Journal of Economics and Social Sciences (JESS)
Vol. 4, 2 (July - December, 2025), pp. 592-599
EISSN: 2808-5094, DOI: 10.59525/jess.v4i2.874

Charcoal from Coconut Shells: An Innovation in Agricultural Waste Management for Local Economic Development

Della Putri Rahayu [1], M. Arif Musthofa[2], Hasna Dewi[3], Erwina Kartika Devi[4]

[1] Institut Islam Al-Mujaddid Sabak; dellaputrir@gmail.com
[2] Institut Islam Al-Mujaddid Sabak; 7ariefherio@gmail.com
[3] Institut Islam Al-Mujaddid Sabak; hasnaanandadewi@gmail.com
[4] Institut Islam Al-Mujaddid Sabak; erwinaelkhalifi@gmail.com

ARTICLE INFO

Keywords:

Coconut Shell;
Charcoal;
Community Empowerment;
Green Economy

Article history:

Received 2025-07-07
Revised 2025-07-30
Accepted 2025-08-17

ABSTRACT

Indonesia is one of the world's largest agrarian countries, with abundant agricultural and plantation outputs. Among its leading commodities, coconut holds a strategic role in both national and regional economies. However, the substantial volume of coconut shell waste is often underutilized. This study aims to explore the processing of coconut shell waste into high-value charcoal in Lagan Tengah Village and to analyze the production process, technical challenges, market potential, and its impact on community economic empowerment. Using a descriptive qualitative approach, data were collected through field observations, in-depth interviews, and documentation studies. The findings reveal that local business initiatives, such as "Jan Rahayu Lestari," have succeeded in producing high-quality charcoal with a fixed carbon content of approximately 75%, low moisture levels, and long burn duration. The simple pyrolysis technology employed proves to be both effective and appropriate for the local community's capacity. This initiative not only generates alternative income for farmers and housewives but also mitigates environmental pollution caused by open burning. The study affirms that the integration of local knowledge with cross-sectoral support can transform agricultural waste management into a replicable, inclusive, and sustainable model for rural economic development. These findings are relevant for the formulation of policies related to green economy, renewable energy, and the strengthening of micro-industries based on local resources.

Corresponding Author:
Della Putri Rahayu
Institut Islam Al-Mujaddid Sabak; dellaputrir@gmail.com

1. INTRODUCTION

Indonesia is recognized as one of the world's leading agrarian countries, with abundant agricultural and plantation outputs (Otsuka, 2021; Tualle et al., 2023). Among its major agricultural commodities, coconut plays a vital role in both national and regional economies. According to data from the Central Bureau of Statistics, Indonesia recorded a coconut production of approximately 18.3 million tons in 2022, making it one of the largest coconut producers globally. The coconut industry not only yields high-value products such as coconut meat and water but also generates substantial waste in the form of coconut shells. Unfortunately, this waste is largely underutilized and often perceived as having little to no economic value (Aldo, Musthofa, & Sunarti, 2025; Bayu, Musthofa, Sunarti, & Nisak, 2025). In fact, coconut shells possess physical and chemical properties that make them suitable for conversion into value-added products, one of which is charcoal (Kamaludin, Narmaditya, Wibowo, & Febrianto, 2021).

The utilization of coconut shells as raw material for charcoal production is not a novel concept. However, its potential remains largely untapped, especially at the rural community level. Coconut shell charcoal is known to be superior to traditional wood-based charcoal due to its higher fixed carbon content, longer burn time, and greater environmental friendliness. Amid growing awareness of forest conservation and the global shift towards cleaner alternative fuels, coconut shell charcoal stands out as a strategic option (Sofiatin, Musthofa, & Sunarti, 2025; Wati et al., 2025). Nonetheless, limited technical knowledge, inadequate equipment, and poor market access remain key barriers that prevent rural communities from managing this agricultural waste in a productive and sustainable manner (Kartodiharjo & Cahyonob, 2021).

Lagan Tengah Village is one of the prominent coconut-producing areas, where most residents rely on coconut farming and agriculture as their primary sources of livelihood. In daily practice, coconut shells left over from fruit processing are commonly burned or discarded without further treatment. This practice not only wastes the economic potential of the waste but also contributes to environmental issues such as air pollution and increased greenhouse gas emissions. Moreover, the economic instability faced by the community—exacerbated by fluctuating prices of coconut and copra—adds to their vulnerability. Diversifying local livelihoods through waste-based businesses such as coconut shell charcoal production offers a promising alternative for generating additional income while addressing environmental concerns (Thaha et al., 2025).

