Conceptual Design of A Greenhouse-Based Cassava Drying System For Sustainable Small-Scale Agroindustry In Sukasari Village, Rumpin, Indonesia

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Abstract.
Cassava is one of the primary agricultural commodities in Sukasari Village, Rumpin, Indonesia, where small and medium enterprises (SMEs) predominantly rely on conventional open-sun drying methods. These practices are highly dependent on weather conditions, resulting in inconsistent drying quality, prolonged processing time, and reduced production efficiency. To address these challenges, an environmentally friendly greenhouse-based cassava drying system was designed as an alternative drying technology that utilizes solar energy while providing a more controlled drying environment. The purpose of this study is to develop the conceptual design of a greenhouse-based cassava drying system and introduce the proposed technology to local SMEs as a sustainable drying solution. The program employed a participatory approach involving field observations, needs assessment, conceptual engineering design, and technology dissemination through socialization and discussion sessions with cassava-processing SMEs. Stakeholder feedback was collected to evaluate the relevance and feasibility of the proposed design. The proposed design applies passive solar heating within a greenhouse structure to create a cleaner and more controlled drying environment. The socialization activities increased participants' understanding of sustainable drying technology and received positive responses regarding its potential to improve drying efficiency and support future productivity. The conceptual design provides a basis for prototype development and subsequent field implementation.
Keywords: *Greenhouse solar dryer, Cassava Drying, Conceptual Design, Community Service and Sustainable Energy.*

I. INTRODUCTION

Cassava processing is an important economic activity for many rural communities in Indonesia, particularly for small and medium enterprises (SMEs) that produce dried cassava products as a source of household income [1]Suherman et al., 2020). In Sukasari Village, Rumpin District, Bogor Regency, cassava processing has considerable economic potential due to the abundant availability of raw materials. However, the productivity and competitiveness of local SMEs remain constrained by traditional post-harvest practices, particularly during the drying process.

Currently, most SMEs still depend on open-sun drying, which is simple and inexpensive but highly influenced by weather conditions. Rainfall, high humidity, and fluctuating solar radiation often prolong drying time and reduce product quality. Furthermore, direct exposure to dust, insects, and other contaminants may affect product hygiene and marketability. These limitations reduce production efficiency and create uncertainty in meeting customer demand, especially during the rainy season [1], [2]. (Suherman et al., 2020; Sujatha & Kavitha, 2015).

The application of renewable-energy-based drying technology offers a sustainable alternative to overcome these challenges. Greenhouse solar drying systems utilize the greenhouse effect to capture and retain solar heat, creating a warmer and more stable drying environment than conventional open drying [3]. (Mohana et al., 2020). Besides improving drying conditions, greenhouse dryers protect agricultural products from environmental contamination while reducing dependence on fossil fuels and electrical energy. Consequently, this technology is considered an environmentally friendly solution that supports sustainable agricultural processing [4]. (Srinivasan & Muthukumar, 2021).

Despite these advantages, the adoption of greenhouse drying technology among rural cassava-processing SMEs remains limited. Most SMEs have limited access to appropriate technology, engineering knowledge, and practical information regarding greenhouse-based drying systems. Therefore, introducing an appropriate conceptual design through community engagement is an important initial step before prototype development and field implementation.

This community service program aimed to develop the conceptual design of an environmentally friendly greenhouse-based cassava drying system and disseminate the proposed technology to cassava-processing SMEs in Sukasari Village. The program focused on identifying community needs, designing an appropriate drying system adapted to local conditions, and increasing community awareness of sustainable post-harvest technology. It is expected that the proposed design will serve as a reference for future prototype development and contribute to improving the efficiency, productivity, and sustainability of cassava-processing SMEs.

II. METHODS

This community service program was conducted in Sukasari Village, Rumpin District, Bogor Regency, Indonesia, involving local cassava-processing small and medium enterprises (SMEs) as the primary beneficiaries. The program adopted a participatory approach to ensure that the proposed technology addressed the actual needs and conditions of the community.

The implementation consisted of four sequential stages as seen in Figure 1. The first stage involved a preliminary field survey and needs assessment to identify existing cassava drying practices, production constraints, and community expectations. Data were collected through direct observations, informal interviews with SME owners, and focus group discussions with community representatives.

The second stage focused on the conceptual design of an environmentally friendly greenhouse-based cassava drying system. The proposed design incorporated passive solar heating principles by utilizing transparent greenhouse covering materials to capture solar radiation and increase the internal drying temperature while protecting cassava from rain, dust, insects, and other environmental contaminants. The design also considered local climatic conditions, ease of construction, the availability of local materials, and affordability for small-scale enterprises.

The third stage involved the dissemination of the proposed design through a community socialization program. The activity included presentations, interactive discussions, and knowledge-sharing sessions to introduce the operating principles, expected benefits, and potential applications of greenhouse drying technology. Participants were encouraged to provide suggestions and discuss potential challenges related to future implementation.

