

Optimization of Hole Variations in Honeycomb Charcoal Briquettes from Corn Waste for Enhanced Combustion Efficiency

Agustinus^{1✉}, Rombe Allo², Enos Tambing³, Selyus Rantepulung⁴,
Mickael Ruben Kaiway⁵

^{1, 2, 3, 4, 5} Department of Mechanical Engineering, Faculty of Engineering, Universitas Cenderawasih, Indonesia

✉ Corresponding Author : Agustinus (e-mail: agustinus@ftuncen.ac.id)

Article Information	ABSTRACT
Article History Received : February 14, 2025 Revised : March 12, 2025 Published : April 04, 2025	This study investigates the viability of corn byproducts as an alternative energy source via conversion into honeycomb charcoal briquettes. Discarded corn byproducts are transformed into briquettes to mitigate fossil fuel reliance, particularly in the Arso region. This research aims to assess the energy output of briquettes with varying perforation configurations (4, 8, and 12 holes) and a diameter of 5 inches. The Water Boiling Test (WBT) method, utilizing temperature measurement tools such as a K-type thermocouple and an infrared thermometer, was utilized for performance assessment. One liter of water was heated to its boiling point during the experiment. The results indicated that the 8-hole briquette had the quickest boiling time of 25 minutes, with a fuel consumption rate of 2.8×10^{-3} kg/s. In comparison, the 4 and 12-hole briquettes required 35 minutes, with an average fuel usage of 2.86 g/s. The maximum combustion temperature for the 4-hole briquette was measured at 589°C, while the 12-hole briquette reached a mere 427°C. These outcomes demonstrate that the 8-hole briquette possesses superior efficiency. A decrease in hole quantity adversely affects boiling speed, while an increase in holes results in greater fuel consumption. These findings highlight the importance of optimized briquette design in improving biomass fuel efficiency.
Keywords: <i>Corn waste utilization; Honeycomb charcoal briquettes; Biomass fuel; Briquette combustion efficiency; Biomass carbonization.</i>	

INTRODUCTION

The global exigency for sustainable and renewable energy sources has escalated due to the escalating depletion of fossil fuels and the mounting environmental apprehensions correlated with their utilization (Mutezo & Mulopo, 2021; Zastempowski, 2023). Biomass energy has surfaced as a promising alternative, presenting a renewable and ecologically sound solution for energy production (Janota et al. 2023). Among various biomass constituents, agricultural waste signifies a predominantly unexploited resource that can be adeptly transformed into solid fuel (Jaffali et al, 2024; Saha et al, 2024). Corn cobs, a byproduct of maize cultivation, are frequently discarded or incinerated as refuse, contributing to environmental degradation and inefficient resource employment (Elyson et al, 2024; Sivaranjanee et al, 2024). By repurposing this agricultural byproduct into charcoal briquettes, it is feasible to furnish an alternative fuel source that is both sustainable and economically practicable.

Keerom Regency, situated in Papua Province, Indonesia, has been actively engaged in extensive maize cultivation, encompassing approximately 1,000 hectares. The region's

considerable corn production has resulted in the accumulation of substantial volumes of corn cob byproducts (Figure 1). Despite its potential for energy conversion, this byproduct remains predominantly underutilized and is frequently discarded via open combustion, which exacerbates air pollution and greenhouse gas emissions. The development of an effective methodology to transform corn cobs into biomass briquettes offers an opportunity to tackle waste management issues while fostering renewable energy solutions (Pramesti et al, 2021). This investigation concentrates on the optimization of honeycomb charcoal briquettes derived from corn cob byproducts to enhance their combustion efficacy.



