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Eco-Enzyme Innovation: Transforming Pineapple Waste into Sustainable Cleaning Liquids through Community Empowerment in Tangkit Baru Village

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Abstract
Tangkit Baru Village is a major pineapple production center in Jambi, yielding over 728,000 quintals annually. However, this massive production generates significant organic waste from local home industries, which remains largely unmanaged. This community service program aimed to address this environmental challenge by empowering the Women's Farmers Group (locally known as *Kelompok Wanita Tani* or KWT) through eco-enzyme technology. The program was implemented in four stages: Survey, Socialization, Technical Training (using a 1:3:10 fermentation ratio), and a three-month Mentoring phase. The results demonstrated a significant impact, with participants' knowledge increasing by 41.1% (from 45.3% to 86.4%). Technical success was high, with 80% of participants successfully producing quality eco-enzymes (pH < 4.0). Furthermore, 90% of participants adopted the liquid for household cleaning, indicating a profound behavioral shift. This program proves that eco-enzyme technology is a feasible, low-cost solution for agro-industrial waste recovery while enhancing community resilience and sustainable waste management practices.

Keywords: Climate Action, Community Empowerment, Eco-Enzyme, Pineapple Waste, Responsible Consumption and Production

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INTRODUCTION

Tangkit Baru is a village located in Sungai Gelam sub-district, Muaro Jambi Regency, Jambi, Indonesia, which serves as a vital center for pineapple production. Most residents depend on pineapple plantations as their primary source of livelihood, with production reaching 728,333.46 quintals in 2024 according to the Central Statistics Agency (BPS). The village's economic activities are heavily driven by the Women's Farmers Group (KWT), which manages various pineapple-based home industries, including the production of dodol, jam, chips, and salai.

While these industries bolster the local economy, they simultaneously generate a substantial amount of organic waste, particularly fruit peels, which creates significant environmental challenges. The current absence of

a comprehensive and integrated waste management system has led to the accumulation of waste that is often disposed of without further processing. This condition contradicts the sustainable practices promoted by global environmental frameworks (Elsaid & Aghezzaf, 2015; Marshall & Farahbakhsh, 2013).

Theoretically, this ineffective handling reflects gaps in the Integrated Solid Waste Management (ISWM) framework, which emphasizes reducing, reusing, and recycling waste before disposal. As noted by Awasthi et al. (2019) and Kiyasudeen et al. (2016), organic waste requires biological processing to prevent environmental degradation. Without such processing, accumulated waste can trigger foul odors, attract pests, and contribute significantly to greenhouse gas emissions (Atelge et al., 2020; Sharma et al., 2024; Westerman & Bicudo, 2005)

In response to these challenges, eco-enzyme technology emerges as a suitable low-cost and community-friendly solution (Aini et al., 2022; Din et al., 2025; Proni et al., 2025; Sudarman et al., 2025). Eco-enzyme is a fermented liquid produced from fruit and vegetable residues mixed with sugar and water, based on the principles of anaerobic fermentation. The resulting solution contains organic acids, enzymes, and beneficial metabolites that function as natural disinfectants, all-purpose cleaners, biopesticides, and biofertilizers (Kalita & Patra, 2022; Rochyani et al., 2020; Vidalia et al., 2023). Despite its benefits, many previous studies focus on general household waste without addressing the specific agro-industrial pineapple waste found in major production hubs like Tangkit Baru.

The novelty of this program lies in its integrated approach through 'Technology Training for Transforming Pineapple Waste into Sustainable Cleaning Liquids,' specifically targeting KWT in a high-production pineapple region. While general eco-enzyme applications are well-documented, this intervention focuses on large-scale agro-industrial waste recovery in a primary production hub.

METHODS

Project Location and Participants

The community service program was strategically conducted in Tangkit Baru Village, Sungai Gelam Sub-district, Muaro Jambi Regency. This location was selected due to its status as a primary pineapple production hub in the region. The participants involved were 20 members of the Women Farmers Group (KWT), aged between 25 and 55 years. These individuals were selected using a purposive sampling method, ensuring that all participants were actively engaged in the local pineapple processing home industries.

Program Implementation Stages

The intervention was executed through a systematic four-stage framework designed to ensure community engagement and technical mastery:

1. Survey Stage: The team conducted initial field observations and mapped existing waste management practices. This stage identified the specific types of waste generated (primarily pineapple peels) and assessed the community's readiness for biological waste processing.

