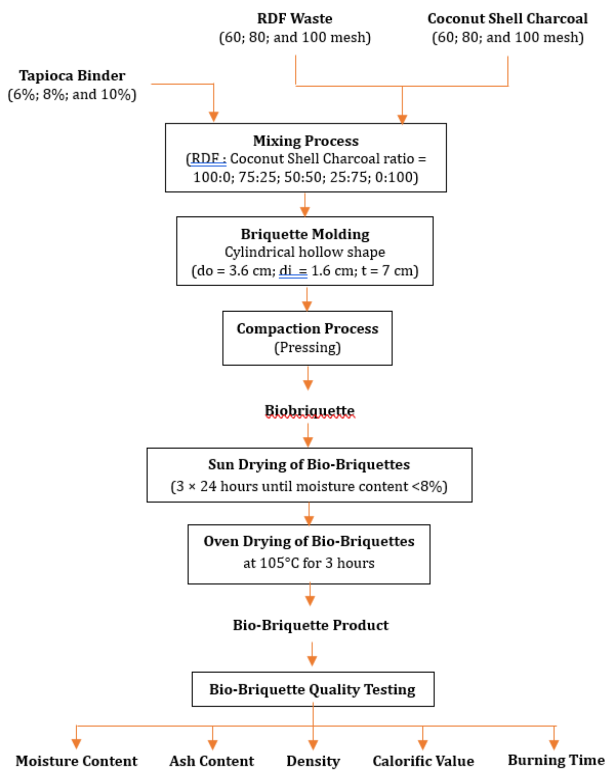


Figure 3. Flow diagram of the bio-briquette production process from mixed biomass of RDF and CSC at various binder concentrations

3. Results and Discussion

In this study, Refuse-Derived Fuel (RDF) refers to fermented organic market waste (*peuyeumisasi*), while Coconut Shell Charcoal (CSC) is charcoal derived from coconut shells through pyrolysis. One of the requirements for briquette raw materials is a carbon content greater than 77%, as stipulated by SNI 01-6235-2000. The characteristics of RDF and CSC used in this research are shown in Table 2.

Table 2. Characteristics of bio-briquette raw materials

No.	Parameter	RDF	RDF:CSC = 50:50	CSC
1	Moisture (%)	6.17	5.82	5.12
2	Ash Content (%)	10.07	7.54	5.42
3	Carbon Content (%)	68.76	70.97	76.21
4	Density (g/ml)	0.35	0.71	0.52

To evaluate the effect of RDF:CSC ratio and binder concentration on the quality of the produced bio-briquettes, measurements were conducted on moisture content, ash content, density, calorific value, carbon content, ignition time, and combustion rate using variations in RDF:CSC ratio (100:0; 75:25; 50:50; 25:75; 0:100) and binder concentrations (6%, 8%, and 10%).

3.1 Effect of RDF:CSC Ratio on Moisture Content of Bio-briquettes

Bio-briquettes were produced by mixing RDF and CSC to improve the calorific value of RDF-based briquettes, as explored in previous studies.

Figure 4 illustrates the effect of RDF:CSC ratio and binder concentration on moisture content. The moisture content of bio-briquettes is a critical quality parameter—lower values indicate better briquette quality. According to SNI 01-6235-2000, the moisture content should be below 8%. All combinations of RDF:CSC ratios and binder concentrations in this study met this standard, with values ranging from 5.01% to 6.67%.

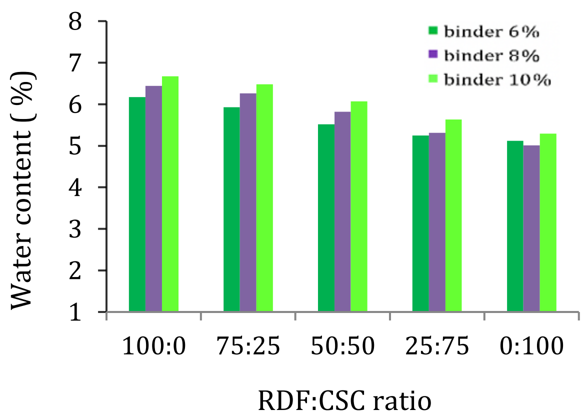


Figure 4. The effect of RDF:CSC ratio and binder concentration on moisture content.

