Control System Design Concept for Coconut Shell Charcoal Powder Processing Equipment as a Base Material for Herbal Toiletries Integrated with PV System

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Abstract

Various raw materials with enhanced benefits have been discovered for the toiletries industry. One promising material is coconut shell charcoal powder (Cocos nucifera), which can be used as a base ingredient in herbal toiletries formulations. However, its production process still faces challenges, particularly in terms of technology and operations, especially for small and medium enterprises. Therefore, this study aims to design a control system concept for a coconut shell charcoal powder processing unit integrated with a PV system.

The methods used include a literature review and a descriptive study through interviews with practitioners and academics specializing in charcoal powder production systems and herbal toiletries formulation. The result of this study is a conceptual design of a control system equipped with a remote monitoring system to oversee and regulate the coconut shell charcoal powder production process more efficiently.

Keywords *— Control System, Charcoal Powder, Coconut Shell*

1. INTRODUCTION

Coconut shell is a biomass that has more economic value if processed into charcoal powder [1][2][3]. Coconut shell charcoal powder is widely used in various industries, including medicine, cosmetics, and herbal toiletries, due to its good adsorptive properties and its ability to absorb hazardous substances and odors [4][5][6]. In addition, this material has environmentally friendly characteristics and can be sustainably renewed [7]. Indonesia, as one of the world's coconut producers, has great potential in developing an industry based on coconut shell charcoal powder [8][9][10]. However, optimization of the use of this material is still constrained by several factors, especially in terms of efficient and sustainable production.

The production of coconut shell charcoal powder involves several main stages, such as carbonization, grinding, and screening [11][12]. This process requires optimal temperature control and powder size dimensions to produce high-quality charcoal powder. Other challenges in this production are energy efficiency, process stability, and technology

availability, especially for small and medium enterprises. Therefore, a more efficient, sustainable, and easy-to-operate production system is needed for small-scale industry players.

To improve production efficiency and stability, a control system is needed that can regulate operational parameters. A control system with IoT-based monitoring can also be used to monitor energy production in PV Systems [13][14][15]. Automation-based control systems enable real-time process monitoring and control, thereby optimizing the production process. Integration with remote monitoring technology can provide more flexibility in operating production equipment, especially for small and medium enterprises that have limited manpower and technical resources [16][17].

In line with the advancement of renewable energy technologies and the growing need for sustainable industry practices, integrating a photovoltaic (PV) system with the charcoal powder processing equipment presents a strategic solution. The PV system not only serves as a clean energy source but also reduces dependency on conventional electricity sources, lowering operational costs and environmental impact. This integration supports the global agenda for decarbonization and aligns with Indonesia's commitment to utilizing renewable energy in local industries. Moreover, the application of such systems can enhance the energy autonomy of small-scale producers in rural or off-grid areas, fostering inclusive industrial development.

The main finding of this study is an automated control system design integrated with energy monitoring from a PV system to support the efficient and sustainable production of coconut shell charcoal powder. Compared to previous research, which focused solely on crushing coconut shell charcoal without considering the fineness level of the material [18][19][20][21], this equipment is equipped with a screening mechanism to determine the required material dimensions. The system developed in this study demonstrates advantages in terms of product quality and operational sustainability. Integration with an IoT-based monitoring system also serves as an additional benefit, addressing the challenges of production management in the small and medium enterprise sector. Thus, this research provides a new contribution to the development of coconut shell charcoal processing technology.

Given these considerations, this article proposes a conceptual design of a control system for coconut shell charcoal powder processing equipment integrated with a PV system. The design emphasizes automation, energy efficiency, and adaptability to the needs of small and medium enterprises. This study aims to contribute to the development of an affordable and reliable processing solution that supports the local herbal toiletries industry, strengthens energy resilience, and promotes the sustainable use of biomass resources.

2. RESEARCH METHOD

This study adopts a literature study and descriptive study approach to explore the appropriate control system for coconut shell charcoal powder production technology as a raw material for herbal toiletries. The literature study was conducted by reviewing various scientific references, such as academic journals, books, and other relevant sources of information regarding the utilization of coconut shells and their applications in the toiletries industry. The purpose of this study is to gain deeper insight into the characteristics of coconut

shell charcoal powder, its production methods, and its potential in the formulation of toiletries products.