The final stage consisted of an evaluation of the socialization activities using participant feedback collected through discussions and questionnaires. The evaluation focused on participants' understanding of the proposed technology, perceived usefulness, and willingness to adopt the greenhouse drying system in future development programs. The collected feedback was used to refine the conceptual design and provide recommendations for prototype development and field implementation in subsequent community service activities.

Fig 1. Sequential stages proposed technology addressed the actual needs and conditions of the community

III. RESULT AND DISCUSSION

Field observations conducted in Sukasari Village revealed that local cassava-processing SMEs predominantly use conventional open-sun drying to reduce the moisture content of cassava slices as seen in

Figure 2. The drying process is carried out by spreading cassava on open drying surfaces and exposing it directly to sunlight. This method is simple and inexpensive; however, it is highly dependent on weather conditions and seasonal variations. Discussions with SME owners identified several challenges associated with the existing drying practice. The drying process is frequently interrupted by rainfall and high humidity, resulting in prolonged drying time and inconsistent product quality. In addition, exposure to dust, insects, and other environmental contaminants may reduce product hygiene and marketability. These findings confirmed the need for a more reliable and environmentally friendly drying system that can be adopted by local SMEs.

Conceptual Design of the Greenhouse-Based Cassava Drying System

Based on the identified needs, a conceptual design of a greenhouse-based cassava drying system was developed. The proposed design applies the greenhouse effect by utilizing transparent covering materials to capture solar radiation and increase the air temperature inside the drying chamber [5] (Sharma, et al. 2012). The enclosed structure is intended to provide a more stable drying environment while protecting cassava products from external contaminants [6], [1], [7]. (Pangavhane, et al., 2002; Suherman et al., 2020; Prakash & Kumar, 2014).

The design consists of a lightweight structural frame, transparent roof and wall coverings, natural ventilation openings, and drying racks arranged to optimize air circulation [6], [8]. (Pangavhane, et al., 2002; Panwar, 2012). Priority was given to the use of locally available materials and a simple construction concept to facilitate future adoption by SMEs. Since the system relies entirely on passive solar energy, the proposed design does not require additional fuel or electrical heating, making it an environmentally friendly alternative for rural agro-processing.

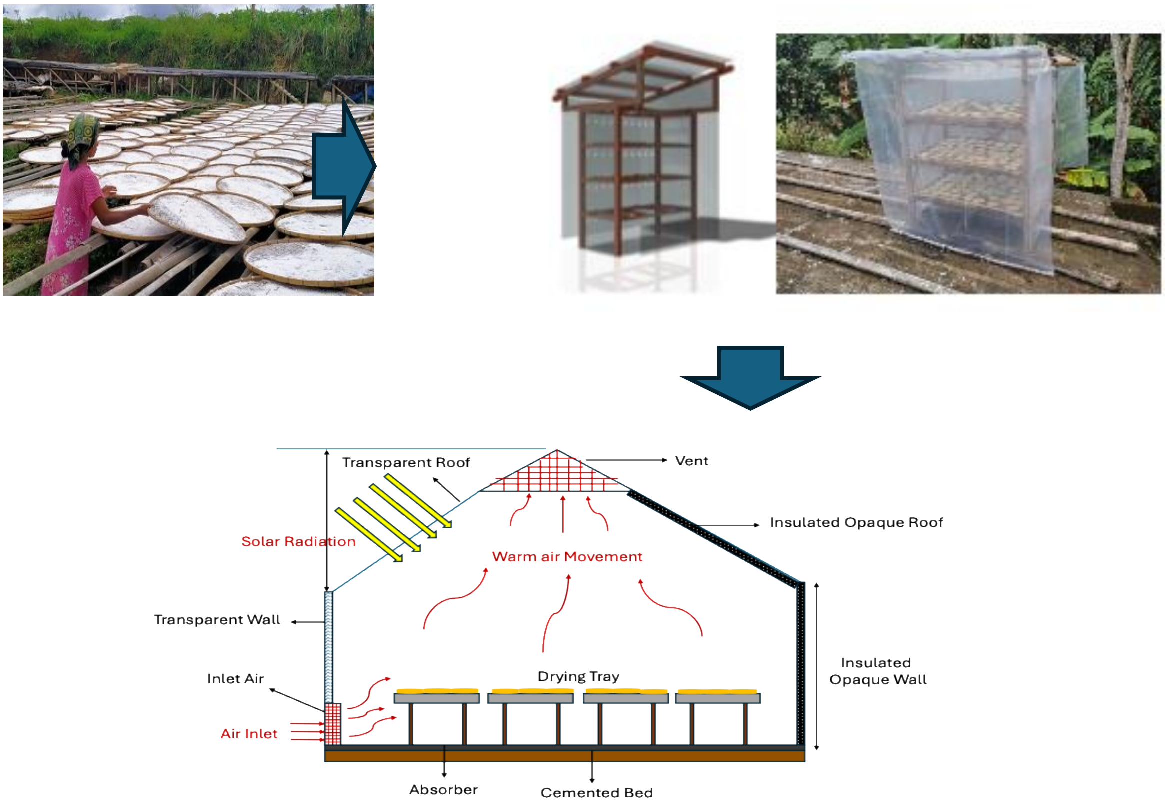

Fig 2. Proposed Conceptual design of the Greenhouse-Based Cassava Drying System

Community Socialization of the Proposed Technology

The conceptual design was introduced to cassava-processing SMEs through a technology socialization program. The activity included presentations on the working principles of greenhouse solar drying, expected advantages over conventional drying methods, and opportunities for future application in cassava processing. Interactive discussions encouraged participants to share their experiences and provide feedback on the proposed design as seen in Figure 3. The participants showed considerable interest in the technology, particularly because of its potential to reduce dependence on weather conditions and improve product cleanliness. The socialization activities also increased participants' awareness of renewable-energy-based drying technology and its potential contribution to sustainable agro-processing.

