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Enhancing the Productivity and Competitiveness of Palm Sugar Producers Through Vacuum Evaporator Technology and Digital Marketing in Tapong Village Enrekang Regency

Nursyawal Nacing*, Wilda Widiawati, Imam Akbar, Nirma Septia Ramlan Anjas, Zamri
Faculty of Science and Technology, Universitas Muhammadiyah Enrekang, Indonesia.
*Corresponding Author. Email: nursyawal.nacing@gmail.com

Abstract: This community service program aims to improve the productivity and competitiveness of palm sugar producers in Tapong Village, Enrekang Regency, Indonesia, through the adoption of vacuum evaporator technology and digital marketing. The program employed a participatory approach involving preliminary assessment, training, technology transfer, hands-on practice, mentoring, and evaluation in collaboration with the Maccolli Loloe Farmer Group. Data were collected through observations, interviews, questionnaires, and documentation and analyzed using descriptive qualitative and quantitative methods. The results indicated that the vacuum evaporator reduced processing time from 7–8 hours to 3–4 hours per production cycle, representing an estimated reduction of 50.0–57.1%. Fuel consumption decreased by approximately 40%, while weekly production increased from around 100 liters to 200–300 liters. Weekly revenue also increased from approximately IDR 200,000 to IDR 800,000–1,500,000. In addition to technology adoption, the program promoted hygienic production practices, environmentally friendly packaging, product branding, and digital marketing. Although participants faced challenges in adapting to the new technology, hands-on training and technical assistance helped them improve their production practices. These findings suggest that integrating appropriate technology with capacity-building initiatives and marketing support can improve production efficiency and strengthen the competitiveness of small-scale palm sugar enterprises. Continued technical assistance and systematic monitoring are recommended to support the sustainability of these outcomes.

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Introduction

Palm sugar is one of Indonesia's strategic non timber forest products that plays a significant role in supporting rural livelihoods and local economic development. In many regions, including Enrekang Regency, South Sulawesi, palm sugar production serves as the primary source of income for farming households (OECD., 2024). The product has considerable market potential due to the increasing consumer preference for natural sweeteners and environmentally friendly food products (Widiawati, 2025). However, the competitiveness of palm sugar produced by small-scale farmers remains relatively low because production processes are still dominated by traditional techniques that limit productivity, product quality, and market expansion.

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Pg : 1226-1235

The palm sugar producers in Tapong Village, Enrekang Regency, continue to rely on conventional open-pan heating systems that require long processing times, high fuel consumption, and intensive manual labor (Karta Jayadi, 2025). This production method often results in inconsistent product quality, darker color, lower hygiene standards, and uneven moisture content, reducing the market value of the final product. Furthermore, the absence of modern processing technology has constrained production capacity, making it difficult for producers to meet increasing market demand and compete in broader regional markets.

In addition to technological limitations, palm sugar producers in Tapong Village face challenges related to product packaging. Branding and market access (Widiawati et al., 2025). Before the implementation of the community service program, producers relied primarily on conventional processing methods and traditional marketing channels. The intervention introduced vacuum evaporator technology to improve production efficiency, with a target processing time of approximately 5-6 hours per production cycle and a reduction in fuel consumption of at least 40%. The program also aimed to improve product consistency and extend shelf life by 30%. In terms of marketing, the intervention included the development of one product packaging design and the utilization of 12 marketing channels to expand product visibility and market access. The program further targeted a 25% increase in selling prices and a 30% increase in sales volume through improved product presentation and marketing strategies. These indicators provide measurable targets for evaluating the potential contribution of technology adoption, product development, and digital marketing to the competitiveness of small-scale palm sugar producers. However, the actual changes in processing time, fuel consumption, product quality, selling prices, and sales volume must be verified through field measurements, production records, and sales data collected before and after the intervention.

Several studies have demonstrated that the adoption of appropriate technology significantly improves the efficiency and quality of agro-industrial production (Wiyono, 2020). Vacuum evaporator technology enables evaporation at lower temperatures under reduced pressure, thereby shortening processing time, reducing energy consumption, preserving natural color and aroma, and producing higher-quality palm sugar with more consistent characteristics. Previous research has also shown that digital marketing and attractive product packaging contribute substantially (Pasigai, 2019) to increasing product visibility, expanding market access, strengthening brand identity, and improving the income of small and medium enterprises. Therefore, integrating processing technology with digital marketing strategies represents an effective approach to enhancing the competitiveness of rural agroindustries.

