Jurnal Pengabdian Magister Pendidikan IPA

Original Research Paper

Enhancing Cocoa Bean Quality through Optimized Roasting Techniques for Sustainable Local Chocolate Production

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DOI: https://doi.org/10.29303/jpmpi.v9i1.14777
Sitasi: Yuhendra AP., Nurrhman, R. K., Fuadi, M., Sabani, R., Sumarsono, J., Putra, G. M. D., Setiawat, D. A., Muttalib, S. A., Puspitasari,I., Khalil, F. I., Dewi, E. P., Ishak, W. R. B. W., Ahmad, H. (2026). Enhancing Cocoa Bean Quality through Optimized Roasting Techniques for Sustainable Local Chocolate Production. *Jurnal Pengabdian Magister Pendidikan IPA, 9(1).*

Article history
Received: 5 March 20126
Revised: 10 March 2026
Accepted: 18 March 2026

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Abstract: This activity aims to improve the quality of cocoa beans and promote sustainable local chocolate production through the application of optimized roasting techniques tailored to the characteristics of locally grown tropical cocoa beans. The program was led by Prof. Wan Rosli Bin Wan Ishak from USM, accompanied by Prof. Haslina Ahmad, along with collaborators from the field of Bioactive Materials and Synthesis at UPM. The activities included the delivery of training modules entitled *Enhancing Cocoa Bean Quality through Optimized Roasting Techniques for Sustainable Local Chocolate Production*, demonstrations of roasting processes involving parameters such as temperature, roasting time, humidity, and variations in roasting schemes, as well as a field visit to the chocolate production house at Kampung Coklat Senare. This visit aimed to provide a deeper understanding of the production workflow, the diversity of local cocoa beans, and opportunities to strengthen supply chains based on locally sourced raw materials. The primary focus of the program was the design of energy-efficient roasting strategies with minimal environmental impact, while preserving bioactive compounds and characteristic cocoa aromas through controlled Maillard reaction pathways. The initiative emphasized technology transfer, community capacity building, and the adoption of sustainable production practices among cocoa-based micro, small, and medium enterprises (MSMEs) in North Lombok. The long-term impact is expected to be reflected in improved processing efficiency, greater utilization of local resources, and more stable income opportunities for cocoa farmers and local MSME actors. The activity was conducted at Kampung Coklat Senare, Genggelang Village, North Lombok, on 21 January 2026, highlighting the importance of international–local partnerships within the context of community engagement in tropical regions.

Keywords: Bioactive compounds; Cocoa roasting optimization; Community empowerment; Sustainable chocolate production; Technology transfer.

Introduction

Cocoa, as a major commodity in tropical regions, plays an important role in the economic livelihoods of smallholder farming communities. In North Lombok, the cocoa sector provides opportunities to increase income through downstream processing into value-added chocolate products. The success of producing high-quality chocolate depends not only on the genetic characteristics of cocoa beans but also on post-harvest handling and roasting processes that determine aroma, flavor, color, and nutritional stability in the final product. Roasting represents a critical stage that develops characteristic cocoa aroma through Maillard reaction pathways and the degradation of aroma precursors; therefore, roasting profiles are key determinants of the final quality of chocolate (Youssef, 2019; Hii et al., 2016). However, production facilities at the community level in tropical regions often face several constraints, including variability in bean moisture content, limited energy resources, and the heterogeneity of cocoa beans produced by smallholder farmer groups (Tunick & Toth, 2023).