2. Socialization Stage: This phase focused on building community trust and providing a theoretical foundation. Participants were introduced to the environmental hazards of untreated organic waste and the ecological benefits of eco-enzyme as a sustainable alternative to chemical agents.
3. Technical Training Phase: This was the core intervention where participants learned the anaerobic fermentation process. The training strictly followed the standard fermentation ratio of 1:3:10, consisting of 1 part molasses/sugar, 3 parts organic fruit waste (pineapple peels), and 10 parts waters. Participants were taught how to prepare the waste, measure the ingredients accurately, and use airtight fermentation containers to ensure optimal results.
4. Mentoring Phase: To ensure success, the team provided continuous mentoring over a three-month fermentation period. This involved periodic monitoring of the containers, managing gas buildup during the first month, and ensuring the stability of the mixture until it reached the harvest stage.

Instruments and Data Analysis

To evaluate the success of the program, two primary instruments were utilized:

1. Knowledge Assessment: Pre-test and post-test questionnaires consisting of several indicators regarding waste management and eco-enzyme technology were distributed to measure the gain of the participants.
2. Product Quality Indicators: The technical success of the eco-enzyme was measured based on physical standards, specifically achieving a pH level of less than 4.0, a dark brown color, and a characteristic fresh fermented aroma.
3. Adoption Tracking: A follow-up survey was conducted to determine how many participants integrated the product into their daily routines (e.g., as household cleaners or fertilizers).

RESULTS AND DISCUSSION

This community service activity was carried out with the Women's Farmers Group (KWT) in Tangkit Baru, Muaro Jambi, beginning on 1 October 2023. The massive pineapple production in Tangkit Baru, which exceeds 728,000 quintals annually, inherently generates a vast amount of organic residue that poses significant environmental risks. Untreated vegetable and fruit peel waste is often difficult to decompose, potentially leading to soil degradation and water pollution (Arvanitoyannis & Varzakas, 2008; Sharma et al., 2019). To mitigate these ecological threats, the program implemented a circular economy approach by converting waste into eco-enzymes through systematic stages of collection, separation, fermentation, and formulation. The program commenced with a formal ceremony involving stakeholders, as shown in Figure 1.

Figure 1. Opening of the Community Service Event of the Department of Agricultural Technology

Figure 1 shows the opening session of the program, which served as the official starting point for the collaboration between the Department of Agricultural Technology and the Tangkit Baru community. This phase was crucial for establishing the administrative foundation and aligning the program's objectives with the specific needs of the local farming group.

Following the opening, the team provided detailed technical learning materials. This session focused on the biochemical potential of fruit and vegetable peel waste as a sustainable raw material for cleaning fluids, as documented in Figure 2.

Figure 2. Providing Learning Materials on Processing Fruit and Vegetable Peel Waste into Cleaning Fluid Raw Materials

Figure 2 shows the training participants listening to the material with great enthusiasm. A total of 20 members of the Women's Farmers Group (KWT) took part in the training, where they learned the science behind fermentation and the chemical properties of eco-enzymes. All participants prepared their own materials, signifying high initial engagement with the proposed waste management technology.

After the theoretical session, the program moved to the practical stage with a live demonstration. Participants were guided through the step-by-step process of mixing waste, sugar, and water using the 1:3:10 ratio, as shown in Figure 3.

Figure 3. Demonstration of Making Cleaning Fluid from Fruit and Vegetable Peel Waste

Figure 3 illustrates the demonstration session delivered by Lisani, S.TP., MP, and the team. This hands-on experience was vital for translating theoretical concepts into practical skills, allowing participants to handle measurements and fermentation containers independently to ensure the quality of the organic extract.

To ensure a deep understanding, a dedicated session was held for interaction between the participants and the speakers. This session allowed for the clarification of technical details regarding the fermentation period and maintenance, as presented in Figure 4.

Figure 4. Discussion and Q&A during Training and Extension on The Use of Fruit and Vegetable Waste as Cleaning Fluid

Figure 4 captures the discussion and Q&A session, where participants actively engaged with the instructors. This dialogue ensured that the KWT members felt confident enough to maintain the fermentation process at home during the critical three-month period required for the eco-enzyme to mature properly.

The effectiveness of this structured intervention was evaluated through pre-test and post-test assessments to measure the change in participant literacy. The results of this knowledge evaluation are presented in Table 1.

Table 1. Improvement in Participant Knowledge

Knowledge Aspect	Pre-test	Post-test	Improvement
Understanding eco-enzyme	40%	85%	+45%
Fermentation technique	35%	82%	+47%
Benefits of eco-enzyme	50%	88%	+38%
Waste management	45%	80%	+35%
Average			41%

Based on the data in Table 1, there was a significant improvement in participant literacy, with average scores rising from 45.3% to 86.4%, marking a 41.1% gain. This improvement directly addresses the critical need for technical literacy in rural areas, proving that the combination of formal socialization and live demonstrations is effective for empowering local communities. Previous studies, such as (Ernawati et al., 2023; Hasanah, 2021; Hemalatha & Visantini, 2020; Rohyani et al., 2022; Permatananda et al., 2023) and community-based eco-enzyme programs in rural agricultural areas, also reported that continuous mentoring significantly improves product quality and participant independence.