Fig 3. Community socialization activities with cassava-processing SMEs in Sukasari Village, Rumpin District, Bogor

Stakeholder Feedback

Feedback obtained during the discussion sessions indicated that the proposed greenhouse drying system was considered appropriate for the operational conditions of local SMEs. Participants appreciated the simplicity of the design and the possibility of constructing the system using locally available materials. Several suggestions were also provided regarding the preferred size of the drying chamber, the arrangement of drying trays, and ease of maintenance. The collected feedback will be incorporated into the subsequent design refinement process before prototype fabrication and field evaluation. This participatory approach ensures that future technology development is aligned with the practical needs and expectations of the community.

Potential Benefits of the Greenhouse-Based Drying System

The conceptual design developed in this community service program offers an alternative approach to overcoming the limitations of conventional open-sun drying. Unlike traditional drying methods, which are directly exposed to weather fluctuations and environmental contaminants, the proposed greenhouse drying system is designed to create a more protected drying environment by utilizing passive solar energy. The transparent enclosure allows solar radiation to enter while reducing heat loss, thereby increasing the internal air temperature through the greenhouse effect [9], [4], [10] (Udomkun et al., 2020; Srinivasa & Muthukumar, 2021; Yahya, 2016). This mechanism is expected to support a more stable drying process while maintaining low operating costs because no external energy source is required [2] (Sujatha & Kavita, 2015).

From an environmental perspective, the proposed system also supports sustainable agricultural practices by relying entirely on renewable solar energy. Consequently, the technology has the potential to reduce dependence on fossil-fuel-based drying systems and contribute to environmentally friendly post-harvest processing.

Community Engagement and Technology Acceptance

An important outcome of this community service activity was the active participation of local SMEs during the socialization program. The discussion sessions enabled participants to identify practical challenges associated with conventional drying while providing valuable feedback on the proposed design. This participatory approach is essential because successful technology adoption depends not only on technical feasibility but also on community acceptance and user involvement.

The positive responses received from participants indicate that the proposed greenhouse drying system is considered relevant to local conditions and operational needs. Furthermore, the exchange of knowledge during the socialization activities increased awareness of renewable-energy-based technologies and encouraged SMEs to consider more sustainable post-harvest practices in the future.

Contribution to Sustainable Rural Development

Introducing an environmentally friendly drying technology aligns with broader efforts to promote sustainable rural development and strengthen the competitiveness of small-scale agro-industries. Although the current program was limited to conceptual design and technology dissemination, it established an important foundation for future innovation by connecting engineering solutions with community needs.

The proposed greenhouse drying system is expected to support several long-term benefits, including improved product hygiene, greater resilience to weather variability, and more efficient utilization of solar energy. If successfully implemented and validated, the technology may contribute to increasing the productivity and economic resilience of cassava-processing SMEs while supporting the transition toward sustainable agricultural processing.

Limitation and Future Work

This community service program has several limitations. First, the activity focused on the conceptual design and community socialization stages; therefore, no prototype was constructed or experimentally evaluated. Consequently, the thermal performance, drying efficiency, product quality, and economic feasibility of the proposed system have not yet been quantified.

Future work should focus on prototype fabrication, experimental performance testing under local climatic conditions, and economic analysis to evaluate the practicality of large-scale implementation. Additional studies may also investigate airflow distribution, temperature uniformity, moisture reduction characteristics, and drying kinetics to optimize the greenhouse drying system for cassava processing.

IV. CONCLUSION

This community service program successfully developed a conceptual design of an environmentally friendly greenhouse-based cassava drying system tailored to the needs of cassava-processing SMEs in Sukasari Village, Rumpin District, Indonesia. The proposed design applies passive solar heating through the greenhouse effect to provide a protected drying environment while utilizing renewable solar energy. In addition to developing the conceptual design, the program introduced the proposed technology to local SMEs through socialization activities, which enhanced participants' understanding of sustainable post-harvest processing and encouraged discussions on future technology adoption.

Although the program was limited to the conceptual design and dissemination stages, it established an important foundation for future technology development. The feedback obtained from community participants provides valuable input for refining the design prior to prototype fabrication and field implementation. Future community service and research activities should focus on constructing the prototype, evaluating its thermal and drying performance, and assessing its technical and economic feasibility to support the sustainable development of cassava-processing SMEs.

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