Demand for coconut shell charcoal continues to rise, particularly in export markets. Export data indicates that Indonesia ships over 300,000 tons of coconut shell charcoal annually, with a value exceeding 200 million USD. Countries such as China, Japan, and Germany are among the primary importers, utilizing the product in various industrial sectors, including as fuel, water filtration media, and active ingredients in cosmetics. Despite the high demand, export-grade charcoal production is still dominated by large-scale industries. Rural communities with direct access to raw materials often lack the capacity to meet export standards due to insufficient knowledge of proper carbonization techniques, inadequate packaging practices, and limited access to modern technology and financial capital (Bayu et al., 2025; Wijaya, Musthofa, & Dewi, 2025). This gap between resource potential and production capability highlights a pressing issue in the value chain (Asfar, Adiansyah, Nur, Asfar, & Nurannisa, 2024).

Developing coconut shell charcoal enterprises at the village level carries strategic value that spans economic, environmental, and social dimensions. Converting waste into marketable products contributes to the reduction of organic waste that would otherwise pollute the environment. Furthermore, coconut shell charcoal offers cleaner combustion compared to wood-based alternatives, thus supporting the clean energy agenda and environmental sustainability. In the context of global efforts to reduce carbon emissions and promote renewable energy, the development of coconut shell

charcoal can serve as a local solution to global challenges. Additionally, this initiative opens up new employment opportunities, particularly for vulnerable groups such as housewives and rural youth, thereby reinforcing empowerment and social inclusion.

Although numerous studies have examined the technical and chemical aspects of coconut shell charcoal, significant research gaps remain concerning its technological application and community-based empowerment models (Asfar et al., 2024; Leelatam et al., 2025; Nandiyanto, Fiandini, Farobie, Kurniawan, & Bilad, 2025). Most existing literature focuses on optimizing carbonization processes in laboratories or industrial settings, while practical, community-oriented models are still scarce. In reality, fostering circular economies and green industries in rural areas requires approaches rooted in local resources and community participation. Thus, further research is needed to explore how charcoal production processes can be tailored to the social, economic, technological, and environmental contexts of rural communities.

This research seeks to address that gap by exploring the processing of coconut shell waste into high-quality charcoal in Lagan Tengah Village. The study focuses on analyzing the production processes carried out by local communities, identifying challenges they face, and assessing the potential for developing sustainable charcoal enterprises. It also evaluates the effectiveness of the technologies employed and how these can be adapted to the local community's capacity without compromising product quality. Moreover, aspects of marketing and institutional support are examined as integral components of a viable, small-scale, waste-based business ecosystem (Syafaat, Devi, & Musthofa, 2025).

The urgency of this research lies in its aim to promote the transformation of agricultural waste into a new, sustainable, and inclusive economic resource. By developing an efficient and locally appropriate model for coconut shell charcoal production, it is expected that rural communities will not only reduce their dependence on raw commodity sales but also significantly enhance the value-added potential of agricultural outputs. This research contributes not only to applied knowledge in the fields of agriculture and energy but also offers practical insights for designing rural economic empowerment policies based on local resources. The findings are expected to serve as a reference for local governments, NGOs, and entrepreneurs in implementing community-based waste management programs with positive economic, social, and environmental impacts.

2. METHODS

This study adopts a descriptive qualitative approach aimed at gaining an in-depth understanding of the coconut shell charcoal production process in Lagan Tengah Village and its impacts on the local community. The primary focus lies in exploring the phenomenon contextually through data obtained from direct observation, in-depth interviews with charcoal producers, and visual documentation conducted at the research site (Fatimah, Devi, Wandi, Mun'amah, & Sarwono, 2024; Sapriandi, Nilfatri, Hidayat, Devi, & Pitri, 2025). This approach was selected to allow the researcher to acquire a comprehensive picture of the social, technical, and economic dynamics involved in coconut waste-based charcoal production.

The role of the researcher is central to this study, serving as the primary instrument for data collection. Direct presence in the field enables the researcher to carry out thorough observations of the production process while also building strong interactions with key actors and stakeholders. These interactions create opportunities to explore the subjective experiences of the charcoal producers and to better understand the social conditions surrounding their economic activities. Research ethics were upheld through informed consent procedures, interview agreements, and careful management of data confidentiality and participant protection.

The data sources used in this research consist of both primary and secondary data. Primary data were gathered through direct observation of the charcoal production process, in-depth interviews with producers, local residents, village authorities, and relevant academics. Secondary data were obtained from a literature review of scholarly journals, books, and previous research reports relevant to the topic. Data analysis employed a thematic analysis technique, which involved the processes of data collection, reduction, presentation, and conclusion drawing based on key emerging themes throughout the research process (Fitri, Haeran, Munip, & Devi, 2024).