Furthermore, the technical implementation was monitored until the harvest period, where 80% of participants successfully produced high-quality eco-enzyme with a pH below 4.0. The high adoption rate and various uses of the final product are summarized in Table 2.

Table 2. Utilization of Eco-Enzyme by Participants

Usage Type	Participants	Percentage
Household cleaner	18	90%
Fertilizer	14	70%
Pest control	10	50%
Drain cleaner	12	60%
Commercialization plan	6	30%

The results of this program reinforce the necessity of localized waste recovery as a sustainable solution for agro-industrial centers. By converting pineapple peels into functional cleaning agents, the community has effectively applied the *Integrated Solid Waste Management* framework (Elsaid & Aghezzaf, 2015). This biological processing is essential to prevent environmental degradation, such as greenhouse gas emissions and unpleasant odors caused by untreated organic waste in residential areas (Awasthi et al., 2019; Atelge et al., 2020).

The success of the fermentation process, which resulted in a final product with a pH level below 4.0 for 80% of the participants, provides a critical scientific validation. Organic waste that is not biologically stabilized can lead to leaching and soil acidification; however, the attainment of an acidic pH ensures the production of organic acids, such as acetic acid, which are responsible for the antimicrobial properties of the fluid. This achievement confirms that the participants effectively mastered the anaerobic fermentation environment, producing a safe and effective household product (Permatananda et al., 2023; Rochyani et al., 2020).

Furthermore, the data in Table 2 highlights a versatile adoption pattern. While 90% of participants used the eco-enzyme as a cleaner, a significant 70% also applied it as a liquid fertilizer and 50% for pest control. This multi-functional use directly supports the agricultural sustainability of Tangkit Baru, where residents depend heavily on pineapple plantations. By using the fermented extract as a bio-fertilizer, farmers can reduce reliance on synthetic chemicals, thereby lowering production costs and promoting an eco-friendly ecosystem (Hasanah, 2021; Sharma et al., 2019).

The shift in knowledge scores was facilitated by continuous formative and summative evaluations during the mentoring phase. This sustained engagement is vital because the primary challenge in community programs is the high drop-out rate during long fermentation periods. The final high scores prove that the KWT members gained a functional understanding of technology development, moving beyond simple disposal to waste valorization (Sudarman et al., 2025; Chaerani et al., 2025).

Economically, the fact that 30% of participants have developed commercialization plans indicates a transition toward green entrepreneurship. Given that Tangkit Baru is a hub for pineapple-based home industries, integrating eco-enzyme production as a side-stream industry adds a new revenue stream while solving the waste problems of local chip and dodol production. This initiative turns a previously discarded "external cost" into a marketable "internal asset," enhancing the economic resilience of the farming group (Lee et al., 2020; Moh & Manaf, 2017).

From a social perspective, the 90% adoption rate indicates that the program has successfully enhanced the community's capacity to solve their own problems using local resources (Perkins & Zimmerman, 1995). In conclusion, the intervention has successfully transformed a significant environmental liability into a value-added asset. By aligning technical results with environmental and social objectives, this program serves as a robust model for sustainable village development, proving that with the right technology and engagement, agricultural waste can be managed in a way that is environmentally sound and economically beneficial.

CONCLUSION

The community service program in Tangkit Baru Village has successfully demonstrated that eco-enzyme technology is an effective and replicable solution for managing large-scale pineapple waste. Through a systematic approach of training and mentoring, the program achieved a significant 41.1% increase in the community's technical knowledge and an 80% success rate in producing high-quality fermented cleaners. The exceptionally

high adoption rate of 90% among the Women's Farmers Group (KWT) signifies that the program has moved beyond mere socialization into a permanent behavioral change toward environmental sustainability. Ultimately, this initiative not only reduces the environmental burden of agro-industrial waste but also provides economic benefits to the village, serving as a model for other pineapple-producing regions in Indonesia.

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DECRALATIONS

Author Contribution	:	S: Conceptualization, Project Administration, Writing - Original Draft, and Formal Analysis; L: Technical Methodology, Data Curation, and Resources; E: Visualization, Supervision, and Validation; FF: Investigation and Field Mentoring; RS: Writing – Review & Editing and Software; R: Writing – Review, Editing, and Proof Reading.
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