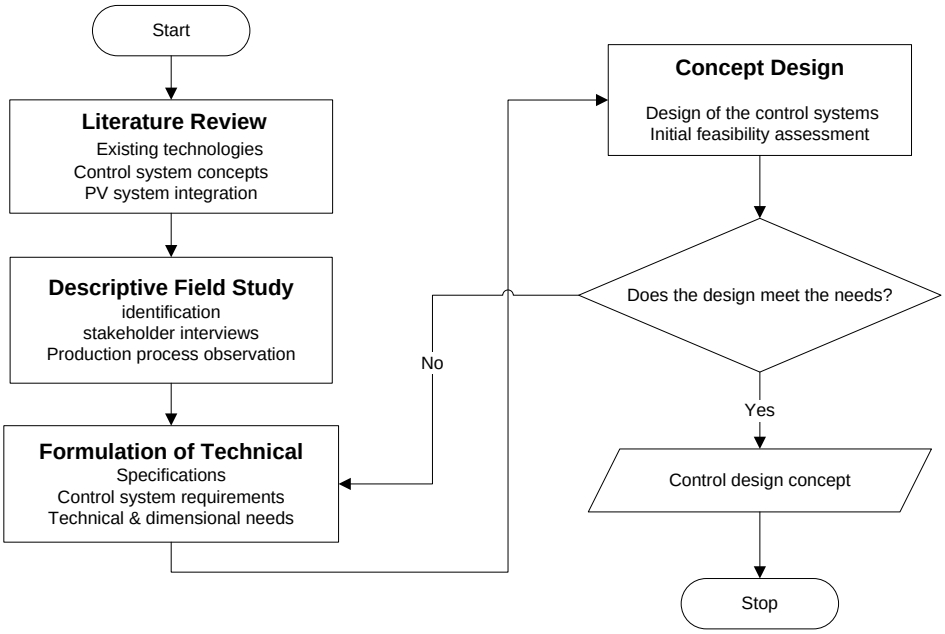


Figure 1. Research Flowchart

3. RESEARCH RESULTS AND DISCUSSION

3.1. Coconut shell charcoal powder production tool design Houses

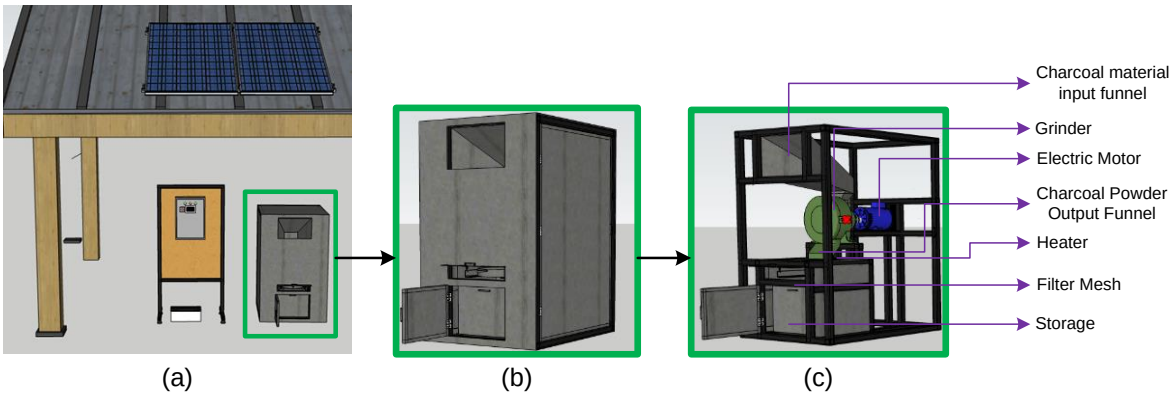


Figure 2. (a) Coconut shell charcoal production equipment system.
(b) Coconut shell charcoal powder processing equipment completes with body cover.
(c) Details of coconut shell charcoal powder processing equipment.

The design of the coconut shell charcoal powder processing tool consists of several main components designed to increase production efficiency and support energy sustainability through the integration of photovoltaic systems. Figure 2 (a) shows the overall production equipment system, which includes a PV system as an energy source, a control panel for system settings, and a coconut shell charcoal grinder. The PV system is used to supply the electrical power needed by the drive motor, thereby reducing dependence on conventional electricity and supporting more environmentally friendly production. The control panel functions as a

control center that regulates the operation of the tool, including activating the electric motor, controlling the heater temperature, and regulating the sieving system. Figures 2 (b) and (c) show the shape of the coconut shell charcoal powder grinding tool consisting of several main components.