The data suggest that increasing binder concentration does not significantly raise moisture content. Therefore, binder concentrations of 6% to 10% are considered suitable for briquette production. The best combination for low moisture and high calorific value was achieved with an RDF:CSC ratio of 25:75 and a binder concentration of 6%, resulting in 75.51% carbon content and a calorific value of 6117.38 cal/g.

3.2 Effect of RDF:CSC Ratio on Ash Content and Carbon Content of Bio-briquettes

The impact of RDF:CSC composition and binder concentration on ash content is shown in Figure 5, while for carbon content is shown in Figure 6. According to SNI 01-6235-2000, acceptable briquettes should have ash content below 8%. Ash content refers to the non-combustible residue left after burning and is influenced by raw material properties and binder type.

The results show that ash content met the standard only for RDF:CSC ratios of 50:50, 25:75, and 0:100 across all binder concentrations. Ratios of 100:0 and 75:25 exceeded 8%, likely due to a higher proportion of RDF. This indicates that incomplete fermentation during *peuyeumisasi* may produce RDF with lower carbon content (66.81–70.94%), resulting in higher ash content.

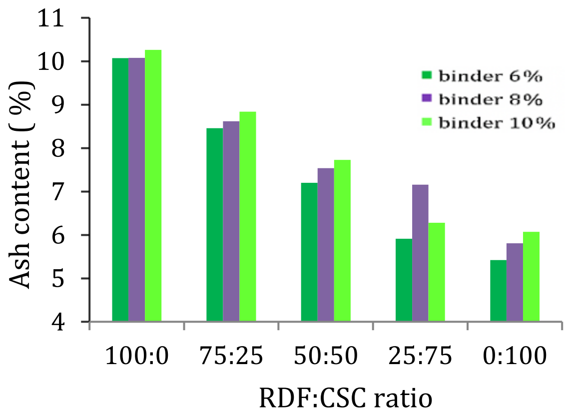


Figure 5. The impact of RDF:CSC composition and binder concentration on ash content

The best results for both carbon and ash content were achieved with RDF:CSC ratios of 25:75 and 0:100 using 6–8% binder. These findings suggest that a lower RDF proportion improves briquette quality by reducing ash content and increasing carbon concentration.

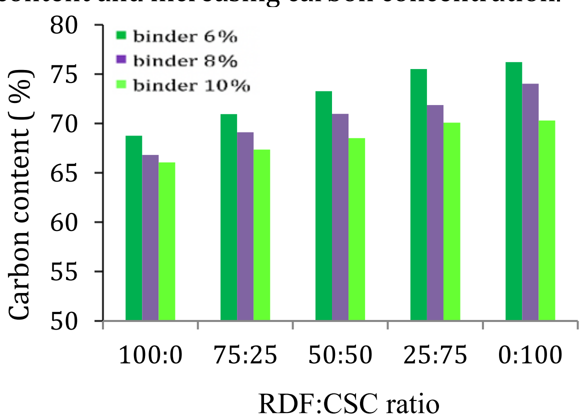


Figure 6. The impact of RDF:CSC composition and binder concentration on carbon content

3.3 Effect of RDF:CSC Ratio on Calorific Value and Ignition Characteristics

The calorific value of the bio-briquettes was measured using a bomb calorimeter. Ignition tests were carried out by lighting a cylindrical briquette specimen (3.6 × 7 × 1.6 cm) and measuring the time until complete combustion. The effect of RDF:CSC ratio on calorific value is shown in Figure 7.

Figure 7 shows that the highest calorific values were obtained for RDF:CSC ratios of 25:75 and 0:100, confirming that higher CSC content leads to greater energy output. However, considering the goal of valorizing market waste, the optimal mix is RDF:CSC = 25:75 with 6% binder, achieving 6117.38 cal/g.