3. FINDINGS AND DISCUSSION

Lagan Tengah Village is recognized as one of the primary coconut-producing centers in its region, generating approximately 15,000 coconuts each month. This high level of production results in a substantial amount of coconut shell waste, estimated at around 2.5 tons per month. Previously, this waste was considered economically worthless and was either openly burned or left to accumulate, contributing to environmental degradation. Growing awareness among the local community regarding the potential of this organic waste has led to initiatives aimed at transforming it into more economically and environmentally beneficial products. With support from the village government and guidance from academic institutions, the community has begun developing coconut shell charcoal production enterprises. By mid-2025, at least seven local business units are engaged in this activity, including a notable enterprise, Jan Rahayu Lestari. The production process is conducted using a traditional but efficient pyrolysis method involving closed metal drums, in which 150 kg of coconut shells can yield approximately 60–70 kg of charcoal in about six hours. This method requires minimal capital investment, making it accessible to the general population. According to the owner of Jan Rahayu Lestari, attention to moisture content and ash levels is critical to ensuring optimal combustion quality. Workers are compensated based on output weight, with a rate of IDR 600 per kilogram. The enterprise emphasizes not only profitability but also job creation and waste reduction. Testimonies from employees and customers affirm satisfaction with the charcoal's quality, highlighting its hardness, low moisture content, and clean, long-lasting burn. The charcoal produced has a fixed carbon content of approximately 75%, placing it in the category of high-quality charcoal suitable for local and external markets. It is sold at prices ranging from IDR 6,000 to IDR 8,000 per kilogram, depending on quality and packaging, and is increasingly distributed through both conventional and digital channels (Sutiani, Mustofa, Fatimah, Devi, & Wargo, 2025).

This charcoal processing initiative has proven to generate tangible economic benefits for the residents of Lagan Tengah Village. Business actors report earning an additional income of IDR 3 million to IDR 5 million per month, serving as an alternative livelihood for farmers and housewives involved in various stages of the production chain, from collection and carbonization to packaging and distribution. In addition to its economic contributions, the initiative also mitigates environmental problems by reducing open burning and shell accumulation, while producing ash that can be repurposed as natural fertilizer for local agriculture (Lestari, Abidin, & Nilfatri, 2023). To ensure the sustainability and further development of this initiative, cross-sector collaboration is essential. The Department of Industry and Trade can offer training in packaging and market access; the Environmental Agency can oversee environmentally sound production practices; and the Cooperatives and SMEs Office can support institutional strengthening and financial management training. Civil society organizations working in environmental and economic empowerment fields can assist in capacity-building and networking among entrepreneurs. Higher education institutions also play a vital role through research on product quality improvement, production technology innovations, and human resource development via community service programs. The Appropriate

Technology Training Center (Balai TTG) can provide training in modern production tools, while village-owned enterprises (BUMDes) could serve as strategic partners in collective enterprise management and the provision of production infrastructure. The utilization of coconut shell waste for charcoal production in Lagan Tengah thus represents a practical solution to organic waste issues and a sustainable local economic development model that holds potential for replication in other rural areas.

Interview findings with the owner, employees, and customers of the coconut shell charcoal enterprise "Jan Rahayu Lestari" reveal several key insights that reflect the integration of technical, socio-economic, and environmental dimensions within its production practices. The charcoal production process is conducted in stages and requires a considerable amount of time to ensure high product quality, with particular attention given to moisture content and ash levels. High moisture content reduces the charcoal's combustibility, while excessive ash indicates incomplete carbonization; these concerns align with biomass carbonization theory, which recommends a moisture content below 10% and low ash levels to achieve combustion efficiency. From a socio-economic perspective, the enterprise contributes directly to the local community by creating employment opportunities and implementing a performance-based wage system, whereby workers are paid IDR 600 per kilogram of produced charcoal. This supports the concept of a people-centered economy, wherein micro and small enterprises play a vital role in enhancing household income and generating local employment. Environmentally, the enterprise offers significant benefits by transforming previously unused coconut shell waste into charcoal and craft products, thereby promoting circular economy principles and sustainable waste management. Product quality is further reinforced by high customer satisfaction with the charcoal's cleanliness, durability, and ease of ignition, reflecting the enterprise's success in meeting or exceeding user expectations. Overall, this enterprise serves as a tangible model of sustainable production theory at the local level, integrating technical efficiency, community empowerment, and the productive use of previously undervalued natural resources (Safitri, Nilfatri, & Haeran, 2025; Ulfa, Nilfatri, & Fatimah, 2023).