Figure 1. Corn cob waste

Honeycomb charcoal briquettes have garnered significant attention owing to their enhanced combustion characteristics and regulated burning rates. The structural architecture of these briquettes, particularly the quantity of apertures integrated into their design, profoundly impacts their efficacy in terms of fuel efficiency, thermal distribution, and combustion duration (Asad et al, 2022). The airflow dynamics engendered by the aperture configurations play an essential role in ascertaining the combustion attributes of the briquettes. Nevertheless, the optimal aperture configuration for maximizing energy efficiency remains a domain of ongoing inquiry (Li et al, 2024). Divergences in the quantity of apertures may result in varying combustion efficiencies, fuel consumption metrics, and thermal outputs. Comprehending these interrelationships is pivotal for engineering biomass briquettes that optimize energy yield while minimizing resource depletion (Capitán et al, 2021; Krinski & Mariani, 2020).

The principal aim of this investigation is to assess the influence of various orifice configurations (4, 8, and 12 orifices) on the combustion efficacy of honeycomb charcoal briquettes fabricated from corn cob by-products. Specifically, this inquiry endeavors to ascertain the optimal orifice arrangement by scrutinizing energy yield, fuel utilization, and thermal distribution. The project adopts the Water Boiling Test (WBT) as a fixed guideline to determine the thermal capability of the briquettes (Oldham et al, 2024). By methodically contrasting the performance of briquettes with disparate orifice configurations, this study aspires to pinpoint the most efficacious design for enhancing energy efficiency and practical applicability.

The combustion mechanism in biomass briquettes encompasses intricate thermochemical transformations, comprising pyrolysis, oxidation, and thermal transfer. Pyrolysis denotes the thermal disintegration of biomass in the absence of oxygen, culminating in the generation of volatile gases and char (Ballice, 2024). This phase is succeeded by combustion, during which the volatile gases engage with oxygen to liberate thermal energy. The success of these approaches is determined by aspects including the biomass structure, moisture levels, and ventilation. Adequate airflow regulation is imperative to guarantee complete combustion and optimal thermal retention. The quantity of apertures in honeycomb briquettes directly influences these parameters, rendering it a pivotal design consideration in augmenting fuel efficiency (Asen et al, 2024; Asad et al, 2022).

The advancement of effective biomass briquettes encompasses considerable ecological and socioeconomic advantages. By transforming agricultural refuse into a feasible energy resource, briquette fabrication contributes to waste minimization and mitigates dependence on

deforestation-derived fuel sources such as firewood (Chiang et al, 2023; Kiang 2018). The utilization of biomass briquettes also results in diminished emissions in comparison to conventional wood-burning stoves, rendering them a more pristine alternative for residential and industrial heating applications. Moreover, the application of biomass briquettes might strengthen energy resilience, especially in remote and off-grid regions where standard fuels like kerosene and LPG are challenging to procure (Martens et al, 2021).

From an economic perspective, briquette manufacturing offers prospects for micro-scale enterprises and regional communities. The establishment of briquette fabrication facilities can generate employment opportunities, create supplementary income streams for agricultural producers, and endorse sustainable development endeavors (Latief & Zhang, 2024). In areas where agricultural residue is plentiful, advocating for the utilization of biomass briquettes can invigorate local economies while addressing energy deficiency challenges (Arévalo et al, 2019). Moreover, incorporating briquette production into circular economy frameworks can augment resource efficiency and contribute to enduring sustainability (Martin, 2020).

This investigation enhances the expanding corpus of knowledge regarding biomass fuel technology by furnishing empirical evidence concerning the influence of aperture variations on combustion efficacy (Uzun, 2023). The results of this inquiry possess pragmatic ramifications for the design and production of high-performance briquettes customized for domestic and industrial utilizations. By determining the optimal aperture configuration, this research aspires to augment the functionality of honeycomb briquettes and broaden their adoption as a viable alternative energy source (Sanka et al, 2023; Yirijor & Bere, 2024). Furthermore, the insights derived from this investigation can guide policy formulations pertinent to the advancement of renewable energy and waste management methodologies.