Considering these challenges, a comprehensive community service program was implemented for palm sugar producers in Tapong Village. The program focused on introducing vacuum evaporator technology to improve production efficiency and product quality, developing environmentally friendly packaging and product branding, and strengthening the participants' capacity in digital marketing through training and practical assistance (Secapramana, 2017). This integrated approach was designed not only to improve production performance but also to increase the economic value and market competitiveness of locally produced palm sugar.

The objectives of this community service program were to: 1) improve the productivity and quality of palm sugar through the application of vacuum evaporator technology, 2) enhance the producers' knowledge and skills in environmentally friendly packaging and branding, 3) strengthen digital marketing capabilities to expand market access

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Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

and 4) increase the income and economic resilience of palm sugar producers in Tapong Village. The program is expected to contribute to sustainable community empowerment by promoting technological innovation, value-added product development, and digital transformation within rural agro-industries.

Method

This community service program employed a Participatory Action Research (PAR) approach, emphasizing active collaboration between the implementation team and the partner community throughout the planning, implementation, monitoring, and evaluation stages. PAR enables community members to participate actively in identifying problems, determining priorities, implementing solutions, and reflecting on program outcomes (Kemmis, S., McTaggart, R., & Nixon, 2014). The program was conducted from May to October 2026 in Tapong Village, Maiwa District, Enrekang Regency, South Sulawesi, Indonesia. The partner community was the Maccolli Loloe Farmer Group, with a total of 30 active members. The group's membership and partnership information were documented in a cooperation agreement, Letter No. 098/SP/KT-M/XII/2025. The participants comprised small-scale farmers and household-based palm sugar processors who traditionally relied on conventional production methods. All 30 active members constituted the target beneficiaries of the community service program. The program consisted of four sequential stages.

The first stage involved a preliminary assessment, during which field observations, interviews, and focus group discussions were conducted to identify the community's primary challenges related to production technology, product quality, packaging, and marketing. This assessment also established the partner group's specific needs and priorities. The second stage focused on capacity building through educational activities and technical training. Participants received theoretical and practical instruction on the operation and maintenance of vacuum evaporator technology, hygienic production practices, quality control, environmentally friendly packaging, product branding, and digital marketing strategies. Training activities included lectures, demonstrations, hands-on practicum, and interactive discussions to encourage active participation and knowledge transfer. The third stage involved technology implementation and mentoring. Participants received practical assistance in operating the vacuum evaporator during palm sugar production, applying improved processing techniques, designing product packaging, developing product labels, and utilizing digital platforms, including social media and online marketplaces, to promote their products. Continuous mentoring was provided to support participants in applying their newly acquired knowledge and skills to their production and marketing activities.

The final stage involved monitoring and evaluation to assess the implementation and outcomes of the program. Evaluation focused on participants' knowledge and skills, adoption of vacuum evaporator technology, production practices, product packaging, and the utilization of digital marketing. Data were collected through direct observation, semi-structured interviews, questionnaires, and documentation. Observations were used to monitor participant involvement and technology implementation, while interviews explored participants' experiences, perceptions, and challenges. Questionnaires were used to assess participants' knowledge and satisfaction, and documentation included photographs, attendance records, activity reports, and, where available, production records.

The collected data were analyzed using descriptive qualitative and quantitative methods. Qualitative data obtained from direct observation, semi-structured interviews, and documentation were analyzed thematically through data organization, data reduction,

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Vol. 7, No. 4 (November 2026)
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Pg : 1226-1235

categorization, interpretation, and conclusion drawing. The analysis focused on participants' experiences, challenges in adopting vacuum evaporator technology, changes in production practices, and the implementation of digital marketing strategies. Data triangulation was conducted by comparing information obtained from observations, interviews, questionnaires, and activity documentation to improve the credibility of the findings. Quantitative data obtained from pre-test and post-test questionnaires were analyzed using descriptive statistics to assess changes in participants' knowledge and understanding before and after the training (Fitriani, 2019). The mean scores and percentage changes were calculated to summarize the results. The percentage improvement was calculated by comparing the difference between the post-test and pre-test scores with the pre-test score.