The process of transforming coconut shell waste into high-quality charcoal in Lagan Tengah Village provides concrete evidence that simple technology, when applied systematically and with attention to quality, can yield high-value products. Based on field observations and in-depth interviews with the owner of "Jan Rahayu Lestari," it was found that each stage of the production process is carried out in a structured manner—from the selection and sun-drying of coconut shells, uniform cutting, to tightly controlled carbonization stages. This production technique demonstrates that product success depends not only on raw materials but also on work discipline and local knowledge possessed by the entrepreneurs. Both the owner and workers emphasize that meticulous attention to the burning process—such as regulating air vents and monitoring temperature and smoke color is key to producing charcoal that is not only physically intact but also rich in carbon content. The cooling phase, which lasts up to six hours without direct water application, indicates a sound technical understanding of vacuum carbonization methods, significantly contributing to the low moisture content in the final product. Testimonies from loyal customers and workers who were once consumers themselves further reinforce the argument that the quality of the final product is heavily influenced by diligence and caution throughout the production process (Dara, Vann, Pitri, & Nilfatri, 2024).

Carbonization stands as the principal technical factor directly influencing the quality of coconut shell charcoal, as it requires high temperatures and limited oxygen to ensure the complete conversion of biomass into carbon. Interviews with workers reveal that their practical understanding of carbonization duration and fire intensity plays a crucial role in producing charcoal that is jet black and structurally intact. In contrast, incompletely carbonized charcoal tends to appear brownish, retains high moisture content, and emits thick smoke during burning making it unsuitable for use as an alternative fuel. These findings align with fundamental biomass carbonization principles, where

optimal temperature and precise timing serve as key indicators of energy efficiency. In this context, the workers at "Jan Rahayu Lestari" have empirically internalized these principles, even if not articulated in theoretical terms. Moreover, the surrounding community perceives the impact firsthand through the amount of smoke released during the process, suggesting that incomplete carbonization not only compromises product quality but also affects environmental and public health. Thus, optimizing the carbonization process is foundational for ensuring the sustainability and competitiveness of small-scale charcoal production at the local level.

The quality of coconut shell charcoal is also heavily influenced by other physicochemical factors, such as moisture content, ash content, and volatile matter. These three elements significantly affect both the combustion efficiency and calorific value of the resulting charcoal. A low moisture content—achieved through a natural cooling process inside sealed drums—allows the charcoal to ignite more easily and maintain a more consistent heat output. Field data reveals that producers are fully aware of the importance of maintaining moisture below optimal thresholds, which not only enhances combustion efficiency but also prolongs the shelf life of the product. Additionally, low ash content indicates a carefully executed combustion process, as excessive ash is a sign of prolonged burning or overexposure to oxygen. High volatile matter content leads to excessive smoke production during use, posing issues for end users and nearby communities. As such, tightly controlled combustion and cooling processes are implemented to minimize these volatile compounds. Interviews with workers and local residents confirm that incomplete burning releases excessive smoke, which only subsides after full carbonization has occurred. This suggests that local understanding of how these variables correlate with charcoal quality reflects a level of technical knowledge that deserves recognition in the context of traditional production systems.

The availability of high-quality coconut shells as raw material serves as a foundational pillar for the success of coconut shell charcoal enterprises in Lagan Tengah Village. Coconut shell waste from local copra industries, previously deemed economically worthless, now holds market value and is utilized as the primary input in charcoal production. Raw material quality proves to be a critical aspect, as fresh and hard shells yield superior carbonization results compared to decayed or damp ones. Interviews show that business owners actively maintain relationships with local coconut producers to ensure a consistent supply of high-grade shells. This model of collaboration reflects an integrated relationship between upstream and downstream sectors, thereby reinforcing the value chain within the local economy. The result is not only an improvement in charcoal quality but also community economic empowerment, as villagers now benefit financially from what was once mere agricultural waste. This indicates that effective raw material sourcing and selection strategies contribute substantially to the consistency and overall quality of the final product. Hence, the production of high-quality charcoal relies not only on technological proficiency and careful combustion processes but also on the availability and integrity of the raw materials from the very beginning.

4. CONCLUSION

This study demonstrates that the charcoal production initiative using coconut shells in Lagan Tengah Village serves not only as a solution to the long-standing issue of organic waste but also as a sustainable and competitive model for community-based economic empowerment. By utilizing simple technology integrated with local knowledge—such as manual control of temperature and ventilation during the pyrolysis process—the community has consistently produced high-quality charcoal, even in the absence of formal training. The novelty of this research lies in its successful presentation of a community-based charcoal production model that extends beyond technical aspects to holistically incorporate social, economic, and environmental dimensions. It shows that local knowledge can be

effectively integrated with modern carbonization techniques to transform agricultural waste into value-added products, create new business opportunities, and support global environmental agendas. Consequently, this model holds strong potential for replication in other rural areas and may serve as a reference in formulating policies on green economy, renewable energy, and the development of micro-industries based on local resources through cross-sector collaboration.

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