In juxtaposition to traditional solid fuels, honeycomb charcoal briquettes proffer numerous advantages, encompassing regulated combustion, diminished smoke emissions, and augmented energy efficiency (Li et al, 2023; Martens et al, 2021). Dissimilar to conventional charcoal, which combusts erratically and generates substantial ash residue, honeycomb briquettes are engineered for consistent thermal distribution and extended combustion duration. The outcomes of this investigation are anticipated to bolster the feasibility of briquettes as a sustainable energy alternative, particularly in locales where biomass waste is abundantly accessible. While this inquiry offers significant insights into the optimization of biomass briquettes, particular constraints should be recognized. The study predominantly emphasizes combustion efficiency without thorough examination of emissions and environmental ramifications. Subsequent investigations should incorporate exhaustive emission evaluations to assess the overarching sustainability of biomass briquettes. Furthermore, probing alternative binding agents, varying orifice diameters, and diverse biomass compositions could further augment briquette efficacy (Vinay Kumar, 2020).

The escalating exigency for sustainable and economical energy alternatives accentuates the significance of cultivating effective biomass fuel substitutes. This investigation aspires to refine the configuration of honeycomb charcoal briquettes by scrutinizing the implications of aperture variations on combustion efficacy. By assessing fuel utilization, boiling duration, and thermal productivity, this inquiry endeavors to furnish pragmatic suggestions for enhancing briquette technology. The projected consequences possess the capacity to facilitate the extensive acceptance of biomass briquettes as a renewable energy reservoir, bolstering global initiatives to transition towards cleaner and more sustainable energy frameworks. Prospective advancements in briquette technology will serve a pivotal function in augmenting energy accessibility, fostering environmental sustainability, and stimulating economic advancement.

RESEARCH METHODS

Materials and Equipment

This research employs corn cobs as the main substrate for producing honeycomb charcoal briquettes, as illustrated in Figure 1. The carbonization procedure was executed utilizing an adapted gas cylinder reactor featuring a closed system. The briquettes were fabricated using a hydraulic press apparatus outfitted with molds of 5-inch diameter, incorporating variations of 4, 8, and 12 minute apertures, each possessing a diameter of 12 mm. The combustion efficacy of the briquettes was evaluated utilizing a standardized briquette stove accessible in the marketplace. A bomb calorimeter was utilized to ascertain the calorific value, while a thermocouple was engaged to document temperature fluctuations. A chronometer was employed to gauge boiling duration, and a digital balance was utilized to ascertain fuel consumption.