Participant satisfaction was assessed using a five-point Likert scale, ranging from 1 (strongly dissatisfied) to 5 (strongly satisfied). Mean scores were calculated for each evaluation aspect, including the relevance of training materials, trainer competence, practical demonstrations, mentoring activities, training facilities, and usefulness for business development. Higher mean scores indicated greater participant satisfaction. The results were presented in tables and graphs to facilitate interpretation. Finally, qualitative and quantitative findings were integrated to evaluate the program's implementation, participant responses, and contributions to production practices, technological adoption, and marketing capacity.

Result and Discussion

The community service program was implemented through a series of integrated activities, including a preliminary assessment, technical training, vacuum evaporator implementation, mentoring, and program evaluation. The program involved the Macolli Loloe Farmer Group, comprising 30 active members in Tapong Village, Maiwa District, Enrekang Regency, South Sulawesi, Indonesia. The group traditionally processed palm sugar using conventional methods, with a production cycle taking approximately 7-8 hours. This process indicated the need for moving efficient processing technology and improved production practices. The implementation was designed to address production efficiency, technical skills, product quality, and market access. The discussion below distinguishes the program's intended outcomes from the result that were directly measured during implementation.

Improvement in Production Efficiency

One of the main interventions was the introduction of a vacuum evaporator with a capacity of 25 liters per processing cycle. The equipment was introduced through technical training, demonstrations, and direct mentoring to help participants understand its operation and maintenance. Vacuum evaporation is relevant to palm sugar processing because operating pressure affects evaporation conditions and the resulting product quality. Wiyono investigated the effect of vacuum pressure on liquid palm sugar processing and reported that processing conditions were important in achieving the desired product characteristics. Their findings support the relevance of evaluating vacuum evaporation technology in palm sugar production. However, processing performance depends on equipment design, operating pressure, raw material characteristics, and process conditions, therefore, results from previous studies cannot automatically be assumed to represent the performance of the equipment used in this program. Before the intervention, the partner group reported a conventional processing time of approximately 7-8 hours per production cycle. The program initially targeted a reduction of approximately 50%, corresponding to an estimated processing time of 3.5-4 hours per cycle. This figure represents a program target rather than a

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Email: pengabdian@undikma.ac.id

Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

verified outcome unless supported by direct technology implementation should be reported based on field testing under documented operating conditions.

The processing time reduction was calculated using the baseline and post-intervention processing times. According to the final community service report, the conventional production process required approximately 7-8 hours per cycle, whereas the use of the vacuum evaporator reduced processing time to approximately 3-4 hours per cycle. This represents a reported reduction of approximately 50-57.1%. Fuel consumption also decreased by approximately 40% compared with traditional processing methods. Furthermore, weekly production increased from approximately 100 liters before the intervention to 200-300 liters after the implementation of the technology and accompanying mentoring activities. These findings indicate improvements in processing efficiency and production capacity. The report also describes efficiency and production capacity. These findings indicate improvements in processing efficiency and production capacity. The report also describes improvements in product consistency through more controlled processing procedures and the application of standard operating procedures (SOPs), although no numerical product quality measurements were reported. Therefore, the result demonstrates improvements in processing time, fuel efficiency, and weekly production volume, while further quantitative testing would be needed to establish the extent of improvement in product consistency and output per individual processing cycle.



Figure 1. Training on the Implementation of Vacuum Evaporator Technology and Guidance on the Implementation of Standard Operating Procedures (SOPs) for Processing and Quality Control

Improvement in Participants' Knowledge and Technical Skills

The training and mentoring activities were designed to strengthen participants' knowledge and practical skills in operating the vacuum evaporator, maintaining equipment, applying hygienic processing practices, controlling product quality, and preparing palm sugar products for marketing. Through practical demonstrations and direct assistance from the implementation team, participants were introduced to improved processing procedures, equipment operation, and product handling practices. According to the quantitative evaluation, presented in the final community service report, the participants' mean pre-test score was 39.8 while mean post-test score was reported as 80.00. This represents an absolute increase of 40.2 points and a reported relative improvement of approximately 100.9%. These results indicate an improvement in participants' assessed knowledge following the training and mentoring activities.