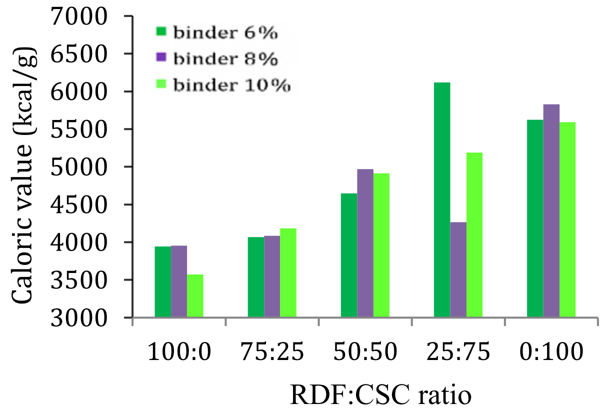


Figure 7. The effect of RDF:CSC ratio on caloric value

The effect of RDF:CSC ratio on time ignitition is shown in Figure 8. Figure 8 indicates the longest burn time (63.78 minutes) for the same ratio of RDF:CSC 25:75 with 6% binder level, suggesting good ignition and prolonged combustion.

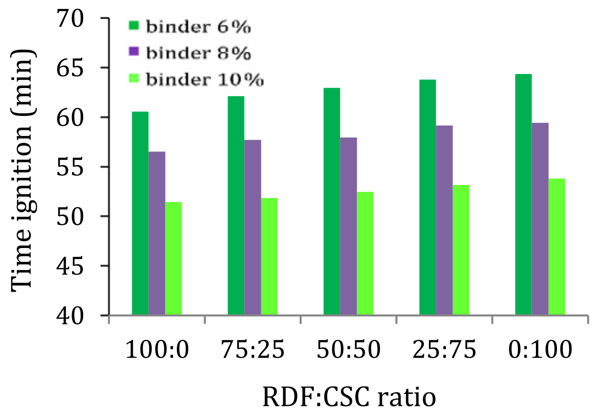


Figure 8. The effect of RDF:CSC ratio on time ignitition

The effect of RDF:CSC ratio on combustion rate is shown in Figure 9. Figure 9 illustrates the bio-briquette produced under optimal conditions (RDF:CSC = 25:75, 6% binder) achieved a combustion rate of 1.55 g/min and met all SNI criteria: moisture content <8%, ash content <8%, carbon content >76%, and calorific value >6000 cal/g. These results classify the product as a high-quality bio-briquette comparable to low-rank coal.

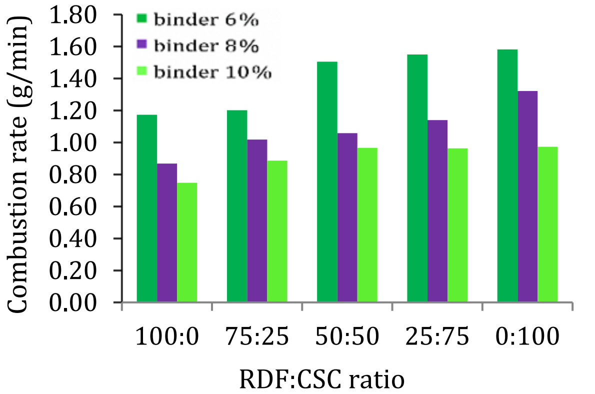


Figure 9. The effect of RDF:CSC ratio on combustion rate

4. Conclusion

Based on the research conducted, it can be concluded that organic market waste has the potential to be converted into Refuse-Derived Fuel (RDF). The carbon content obtained from RDF was 68.76%, from Coconut Shell Charcoal (CSC) was 76.21%, and from the RDF-CSC mixture was 70.97%. Although the characteristics of RDF and CSC do not fully meet the requirements of SNI 01-6235-2000, the resulting calorific values qualify within the range of low-rank coal (>2000–4000 cal/g).

The amount of binder significantly affects the moisture content of the bio-briquettes. As the binder concentration increases, moisture content, ash content, and density tend to increase, while the calorific value, ignition duration, and combustion rate decrease.

The produced briquettes are cylindrical with a central hole, having dimensions of 7 cm in height, 3.6 cm in outer diameter, and 1.6 cm in inner diameter. The optimal bio-briquette was obtained at an RDF:CSC ratio of 25:75 with a binder concentration of 6%, yielding a briquette weight of 30 g, a density of 0.46 g/ml, carbon content of 75.51%, moisture content of 5.25%, ash content of 5.91%, a calorific value of 6117.38 cal/g, an ignition time of 63.78 minutes, and a combustion rate of 1.55 g/min.