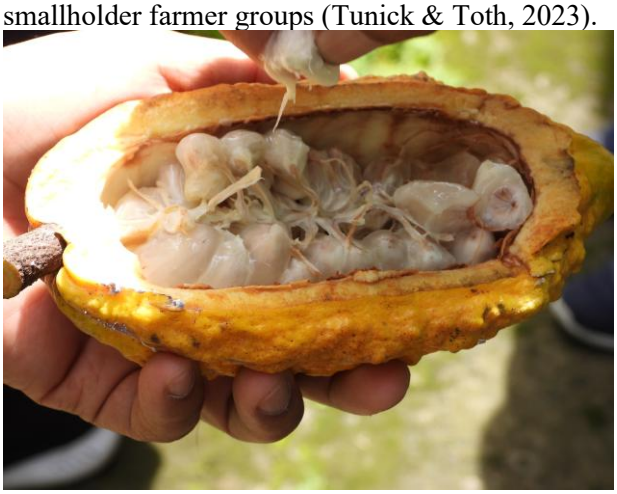

Figure 1. Fresh cocoa beans from a newly opened cocoa pod

Recent studies emphasize that increasing roasting temperature and duration generally reduces polyphenol content and antioxidant activity, although it enhances cocoa aroma and color. This trade-off between functional and sensory quality becomes an important consideration when designing roasting strategies for community-scale production systems (Chu & Lin, 2020; Djikeng et al., 2018). Alternative roasting technologies such as microwave roasting show promising potential to preserve physicochemical quality while improving energy efficiency, making them particularly relevant for tropical regions facing energy access limitations (Schouteten et al., 2023). Furthermore, aroma volatile analysis using techniques such as GC-MS and FTIR highlights that volatile profiles are strongly influenced by bean origin, degree of fermentation, and roasting parameters. Consequently, quality evaluation should carefully consider the specific context of small-scale production environments (Hala et al., 2024; Akoa et al., 2021).

Beyond the technical dimension, this community engagement program also emphasizes the cultural, social, and economic values of local communities. Improving the quality of cocoa beans and locally produced chocolate products has the potential to strengthen competitiveness in both national and international markets while simultaneously increasing farmers' income (Gutiérrez, 2017; Mahrizal et al., 2023). This collaborative framework aligns with existing literature highlighting the importance of designing roasting strategies that are tailored to the characteristics of locally produced cocoa beans, as well as establishing supply chain systems based on locally available resources to ensure the sustainability of tropical cocoa products. The program location at Kampung Coklat Senare was selected to explore the unique potential of cocoa beans from North Lombok and to identify opportunities for improving the cocoa supply chain through advanced knowledge transfer and direct observation of local chocolate production facilities. In addition to technical aspects, the program also highlights sustainability practices, energy efficiency, and strategies to enhance community income through the implementation of optimized roasting technologies (Marpaung et al., 2024; Bordiga et al., 2015).

Figure 2. Community service training session on optimized cocoa roasting techniques.

This community engagement framework also considers product quality and safety through the application of Good Manufacturing Practices (GMP) and quality management systems relevant to small and medium enterprises (SMEs). Recent studies indicate that GMP implementation and the adoption of appropriate QA/QC practices play a crucial role in improving food product quality and ensuring safety for broader public consumption, including in community-based cocoa and chocolate sectors (Indrawan et al., 2023). In addition, community involvement through training sessions, case studies in local cocoa SMEs, and customer satisfaction evaluations serves as a key strategy to ensure that the transferred technologies remain aligned with market preferences and the operational capacities of local business actors (Hanifah et al., 2024). Ultimately, efforts to enhance quality through optimized roasting design and the adoption of sustainable production practices are expected to encourage diversification of local chocolate products, increase community income, and strengthen the resilience of the cocoa supply chain in North Lombok (Onelli et al., 2024).

Methodology

The training module used in this community engagement program was entitled *Enhancing Cocoa Bean Quality through Optimized Roasting Techniques for Sustainable Local Chocolate Production*. The material was delivered by Prof. Wan Rosli Bin Wan Ishak from the School of Health Sciences, Universiti Sains Malaysia (USM), with the support of Prof. Haslina Ahmad and collaborators specializing in Bioactive Materials and Synthesis from Universiti Putra Malaysia (UPM).

The learning objectives included developing participants' understanding of quality determinants of cocoa beans after fermentation, designing optimized roasting strategies to improve both organoleptic quality and functional properties, introducing simple analytical approaches for quality evaluation (without detailed advanced laboratory procedures), and applying sustainability principles within the local cocoa supply chain.

Figure 3. Training module presentation on optimized cocoa bean roasting for sustainable local chocolate production

Result and Discussion

This community engagement activity resulted in an improved understanding among participants regarding how optimized roasting influences the quality of local cocoa beans and the chocolate products produced by local MSMEs. Through lectures, interactive discussions, and direct observation of chocolate production facilities, participants were able to recognize how roasting parameters—including temperature, duration, and humidity—play a crucial role in controlling color, aroma development, and the degree of bioactive compound loss in tropical cocoa beans. This knowledge enrichment aligns with findings from recent studies demonstrating that roasting plays a critical role in the formation of key cocoa aromas through Maillard reaction pathways. Variations in roasting parameters have also been shown to influence phenolic profiles, antioxidant capacity, and volatile compounds associated with chocolate aroma (Chu & Lin, 2020).

In addition, the field visit enabled the identification of practical challenges encountered in local production environments, including variability in bean moisture content, heterogeneity of cocoa beans among smallholder farmer groups, and limited access to energy resources. These findings are consistent with previous studies emphasizing the importance of designing roasting strategies that are tailored to the characteristics of tropical cocoa beans in order to maximize organoleptic quality while preserving nutritional value.