The percentage improvement was calculated using the following formula:

Percentage improvement (%) = [(Mean post-test score – Mean pre-test score)/ Mean pre-test score] x 100.

Based on the reported scores, the calculation is [(80.0-39.8)/ 39.8] x 100, yielding approximately 101.0% when rounded to one decimal place. The slight difference from the 100.9% reported in the final PKM report may result from rounding or the underlying unrounded scores. The reported values should therefore be checked medium the original

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Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

assessment records before final publication. The findings provide quantitative support for the contribution of the training and mentoring activities to participants' learning outcomes. Nevertheless, the score improvement should be interpreted as a change in assessed knowledge rather than direct evidence of mastery of every practical skill. Further observation of equipment operation, hygienic processing, and quality control practices would help establish the extent to which the knowledge gained was translated into practical competence.

Product Development and Digital Marketing

In addition to production technology, the program addressed product presentation and market access through guidance on hygienic handling, packaging, branding, and digital marketing. These activities were intended to help participants present palm sugar products more consistently and reach potential customers beyond their immediate local market. The importance of marketing capabilities for small and medium sized enterprises is discussed, whose systematic literature review highlights the role of information and communication technologies and business networks in marketing. In the context of the Maccolli Loloe Farmer Group, digital marketing can provide opportunities to communicate product information, display product characteristics, and facilitate contact with potential buyers. Nevertheless, the establishment of digital marketing channels should not be interpreted as evidence of increased sales unless supported by transaction records or other measurable indicators. The outcomes of this component should therefore be evaluated using available evidence, such as the number of marketing channels established, the availability of product information and branding materials, customer inquiries, sales transactions, and changes in sales volume where records are available. These indicators can help determine whether the training has translated into practical marketing activities and business development.



Figure 2. Training in Financial Record-Keeping, Business Planning, and Digital Packaging

Overall Program Evaluation

The program combined technological intervention, practical training, mentoring, and marketing assistance to address several challenges faced by the partner group. Its contribution should be evaluated by distinguishing between activities completed, targets established, and outcomes measured. Processing efficiency should be assessed using recorded production data, while changes in participants' knowledge should be based on assessment scores where available. Product development and marketing outcomes should likewise be supported by documented evidence. This distinction is important for ensuring that the conclusions accurately reflect the evidence collected during implementation. Where baseline and follow-up data are available, the comparison can demonstrate the extent of change following the intervention. Where such data are unavailable, the results should be presented as implementation achievements or preliminary observations rather than quantified impacts.

Participant Satisfaction and Program Acceptance

The program was positively received by participants. Based on the participant satisfaction questionnaire, the highest-rated aspects were the usefulness of the program for business development (4.91/5), trainer competence (4.90/5). and practical demonstrations (4.88/5). The relevance of the training materials received a mean score of 4.85/5, while

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Email: pengabdian@undikma.ac.id

Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

mentoring activities received 4.82/5. Training facilities received a comparatively lower score of 4.55/5. although they remained within the satisfactory category. Overall participant satisfaction reached a mean score of 4.82/5, indicating a very positive response to the community service activities. These findings suggest that participants considered the program relevant and applicable to their production activities. In particular, the high scores for practical demonstrations and usefulness for business development indicate that participants valued activities that directly addressed their production and entrepreneurial needs.

Challenges and Mitigation Strategies

Despite the positive outcomes, the implementation process encountered several challenges, particularly participants' need to adapt to the operation of the vacuum evaporator and integrate the new technology into their established production practices. The Maccolli Loloe Farmer Group had traditionally processed palm sugar using conventional methods, with production taking approximately 7–8 hours per cycle. The introduction of a different processing system therefore required participants to become familiar with equipment operation, process control, and new production procedures.