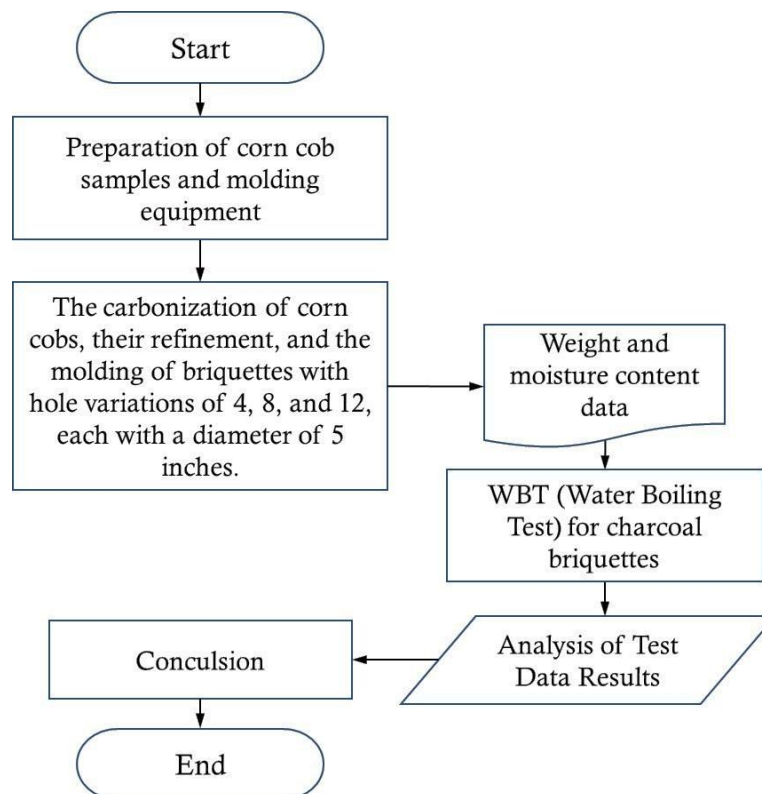


Figure 2. Research Flowchart

Preparation of Briquettes

The formulation of the briquettes adhered to the following systematic procedures: 1) The maize cobs were fragmented into diminutive segments to promote desiccation; 2) The fragmented segments were subjected to solar desiccation to diminish moisture content and expedite the carbonization process; 3) The desiccated maize cobs were positioned within the reactor tube in a systematic configuration to guarantee uniform carbonization; 4) To commence the carbonization process, kerosene was utilized as an ignition enhancer, and the reactor was sealed to restrict oxygen supply, thereby facilitating pyrolysis; 5) Upon the completion of the carbonization process, the resultant charcoal was cooled and pulverized into fine particulates using a grinder; 6) The pulverized charcoal was amalgamated with a binder comprising 5% tapioca starch, which had been preheated to create a gel-like adhesive; 7) The amalgamation was agitated comprehensively to ensure consistent binding and subsequently shaped into briquettes utilizing a hydraulic pressing apparatus; dan 8) The shaped briquettes were subjected to oven drying to diminish residual moisture content prior to further examination.

Combustion Performance Testing

The combustion efficacy of the briquettes was assessed through the application of the Water Boiling Test (WBT) methodology, which encompassed the following procedures: 1) Each briquette specimen (4-hole, 8-hole, and 12-hole variants) was examined individually employing a standardized briquette stove; 2) A kettle containing 1 liter of water was positioned on the stove, and the briquette was ignited; 3) The duration required for the water to attain 100°C was documented using a chronometer; 4) The mass of the briquette prior to and subsequent to combustion was quantified utilizing a digital scale to ascertain fuel consumption; 5) The temperature of the flame was observed employing a thermocouple sensor; dan 6) The identical procedure was reiterated for each briquette variant to ensure consistency and veracity of the data.



Figure 2. Combustion performance testing

Data Analysis

The amassed information encompassed: 1) Boiling Duration: The period required for the water to attain 100°C; 2) Fuel Utilization: The weight of the briquette incinerated during the boiling procedure; and 3) Thermal Transfer Efficacy: Computed utilizing standardized thermodynamic formulas to ascertain the energy output of each briquette variant.

The findings were scrutinized to ascertain the most effective briquette arrangement predicated on fuel utilization, boiling duration, and thermal efficiency.

RESULTS AND DISCUSSION

Fuel Consumption Analysis

The energy expenditure rate was a pivotal parameter in evaluating the efficacy of the honeycomb charcoal briquettes. The incineration process was scrutinized by quantifying the mass of fuel prior to and subsequent to combustion. The findings demonstrated that fuel expenditure fluctuated contingent upon the quantity of apertures in the briquettes. The 8-aperture briquette manifested the minimal fuel expenditure rate of 2.8×10^{-3} kg/s, whereas the 4-aperture and 12-aperture variants utilized fuel at an average rate of 2.86 g/s.

The elevated fuel utilization in the 12-hole briquette could be ascribed to augmented airflow, which resulted in an accelerated combustion rate and elevated fuel depletion. In contrast, the 4-hole briquette, notwithstanding possessing a more gradual combustion rate, necessitated a greater duration to attain boiling temperature, culminating in an increased overall fuel consumption. The 8-hole briquette exhibited an optimal equilibrium between airflow and combustion efficacy, rendering it the most energy-efficient variant.