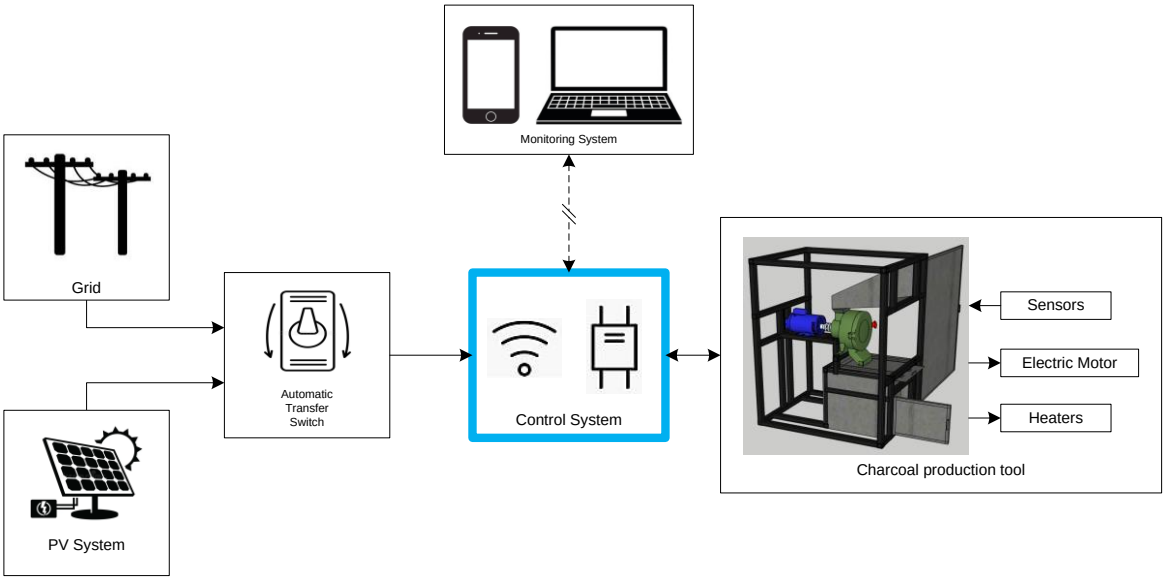


Figure 3. Control System Block Diagram

The production process begins with the charcoal material input funnel, where the raw material in the form of coconut shell charcoal is fed into the system. The material then enters the grinder, which functions to crush the coconut shell charcoal into smaller particles. An electric motor is used as the main driver of the grinder, ensuring that the crushing process runs efficiently. After the grinding process, the resulting charcoal powder is flowed through the charcoal powder output funnel, where the material will pass through a mesh sieve. This sieve functions to separate powder based on particle size, ensuring that only powder with the appropriate size can be used in further production processes. To increase the efficiency of the drying process and reduce water content, this tool is also equipped with a heater that helps maintain the quality of the charcoal powder. The filtered material is then collected in a container, ready to be packaged or used in the formulation of herbal toiletries products.

3.2. Control System Design

The design of the coconut shell charcoal powder production system is equipped with a flexible source of electrical energy, which can be obtained from the grid or Solar Power Plant. This system uses an Automatic Transfer Switch (ATS) which allows the selection of the main power source, either from the grid or Solar Power Plant as a backup, or vice versa. With the concept of the Internet of Things (IoT), the control system of this tool can be monitored and controlled remotely, thereby increasing efficiency and ease of operation.