These challenges are consistent with previous research showing that agricultural technology adoption is influenced by a combination of technical, economic, institutional, and behavioral factors. Nor Diana et al. (2024), in their systematic review of technology adoption among farmers in Southeast Asia, identified technological characteristics, institutional support, economic circumstances, and behavioral factors as important considerations in understanding farmers' willingness to adopt new technologies. Similarly, the meta-analysis by [the authors of the 2021 study] found that access to agricultural extension services and farmer education were positively associated with the adoption of several agricultural technologies, although the strength of these relationships varied across contexts (Nor Diana, M. I., Zulkepli, N. A., Ern, L. K., & Zainol, 2024). These findings suggest that introducing equipment alone may be insufficient; appropriate training, technical support, and adaptation to local production conditions are also important. To address these challenges, the program combined equipment demonstrations, hands-on practice, direct technical assistance, and continued mentoring. This approach allowed participants to observe the production process, practice operating the vacuum evaporator, and receive guidance when difficulties arose. The strategy is consistent with the findings, whose systematic review found that participatory and experiential farmer training can improve knowledge and the adoption of beneficial practices, while also noting that outcomes depend on implementation conditions and the continuity of support (Waddington, H., Snilstveit, B., Hombrados, J. G., Vojtkova, M., Phillips, D., Davies, P., & White, 2014).

The technical intervention also relates to previous research on vacuum evaporation in palm sugar processing. Wiyono et al. (2022) examined the effect of vacuum pressure on liquid palm sugar processing and demonstrated the importance of processing conditions in achieving product characteristics. In the present community service program, the vacuum evaporator was introduced to address the partner group's lengthy traditional processing cycle. According to the final program report, processing time decreased from approximately 7–8 hours to 3-4 hours per cycle, while fuel consumption was reported to decrease by approximately 40%. Weekly production also increased from approximately 100 liters to 200–300 liters (Wiyono, S., Fachry, M. S., Abdullah, S., Sidik, D., 2022). These reported outcomes indicate improvements in processing efficiency and production capacity in the partner group's operational context. The contribution of this program lies in combining

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Email: pengabdian@undikma.ac.id

Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

technology transfer with capacity building and practical assistance within a smallholder palm sugar enterprise. Rather than treating equipment delivery as the sole intervention, the program integrated technical training, production guidance, product packaging, branding, and digital marketing. This integrated approach responds to the partner group's interconnected needs in production and market development. Nevertheless, continued technical assistance and routine monitoring remain important to support consistent equipment use, maintenance, product quality, and the sustainability of the improvements achieved. The experience suggests that introducing appropriate technology should be accompanied by systematic capacity building and post-training support so that participants can incorporate new practices into their regular production activities.