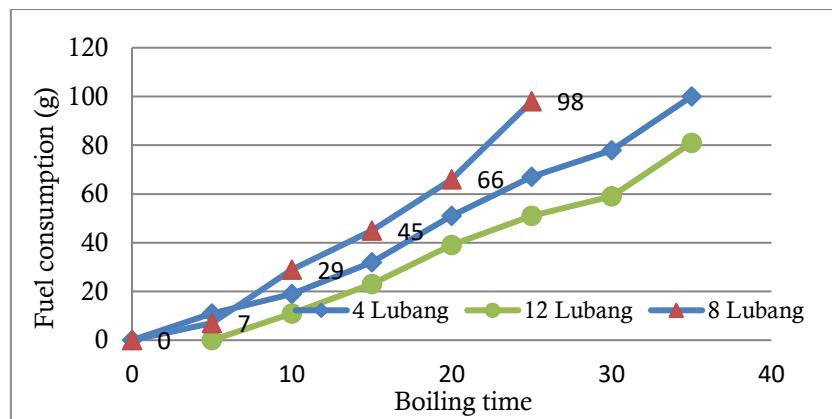


Figure 3. Fuel consumption

Water Boiling Test (WBT) Analysis

Employing the Water Boiling Test (WBT), we evaluated how well the briquettes performed thermally. Briquettes with 4 holes, 8 holes, and 12 holes had boiling durations of 35 minutes, 25 minutes, and 35 minutes, in that sequence. The 8-hole briquette demonstrated the most rapid boiling duration, indicating that it facilitated optimal heat transmission conditions.

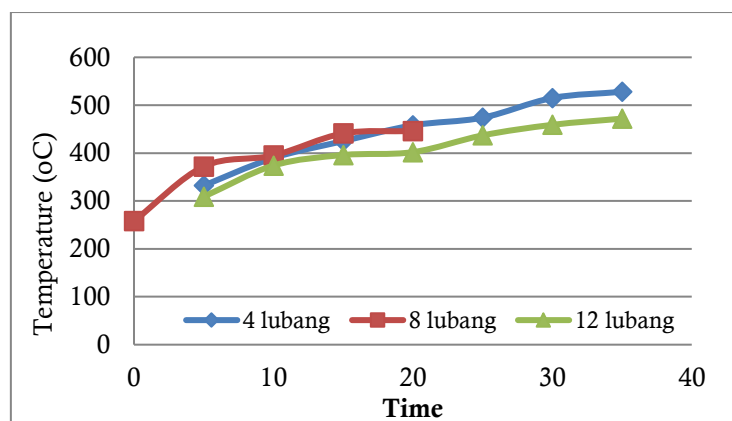


Figure 4. WBT testing of wasp nest briquettes

The extended boiling duration in the 4-hole briquette was presumably attributable to restricted aeration, culminating in insufficient combustion and suboptimal thermal generation. Conversely, the 12-hole briquette experienced augmented airflow but was impeded by excessive thermal dissipation, resulting in energy depletion. The 8-hole arrangement afforded adequate oxygen for combustion whilst preserving a stable thermal distribution, thereby augmenting energy efficiency.

Temperature Distribution and Heat Transfer

Temperature examination disclosed that the apex combustion temperature was documented in the 4-hole briquette, attaining 589°C, whereas the 12-hole briquette achieved a maximum temperature of 427°C. The 8-hole briquette, notwithstanding possessing a lower peak temperature than the 4-hole briquette, sustained a more uniform thermal output, which augmented its exceptional boiling efficacy.

The elevated thermal conditions discerned in the 4-hole briquette were an outcome of extended combustion, yet the constrained oxygen availability diminished overall efficacy. The 12-hole briquette, conversely, demonstrated inferior peak temperatures attributable to excessive aeration, which resulted in swift thermal dissipation. The 8-hole briquette refined the equilibrium

between thermal retention and regulated combustion, rendering it the most efficacious in empirical applications.