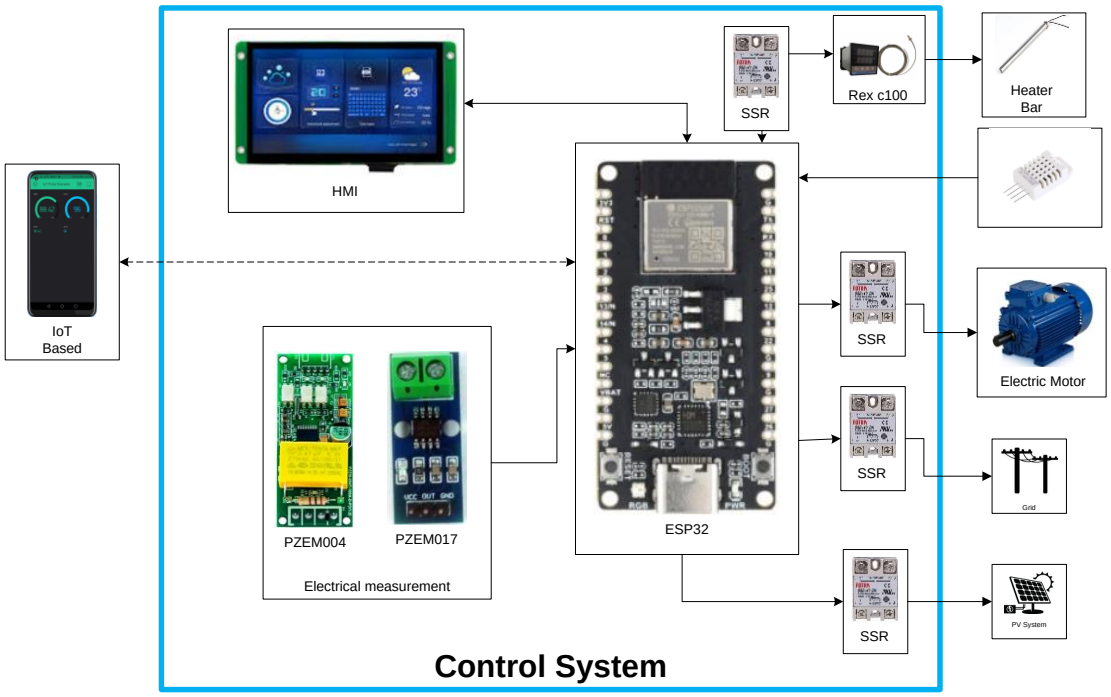


Figure 4. Detail of Control System

The equipment control system uses several main components to ensure optimal performance. The ESP32 functions as the main controller, responsible for processing data from sensors and executing system control commands. To facilitate the operation of the device, a Human-Machine Interface (HMI) is used to display the system status and allow users to set working parameters.

In the power monitoring system, this device is equipped with PZEM 004 which is used to measure voltage, current, power, and electrical energy from the grid, and PZEM 017 which measures electrical parameters from the Solar Power Plant. Both of these sensors help in analyzing energy consumption and resource usage efficiency. To maintain optimal temperature during the production process, this device is equipped with RexC100, a temperature controller that works with the heater bar to generate the heat needed in the charcoal powder drying process. The temperature sensor is used to monitor the temperature in real-time and send data to the ESP32 so that the temperature remains stable according to production needs. The electric power control system uses several Solid-State Relays (SSR). The SSR for the electric motor functions as an electronic switch to control the operation of the charcoal grinder, ensuring that the motor works as needed. SSR for grid and SSR for PLTS are used to regulate the power source used by the system based on priority settings from the ATS.