The primary challenges identified during the program included variability in cocoa bean moisture content, limited availability of energy-efficient roasting equipment, and the need for

standardized quality parameters for cocoa beans produced in North Lombok. Strengthening the supply chain through the adoption of Good Handling Practices and Good Manufacturing Practices (GMP) was therefore highlighted as an important step to maintain the quality of chocolate products produced by local MSMEs. Several practical recommendations were proposed, including: (1) standardizing roasting parameters based on the characteristics of local cocoa beans; (2) introducing scientifically validated alternative roasting methods (e.g., microwave roasting) in community facilities with appropriate operational guidelines; (3) implementing simple analytical methods for evaluating cocoa bean and chocolate quality at the MSME level; (4) strengthening supply chain capacity through training programs, technology transfer, and support for environmentally friendly roasting facilities; and (5) enhancing cross-institutional collaboration to promote economically and environmentally sustainable local chocolate production.

Figure 4. Discussion with farmers on cocoa bean characteristics and harvesting practices.

Qualitative results indicated increased participant satisfaction in terms of knowledge improvement, the ability to identify quality-related issues in cocoa beans, and the capacity to plan improvements in community-scale chocolate production processes (Savitri et al., 2021; Wahyudi et al., 2023).

Although several operational constraints remain—such as variations in cocoa bean moisture content, limited access to energy-efficient roasting equipment, and the need for standardized quality parameters for North Lombok cocoa beans—the use of a structured learning module delivered by four international–local experts, combined with direct observation of chocolate production at Kampung Coklat Senare, demonstrated strong potential for improving both cocoa bean quality and the organoleptic characteristics of chocolate produced by local MSMEs. In the long term, the program is expected to enhance community capacity, encourage the adoption of optimized roasting practices, improve energy efficiency, and increase income through the production of more consistent and competitive local chocolate products.

Furthermore, variations in aroma and color preferences were observed in chocolate produced from North Lombok cocoa beans, reflecting patterns similar to those reported in cross-country studies that highlight the interaction between roasting variables and aroma profiles, as well as the importance of cocoa bean origin in determining final product quality (Faturrahman et al., 2021). At the same time, the relationship between cocoa bean moisture content during roasting and the retention of bioactive compounds suggests that optimized roasting design can significantly reduce polyphenol loss when temperature and roasting duration are adjusted according to the specific characteristics of local beans (Mulyati et al., 2020).

Figure 5. Observation of cocoa roasting equipment at the local chocolate production facility.

The role of GMP and Sanitation Standard Operating Procedures (SSOP) in maintaining final product quality at the MSME scale was also emphasized as a fundamental component of sustainable production practices in tropical regions. Operational challenges such as the limited availability of energy-efficient roasting facilities

require a gradual approach, including demonstration activities in community facilities aimed at strengthening technical capacity and reinforcing local raw material supply chains (Indrawan et al., 2023). Ultimately, the implementation of this program may serve as a model for international community engagement initiatives that are relevant to other tropical regions facing similar production contexts.

Conclusion

The main conclusion of this community engagement program is that optimized roasting designs tailored to the characteristics of cocoa beans from North Lombok have significant potential to improve both cocoa bean quality and the quality of chocolate products produced by MSMEs in Kampung Coklat Senare. Knowledge transfer through a combination of theoretical modules and practical activities, supported by field visits and interactive discussions, contributed to strengthening community capacity to adopt energy-efficient and sustainable roasting practices.

Recommendations

Further implementation is recommended to: (1) expand the standardization of roasting parameters based on the characteristics of local cocoa beans; (2) promote the broader adoption of energy-efficient roasting technologies accompanied by comprehensive operational guidelines; (3) strengthen GMP and SSOP training for local chocolate MSMEs; (4) expand partnership networks with educational and research institutions to support innovation in local chocolate products; and (5) ensure the sustainability of the cocoa supply chain through optimal utilization of local resources.

Acknowledgements

The authors would like to express their sincere gratitude to Mr. Pardan, the owner of Kampung Cokelat Senare, for his valuable support and collaboration throughout the implementation of this community service program. Special appreciation is also extended to the Vice Dean for Financial Affairs (Vice Dean II) of the Faculty of Food Technology and Agroindustry for providing financial assistance that significantly contributed to the successful execution of the activities.

The authors also gratefully acknowledge the dedicated support of the faculty staff members—Basri, Zulfiana Jayanti, Hamdan Habibi, Lalu Haeri Ulfi, Saparudin, and Nanda Wafiya—whose active involvement and cooperation played an essential role in ensuring the success of this international community service initiative in Genggelang Village. In addition, sincere appreciation is extended to the local community members and cocoa farmers who actively participated in and supported the activities, as their engagement was fundamental to the achievement of the program's objectives.

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