The combination of RDF and CSC biomass has the potential to serve as an alternative fuel material comparable to low-rank coal.

References

[1] Fitrianingrum, Y.& Surjasatyo, A., 2023. *Techno-economic analysis of co-firing waste refused derived fuel (RDF) in coal-fired power plant.* International Journal of Engineering Business and Social Science, Vol. 1, No. 05, pp. 372-386.

[2] Sarquah, K. *et al.*, 2022. *Characterization of municipal solid waste and assessment of its potential for refuse-derived fuel (RDF) valorization.* Energies, Vol. 16, No. 1, p. 200.

[3] Rizkiantika, N. & Jundika, P., 2023. *Karakteristik refuse derived fuel (RDF) pada tempat pembuangan sampah (TPS) Fakultas Teknik Universitas Sultan Ageng Tirtayasa*. Fakultas Teknik Universitas Sultan Ageng Tirtayasa.

[4] Iskandar, N., Nugroho, S., & Feliyana, M. F., 2019. *Uji kualitas produk briket arang tempurung kelapa berdasarkan standar mutu SNI.* Jurnal Ilmiah Momentum, Vol. 15, No. 2.

[5] Amin, A. Z., Pramono, P., & Sunyoto, S., 2017. *Pengaruh variasi jumlah perekat tepung tapioka terhadap karakteristik briket arang tempurung kelapa.* Sainteknol: Jurnal Sains dan Teknologi, Vol. 15, No. 2, pp. 111-118.

[6] Milya, C., Kurniawan, E., Hakim, L., Dewi, R., & Muhammad, M., 2023. *Pembuatan briket cangkang kelapa sawit menggunakan variasi jenis dan persentase perekat tepung tapioka dan tepung beras.* Chemical Engineering Journal Storage (CEJS), Vol. 3, No. 4, pp. 505-516.

[7] Adeleke, A. A. *et al.*, 2023. *A review on biomass briquettes as alternative and renewable fuels*. in *2023 2nd International Conference on Multidisciplinary Engineering and Applied Science (ICMEAS)*: IEEE.

[8] Navalta, C. J. L. G., Banaag, K. G. C., Von Adrian, O. R., Go, A. W., Cabatingan, L. K., & Ju, Y.-H., 2020. *Solid fuel from co-briquetting of sugarcane bagasse and rice bran.* Renewable Energy, Vol. 147, pp. 1941-1958.

[9] Demirbaş, A., 2001. *Biomass resource facilities and biomass conversion processing for fuels and chemicals.* Energy Conversion and Management, Vol. 42, No. 11, pp. 1357-1378.

[10] Sanchez, P. D. C., Aspe, M. M. T., & Sindol, K. N., 2022. *An overview on the production of bio-briquettes from agricultural wastes: Methods, processes, and quality.* Journal of Agricultural and Food Engineering, Vol. 1, p. 0036.

[11] Nurhamida, N., Rusdianasari, R., & Zamhari, M., 2023. *Pembuatan briket komposit cangkang sawit dan tempurung kelapa dengan variasi perekat tepung tapioka sebagai bahan bakar alternatif.* Jurnal Teknologi, Vol. 23, No. 2, pp. 106-112.

[12] Habib, M. A.& Khan, R., 2021. *Environmental impacts of coal-mining and coal-fired power-plant activities in a developing country with global context.* Spatial modeling and assessment of environmental contaminants: risk assessment and remediation, pp. 421-493.

[13] Jaswella, R. W. A., Sudding, S., & Ramdani, R., 2022. *Pengaruh ukuran partikel terhadap kualitas briket arang tempurung kelapa.* Chem. J. Ilm. Kim. dan Pendidik. Kim, Vol. 23, No. 1, p. 7.

[14] Wardani, W. I., 2023. *Pengaruh jumlah perekat tepung tapioka terhadap campuran briket arang bambu dan arang tempurung kelapa.* JURNAL PROTEKSI: Jurnal Lingkungan Berkelanjutan, Vol. 3, No. 1, pp. 1-10.

[15] Saptutyningsih, E.& Kamiel, B. P., 2019. *Pemanfaatan sampah organik untuk pembuatan briket arang dalam meningkatkan kapasitas ekonomi masyarakat*. in Prosiding Seminar Nasional Program Pengabdian Masyarakat.