3.3. *Work Process Flow Diagram*

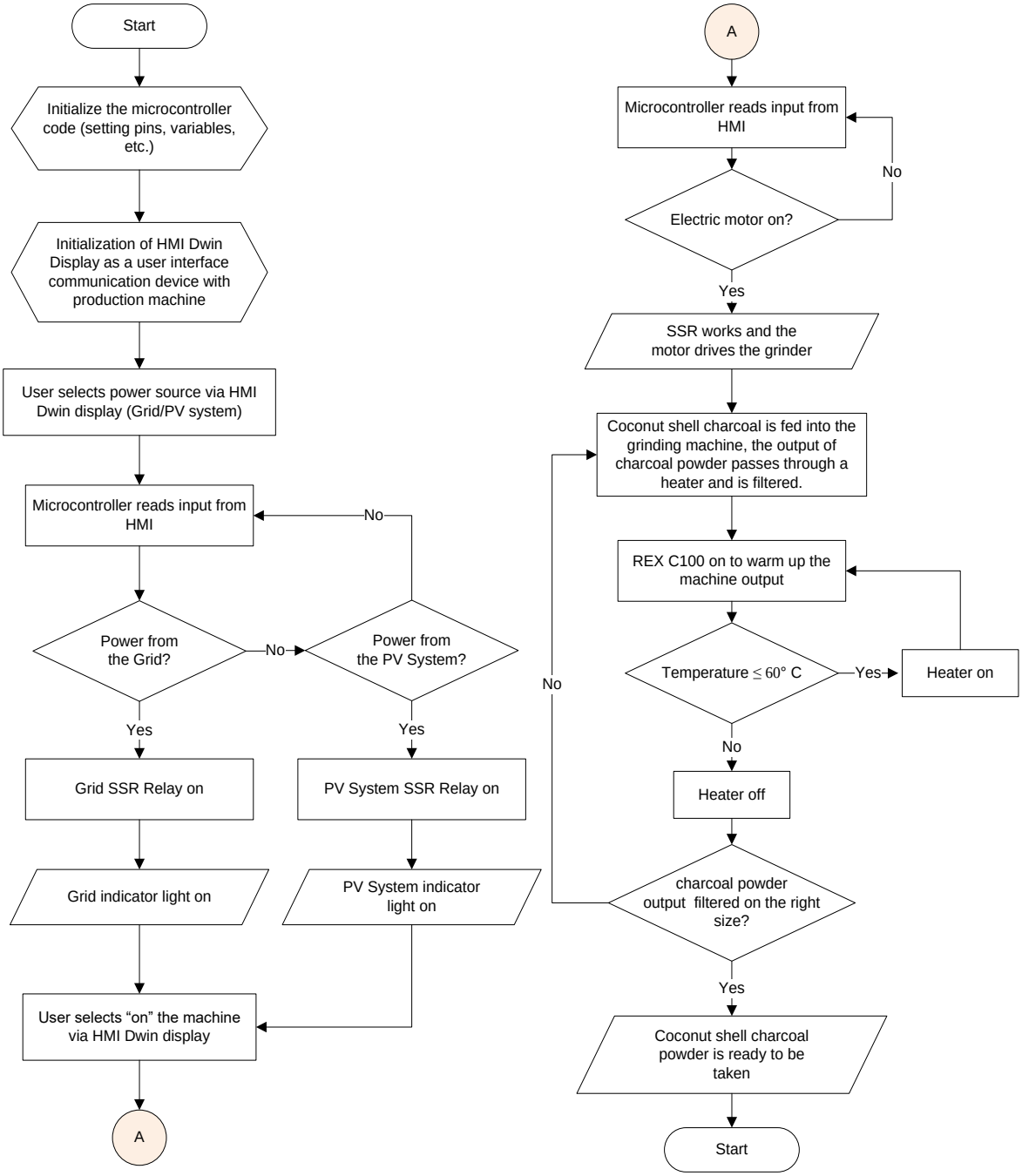


Figure 5. Work process flow diagram

The flow diagram of the coconut shell charcoal powder production process illustrates the operational stages from start to finish with an integrated automatic control system. The process begins with the selection of an energy source, where the user can determine whether the device will operate using electricity from the grid or PV System. Determination of the electricity source is done through the Automatic Transfer Switch (ATS) which automatically switches to a backup power source if the main source is disrupted.

Once the energy source is available, the ESP32-based control system will check the status of the main components, such as temperature sensors, electrical power, and heating systems. If all parameters are correct, the system will enter the coconut shell charcoal grinding stage. The charcoal material is fed through the input funnel, then the electric motor drives the grinder to crush the charcoal into powder of a certain size. This process is controlled by a Solid-State Relay (SSR) which regulates the electrical power to the motor.

After the grinding process, the charcoal powder will enter the heating system using a heater bar controlled by the RexC100 to ensure that the water content in the charcoal powder remains optimal. The temperature sensor monitors the temperature in real time and sends data to the ESP32 so that the heating system works automatically as needed. The heated charcoal powder is filtered with a mesh screen, where particles that are too large will be returned to the grinding process, while particles that have reached the desired size will exit through the output funnel to the final container. During the process, all operational data, including electricity consumption, heating temperature, and motor status, can be monitored in real time via the Human-Machine Interface (HMI) or via an IoT connection that allows remote monitoring. If an anomaly occurs such as overheating or unstable power, the system will provide a warning notification and can automatically shutdown to prevent damage to the equipment.

4. CONCLUSION

This research produces a conceptual design of a control system for coconut shell charcoal powder production equipment integrated with a photovoltaic (PV) system. The designed control system automates critical stages in the production process, including grinding, sieving, and heating, to ensure consistent product quality and improve operational efficiency. The automation not only enhances process reliability but also reduces dependency on manual labor, which is particularly beneficial for small and medium enterprises with limited human resources. The integration of the PV system introduces a renewable energy source that supports sustainable and environmentally responsible operation. By utilizing solar energy, the system reduces reliance on conventional grid electricity, lowers operational costs, and aligns with global and national initiatives for carbon emission reduction and energy diversification. The combined implementation of automated control and PV integration presents a resilient and scalable solution for local industries, particularly in rural and off-grid areas.