Effect of Hole Variations on Combustion Efficiency

The quantity of apertures in the briquettes substantially affected combustion dynamics. The 4-aperture briquette exhibited a diminished burning rate, resulting in incomplete combustion and elevated fuel consumption. The 12-aperture briquette ignited more rapidly, yet the superfluous airflow diminished thermal efficiency. The 8-aperture briquette sustained consistent combustion with effective heat transfer, establishing it as the most advantageous configuration.

Prior investigations concerning honeycomb briquettes have underscored the significance of aeration regulation in combustion efficacy. In this inquiry, the octadic aperture arrangement demonstrated to be the most efficacious, corroborating conclusions that moderate air permeability improves ignition efficiency without undue thermal dissipation.

Implications for Sustainable Energy Use

The findings of this investigation possess considerable ramifications for sustainable energy consumption in biomass fuel utilizations. The enhanced 8-hole honeycomb briquette offers an energy-conserving substitute to traditional fuels, diminishing reliance on fossil fuels and alleviating ecological repercussions linked to biomass waste management. By transforming corn byproducts into effective fuel, this inquiry advances circular economy tenets and sustainable energy resolutions.

Additionally, the results underscore the possibility for additional refinement of briquette configurations. Subsequent investigations could examine alterations in orifice dimensions, briquette circumference, and adhesive formulation to augment functionality further. Integrating sophisticated combustion modeling methodologies could also yield more profound understanding of thermal dispersion and efficacy advancements.

Comparison with Conventional Fuels

In comparison to conventional charcoal or wood-derived fuel sources, honeycomb briquettes present numerous benefits, encompassing regulated combustion rates, diminished smoke emissions, and augmented energy efficiency. The 8-hole briquette, specifically, exhibited exceptional performance concerning combustion stability and fuel economy. This observation corresponds with antecedent investigations on biomass briquettes, which underscores the significance of structural design in augmenting thermal efficiency.

Furthermore, the fiscal advantages of employing agricultural refuse for energy generation are significant. By reassigning maize husks, communities can diminish waste disposal expenditures and establish supplementary revenue streams through briquette fabrication. The extensibility of this methodology implies its capacity for extensive implementation in agrarian and peri-urban regions where accessibility to traditional fuels is constrained.

Limitations and Future Research Directions

While this examination furnished significant revelations regarding the influence of aperture fluctuations on briquette efficacy, several constraints ought to be recognized. The investigation concentrated predominantly on combustion efficiency devoid of thorough analysis of effluents and ecological repercussions. Subsequent inquiries should integrate emission assessments to appraise the environmental sustainability of honeycomb briquettes in a comprehensive manner.

Furthermore, investigating the influence of various biomass formulations, alternative adhesive substances, and mechanical compaction techniques could further augment briquette excellence. The application of computational fluid dynamics (CFD) simulations may also furnish

a more comprehensive comprehension of airflow dynamics and combustion attributes, resulting in enhanced briquette configurations.

CONCLUSION

This investigation demonstrates that the number of perforations in honeycomb charcoal briquettes significantly influences combustion efficiency, fuel consumption, and boiling duration. The 8-hole briquette exhibited the best performance, achieving the shortest boiling time (25 minutes), optimal fuel consumption (2.8×10^{-3} kg/s), and uniform heat distribution. The results indicate that proper airflow regulation is crucial for optimizing energy efficiency in biomass fuel applications.

Furthermore, this study asserts that briquettes derived from corn residues can be applied as a sustainable energy resource, facilitating advancements in renewable energy and waste management strategies. However, the current application of these briquettes remains limited to meeting household energy demands as a substitute for gas and kerosene fuels. By refining briquette structure, future investigations can further enhance the feasibility and efficiency of biomass fuel, contributing to global efforts toward sustainable energy transformation.