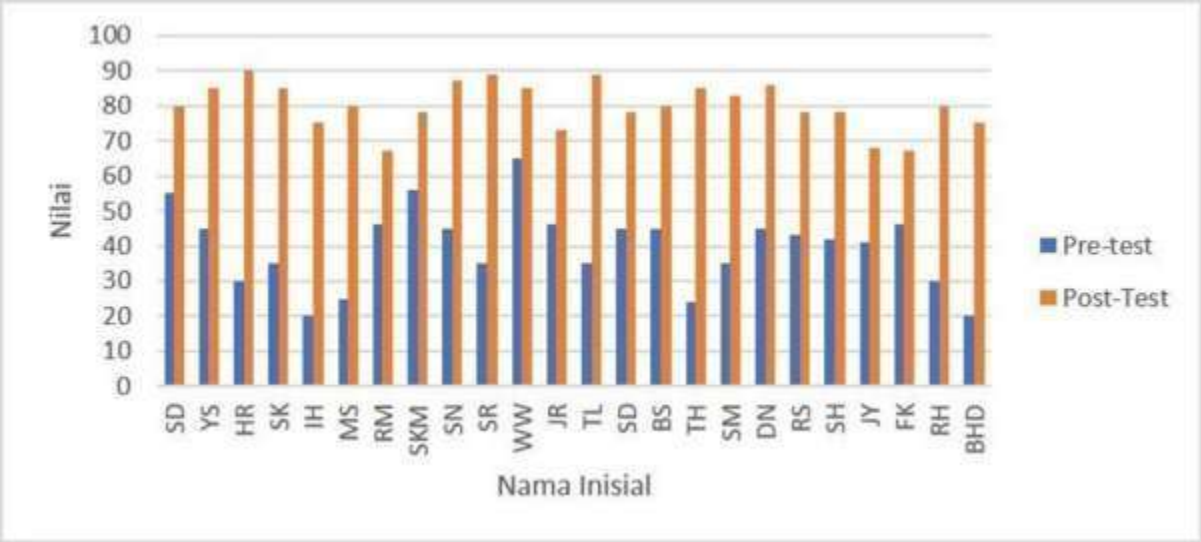


Figure 3. Participants Satisfaction with the community service program.

The graph indicates that post-test scores were higher than pre-test scores for all participants shown, suggesting an improvement in their knowledge and understanding after participating in the program. This improvement may be associated with the program's combination of technology demonstrations, hands-on practice, and direct assistance in palm sugar processing and product development.

These findings are consistent with Nor Diana et al. (2024), whose systematic review discusses factors influencing farmers' adoption of agricultural technology. Their review highlights the importance of considering the factors that shape farmers' willingness and ability to adopt new technologies. In addition, Waddington et al. (2014) examined farmer field schools and reported evidence concerning the role of participatory agricultural learning approaches in improving farming practices and farmer outcomes. These studies support the relevance of practical learning and capacity-building activities when introducing new production methods to farming communities.

In the context of this program, the improvement in post-test scores provides an indication that the training activities helped participants understand the introduced technology and production practices. Nevertheless, the test scores should be interpreted as evidence of improved knowledge or understanding rather than direct proof of long-term technology adoption or increased production performance. Further monitoring is needed to determine whether the knowledge gained is consistently applied in daily production activities. Therefore, the program's contribution lies not only in introducing appropriate technology but also in combining equipment demonstrations, practical training, and

Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

mentoring to strengthen participants' capacity to improve their production practices.

Conclusion

The community service program successfully achieved its primary objective of improving the productivity of palm sugar producers in Tapong Village through the implementation of vacuum evaporator technology and digital marketing strategies. The program enhanced participants' knowledge and technical skills in hygienic production practices, vacuum evaporator operation, environmentally friendly packaging, product branding, and digital marketing. Participant feedback indicated a high level of satisfaction with the training and mentoring activities, demonstrating the relevance and usefulness of the program in addressing the community's needs. The integration of appropriate processing technology with capacity-building activities contributed to improved production practices and strengthened the participants' ability to add value to their products and expand market opportunities. Although several production-related challenges were encountered during the implementation process, continuous mentoring and technical assistance enabled participants to gradually adapt to the new technology and production methods. Overall, this community service program demonstrates that combining technological innovation, community empowerment, and digital marketing is an effective strategy for enhancing the productivity and competitiveness of small-scale palm sugar producers. The experience gained from this program may serve as a practical model for similar community empowerment initiatives aimed at promoting sustainable rural economic development.

Recommendation

To sustain the outcomes of this community service program, the following recommendations are proposed for the relevant stakeholders:

1) For the Partner Group (Palm Sugar Producers).

   The Maccolli Loloe Farmer Group is encouraged to conduct regular maintenance of the vacuum evaporator, apply hygienic production procedures, and maintain product quality standards. Continuous skills development, product innovation, improved packaging, and digital marketing should be strengthened to support the long-term adoption of improved production practices and increase product competitiveness.

2) For Local Government and Related Agencies.

   Local government agencies and related stakeholders are encouraged to support palm sugar producers through access to appropriate processing technologies, technical assistance, financial support, business development programs, and wider marketing networks. These initiatives can help strengthen local palm sugar enterprises and improve the economic welfare of rural producers.

3) For Future Community Service Teams.

   Future community service programs should provide follow-up training and monitoring to evaluate the sustained use of the technology and its impact on production efficiency and product quality. Collaboration among universities, government institutions, and community organizations should also be strengthened to support innovation and community empowerment. Similar programs may be replicated in other palm sugar-producing areas, with implementation strategies adapted to local needs and available resources.

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Vol. 7, No. 4 (November 2026)
E-ISSN : 2722-5097
Pg : 1226-1235

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