Moreover, the use of IoT-based monitoring in the control system opens the possibility for remote supervision, data logging, and predictive maintenance, thus offering further advantages in terms of system optimization and long-term sustainability. The proposed design is adaptable for replication in other biomass-based processing industries and serves as a strategic model for developing green and decentralized production systems. Future work may include the development of a prototype to validate the conceptual design, performance testing under different environmental and load conditions, and economic feasibility studies to support widespread implementation. Overall, the research contributes to the development of innovative, energy-efficient, and environmentally friendly production systems that support the circular economy and renewable energy integration in small-scale industries.

5. SUGGESTED

The next stage of this research is the development and implementation of a physical prototype based on the conceptual control system design. The prototype will serve as a tangible model to validate the system's functionality, reliability, and energy efficiency in real operating conditions. During this stage, design adjustments can be made to accommodate specific dimensional, mechanical, and operational requirements based on the intended production scale and user needs, particularly in small and medium enterprises.

It is also recommended that the prototype be designed with modularity and scalability in mind, allowing for flexible configurations depending on the volume of production and the availability of solar energy resources. This would enable the system to be more adaptable for deployment in various geographic and socio-economic settings, including rural or off-grid communities.

6. REFERENCES

[1] Y. Nustini and A. Allwar, "Pemanfaatan Limbah Tempurung Kelapa Menjadi Arang Tempurung Kelapa dan Granular Karbon Aktif Guna Meningkatkan Kesejahteraan Desa Watuduwur, Bruno, Kabupaten Purworejo," *AJIE - Asian J. Innov. Entrep.*, vol. 4, no. 3, pp. 217–226, 2019.

[2] N. D. Fadila, W. Rahmawati, and S. Suharyatun, "Kinerja Industri Kecil Arang Tempurung Kelapa," *J. Agric. Biosyst. Eng.*, vol. 2, no. 2, pp. 287–297, 2023.

[3] U. A`yunina, A. D. Moelyaningrum, and E. Ellyke, "Pemanfaatan Arang Aktif Tempurung Kelapa (Cocos nucifera) untuk Mengikat Kromium (Cr) (Study Pada Limbah Cair Batik)," *J. Kesehat. Lingkung. Indones.*, vol. 21, no. 1, pp. 93–98, 2022, doi: 10.14710/jkli.21.1.93-98.

[4] L. G. Carbonel, M. Mina, P. Odiem, and E. Calma, "Powdered Coconut Shell Charcoal: a Potential Alternative Medicine for Some Identified Ailments in Soft Tissues: an Interdisciplinary Research," *Int. J. Adv. Res. IT Eng.*, vol. 2, no. 7, pp. 2278–6244, 2013, [Online]. Available: www.garph.co.uk

[5] R. Nandhakumar, R. D. Ramesh, G. Ayyadurai, K. Sivasankaran, M. Koperunchozhan, and S. V. Tharumasivam, "Assessment Write-Up on Coconut Shell Derived Activated Charcoal - Use of Charcoal in Modern Medicine," *Int. J. Res. Publ. Rev.*, vol. 3, no. 3, pp. 1467–1470, 2022, doi: 10.55248/gengpi.2022.3.3.4.

[6] M. Sajjad, R. Sarwar, T. Ali, L. Khan, and S. U. Mahmood, "Cosmetic uses of activated charcoal," *Int. J. Community Med. Public Heal.*, vol. 8, no. 9, p. 4572, 2021, doi: 10.18203/2394-6040.ijcmph20213569.

[7] I. F. Yanti, P. J. Wibawa, and A. Mukimin, "Fabrication of Coconut Shell-Derived Graphitic Activated Carbon for Carbon-based Electrode Materials," *J. Sci. Appl. Chem.*, vol. 27, no. 9, pp. 456–463, 2024.

[8] J. C. Alouw and S. Wulandari, "Present status and outlook of coconut development in Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 418, no. 1, pp. 1–10, 2020, doi: 10.1088/1755-1315/418/1/012035.