REFERENCES

- Arévalo, J., Quispe, G., & Raymundo, C. (2019). Sustainable energy model for the production of biomass briquettes based on rice husks in peruvian low-income agricultural areas. Dalam D. Enescu (Ed.), *Green Energy Advances*. IntechOpen. <https://doi.org/10.5772/intechopen.81817>
- Asad, U., Divekar, P. S., & Zheng, M. (2022). High efficiency ethanol–diesel dual-fuel combustion: Analyses of performance, emissions and thermal efficiency over the engine load range. *Fuel*, 310, 122397. <https://doi.org/10.1016/j.fuel.2021.122397>
- Asen, B., Akombo, P. M., Annune, P. A., & Nyakuma, B. B. (2024). Assessing nutrient retention, cost-effectiveness and fuel efficiency of charcoal briquettes for fish smoking in nigeria. *The 3rd International Electronic Conference on Processes*, 77. <https://doi.org/10.3390/engproc2024067077>
- Ballice, L. (2024). *Pyrolysis properties of cellulose and lignins isolated from different turkish biomass: Evolved gas analysis in pyrolysis of biomass and combustion of char via tg-ftir*. <https://doi.org/10.21203/rs.3.rs-3934708/v1>
- Capitán, T., Alpizar, F., Madrigal-Ballester, R., & Pattanayak, S. K. (2021). Time-varying pricing may increase total electricity consumption: Evidence from Costa Rica. *Resource and Energy Economics*, 66, 101264. <https://doi.org/10.1016/j.reseneeco.2021.101264>
- Chiang, L. E., Castro, F. A., & Molina, F. A. (2023). Socioeconomic and environmental benefits of substituting firewood with charcoal briquettes produced from biomass residues in the Forestry Belt in Chile. *Energy for Sustainable Development*, 77, 101341. <https://doi.org/10.1016/j.esd.2023.101341>
- Elyson, S., Jonathan, C., Kudakwashe, C., & Loice, C. (2024). *Evaluation of wheatstraw, sawdust, banana fronds, maize cobs and cotton hulls substrate combinations for Pleurotus ostreatus cultivation*. <https://doi.org/10.21203/rs.3.rs-4831136/v1>
- Jaffali, C., Khadhri, A., & Aschi-Smiti, S. (2024). Domestication of pleurotus eryngii mycelium and primordia formation on various agricultural residues. *Waste and Biomass Valorization*, 15(2), 1113–1122. <https://doi.org/10.1007/s12649-023-02239-9>
- Janota, L., Vávrová, K., & Bízková, R. (2023). Methodology for strengthening energy resilience with SMART solution approach of rural areas: Local production of alternative biomass

- fuel within renewable energy community. *Energy Reports*, 10, 1211–1227. <https://doi.org/10.1016/j.egy.2023.07.057>
- Kiang, Y.-H. (2018). Database and analysis of fuel properties, fossil fuel, biomass, refuse-derived fuel, waste, biosludge and biocarbon. Dalam *Fuel Property Estimation and Combustion Process Characterization* (hlm. 67–169). Elsevier. <https://doi.org/10.1016/B978-0-12-813473-3.00004-0>
- Krinski, I., & Mariani, V. (2020). Briquettes production from lignocellulosic waste for energy purposes as an alternative fuel. *Proceedings of the 18th Brazilian Congress of Thermal Sciences and Engineering*. 18th Brazilian Congress of Thermal Sciences and Engineering. <https://doi.org/10.26678/ABCM.ENCIT2020.CIT20-0450>
- Latief, R., & Zhang, L. (2024). Nexus between government agricultural expenditures and agricultural credit: The role of sustainable agricultural growth and sustainable agricultural income. *Sustainable Development*, 32(4), 3344–3355. <https://doi.org/10.1002/sd.2853>
- Li, P., Cheng, P., Wang, G., Wang, F., Cheong, K.-P., Liu, Z., & Mi, J. (2023). Mild combustion of solid fuels: Its definition, establishment, characteristics, and emissions. *Energy & Fuels*, 37(14), 9998–10022. <https://doi.org/10.1021/acs.energyfuels.3c01097>
- Li, S., Lin, H.-C., & Hsu, C. W. (2024). High-efficiency high-numerical-aperture metalens designed by maximizing the efficiency limit. *Optica*, 11(4), 454. <https://doi.org/10.1364/OPTICA.514907>
- Martens, P., Czech, H., Tissari, J., Ihalainen, M., Suhonen, H., Sklorz, M., Jokiniemi, J., Sippula, O., & Zimmermann, R. (2021). Emissions of gases and volatile organic compounds from residential heating: A comparison of brown coal briquettes and logwood combustion. *Energy & Fuels*, 35(17), 14010–14022. <https://doi.org/10.1021/acs.energyfuels.1c01667>
- Martin, M. (2020). Industrial symbiosis networks: Application of the circular economy for resource efficiency. Dalam M. Brandão, D. Lazarevic, & G. Finnveden (Ed.), *Handbook of the Circular Economy*. Edward Elgar Publishing. <https://doi.org/10.4337/9781788972727.00012>
- Mutezo, G., & Mulopo, J. (2021). A review of Africa's transition from fossil fuels to renewable energy using circular economy principles. *Renewable and Sustainable Energy Reviews*, 137, 110609. <https://doi.org/10.1016/j.rser.2020.110609>
- Oldham, N., Tippet, M., Durtschi, B., Worrall, M., Barney, J., Horman, K., Kamerman, D., & Prince, A. (2024). *Boiling-water reactor testing capability in the advanced test reactor* (No. INL/RPT--24-77958-Rev000, 2373120; hlm. INL/RPT--24-77958-Rev000, 2373120). <https://doi.org/10.2172/2373120>
- Pramesti, Y. S., Kristanto, B., & Pratama, H. (2021). Processing of corn cobs waste into briquettes using cob press machine capacity 40 kg / hour. *Procedia of Engineering and Life Science*, 1(1). <https://doi.org/10.21070/pels.v1i1.852>
- Saha, N., Klinger, J., Islam, M. T., Reza, T., Egan, K., & Yancey, N. (2024). Experimental investigation and characterization of the thermal insulating behavior of municipal solid waste and its constituents. *Waste and Biomass Valorization*. <https://doi.org/10.1007/s12649-024-02684-0>
- Sanka, P. M., Germain, O., Khalifa, L., Komakech, H., & Magambo, H. (2024). Production of low emission briquettes from carbonized faecal sludge as an alternative source of cooking energy. *Energy, Sustainability and Society*, 14(1), 14. <https://doi.org/10.1186/s13705-024-00449-0>
- Sivaranjane, R., Kumar, P. S., & Rangasamy, G. (2024). Hydrothermally produced activated carbon spheres from discarded maize cobs for efficient removal of rose bengal dye from

- water environment. *Desalination and Water Treatment*, 317, 100123. <https://doi.org/10.1016/j.dwt.2024.100123>
- Uzun, Z. Y. (2023). Investigation of fuel properties of hydrochars obtained from pomegranate peel: Characterization and combustion kinetic. *Biomass Conversion and Biorefinery*. <https://doi.org/10.1007/s13399-023-03840-7>
- Vinay Kumar, D. (2020). Performance and emission characteristics of gasoline-ethanol blends on pfi-si engine. *JOURNAL OF MECHANICS OF CONTINUA AND MATHEMATICAL SCIENCES*, 15(7). <https://doi.org/10.26782/jmcms.2020.07.00051>
- Yirijor, J., & Bere, A. A. T. (2024). Production and characterization of coconut shell charcoal-based bio-briquettes as an alternative energy source for rural communities. *Heliyon*, 10(16), e35717. <https://doi.org/10.1016/j.heliyon.2024.e35717>
- Zastempowski, M. (2023). Analysis and modeling of innovation factors to replace fossil fuels with renewable energy sources—Evidence from European Union enterprises. *Renewable and Sustainable Energy Reviews*, 178, 113262. <https://doi.org/10.1016/j.rser.2023.113262>