[9] E. P. Yudha *et al.*, "Analisis Daya Saing Dan Kinerja Perdagangan Kelapa Kering Indonesia Di Pasar Internasional," *Dep. Sos. Ekon. Pertan.*, vol. 1, pp. 1–17, 2022.

[10] J. Hestina *et al.*, "Industri Kelapa Indonesia: Kinerja Dan Perspektif Pengembangan Menuju Peningkatan Nilai Tambah Dan Daya Saing," *Forum Penelit. Agro Ekon.*, vol. 40, no. 1, p. 55, 2023, doi: 10.21082/fae.v40n1.2022.55-69.

[11] S. N. Rumokoy, K. L. R. Mansauda, and C. H. Simanjuntak, "Alat Produksi Serbuk Arang Tempurung Kelapa (Cocos nucifera) Sebagai Bahan Dasar Sediaan Toiletris Herbal : Studi Potensi dan Teknologi," *J. Elektr.*, vol. 02, no. 02, pp. 8–13, 2023.

[12] Maryono, S. Dan, and Rahmawati, "Pembuatan dan Analisis Mutu Briket Arang Tempurung Kelapa Ditinjau dari Kadar Kanji," *J. Chem. 74-83*, vol. 14, no. 1, pp. 74–83, 2013.

[13] Ramadhan Lubis, Putri Nabila, Nurul Ilmi Nasution, Lathifah Azzahra, Hasraful, and Fadillah Andina6, "Sistem Pemantauan Dan Pengendalian Energi Berbasis Iot Untuk Meningkatkan Efisiensi Energi Dalam Lingkungan Cerdas," *J. Rev. Pendidik. dan Pengajaran*, vol. 7, no. 3, pp. 7899–7906, 2024.

[14] D. T. Laksono, R. Afrianti, M. W. Fatma, M. Prasafitri, and H. Alchudri, "Rancang Bangun Sistem Pemantauan Energi Listrik Dengan Automatic Transfer Switch," *J. Inform. dan Tek. Elektro Terap.*, vol. 13, no. 1, pp. 61–68, 2025.

[15] D. Teknik and U. G. Mada, "Analisis Kinerja Sistem Photovoltaic Management Platform pada Implementasi Sistem PLTS Hybrid Berbasis Internet of Things Area R & D Syngenta Cikampek," *J. List. Instrumentasi, dan Elektron. Terap.*, vol. 5, no. 2, pp. 75–83, 2024.

[16] S. N. Rumokoy, C. S. Tumiwa, A. C. Y. Lengkey, "Konsep Pencegahan Kematian Ikan Hias Dengan Sistem IoT Terintegrasi Energi Surya Pada Usaha Ikan Skala Besar," *J. Elektr.*, vol. 02, no. 02, pp. 1–7, 2023, [Online]. Available: http://jurnal.polimdo.ac.id/index.php/elektrik/article/view/706

[17] M. A. Fathoni and A. A. Bhrata, "Smart Manufacturing Management System Memanfaatkan Big Data Dan Algoritma Machine Learning Untuk Produksi UMKM," *J. Sci. Innov. Technol.*, vol. 3, no. 1, pp. 36–47, 2023, doi: 10.47701/sintech.v3i1.2523.

[18] C. Cipto, F. Sariman, N. Jusman, and S. Saliki, "Model Design of Active Charcoal Powder Mixing Machine as Briquet Raw Material," *Int. J. Res. Publ. Rev.*, vol. 4, no. 1, pp. 544–549, 2023.

[19] P. Cindy Vena Ariesta, Iswanto, Yoga Alvero, M. Haritsah Amrullah, "Rancang Bangun Mesin Penghancur Arang Tempurung Kelapa," *Pros. Semin. Nas. Inov. Teknol. Terap.*, vol. 2, no. January, pp. 978–979, 2022.

[20] S. Arif, H. Rahmad, R. E. W. Susanto, F. N. Hamidah, and R. Widyastuti, "Aplikasi Mesin Pengayak Arang Tempurung Kelapa Guna Meningkatkan Produktivitas Di UD. Arang Tempurung Blitar," *J. ABDINUS J. Pengabdi. Nusant.*, vol. 6, no. 1, pp. 152–162, 2022, doi: 10.29407/ja.v6i1.16742.

[21] A. Gilang Wira Pratama, "Design and manufacture of coconut shell charcoal crusher for briquette," *J. Mech. Eng. Fabr.*, vol. 1, no. 1, pp. 6–9, 2024.