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Eco-Enzyme-Based Dishwashing Soap Production as a Step Toward Achieving a Green Pesantren

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ABSTRACT

The Integrated Islamic Boarding School Al Falah Abu Lam U produces approximately 30 kg of organic waste daily, primarily from dormitory activities. This waste has not yet been optimally managed, despite its high potential to be converted into eco-enzyme (EE), a versatile product that can be used as fertilizer and natural dishwashing soap. This community service program aimed to empower the pesantren community through the utilization of fruit peel waste for the production of EE and EE-based dishwashing soap. The program involved training male and female students (santriwan and santriwati) as well as female teachers (ustadzah) in sorting organic waste, fermenting fruit peels to produce EE, and using it to formulate dishwashing soap. As a result of the activities, approximately 100 kg of fruit peels were successfully fermented, producing around 342.5 L of EE. For soap production, around 0.4 L of EE was used per liter of soap. Participants also demonstrated the ability to independently produce both EE and dishwashing soap. Results of the feedback questionnaire on the implementation of the EE and EE-based dishwashing soap production program showed that all participants expressed satisfaction with the program, felt it met their expectations, and stated that the outcomes were easy to apply in daily life. The majority also indicated a willingness to continue using the EE-based soap and to introduce it to others. These findings suggest that the program not only enhanced environmental awareness and waste management skills within the pesantren but also successfully integrated scientific knowledge into everyday practice with high levels of community acceptance and engagement.

1. Introduction

Organic waste represents a persistent global challenge, contributing significantly to greenhouse gas emissions, environmental pollution, and inefficient resource use. According to the FAO, roughly one-third of food produced globally is lost or wasted, creating not only ecological burdens but also missed opportunities for circular economy practices. In response, eco-enzyme (EE)—a bio-solution derived from the fermentation of organic materials with brown sugar and water—has gained traction as an affordable, sustainable alternative for waste management, particularly in community-based settings. EE exhibits multifunctional properties, including antibacterial, enzymatic, and nutrient-rich characteristics, making it useful as a natural cleaning agent, fertilizer, and even a health-supportive household product (Patricia, 2022; Nazim & Meera, 2017).

The fermentation process produces bioactive compounds such as acetic acid, lipase, trypsin, and amylase, which have demonstrated antibacterial and biodegrading capabilities (Sulaeman et al., 2005; Sambaraju et al., 2020; Sultan & Zikri, 2021). Additionally, EE contains nitrate (NO_3^-) and carbonate (CO_3^{2-}), supporting its function as an organic fertilizer (Rasit et al., 2019; Tokpohozin et al., 2015). These properties position EE as a promising solution for transforming household and institutional waste into value-added products aligned with the zero-waste model.

Despite growing awareness of sustainable waste practices globally, many educational institutions—particularly Islamic boarding schools (*pesantren*)—in Indonesia continue to lack structured systems for managing organic waste. This represents a missed opportunity not only for environmental protection but also for practical student empowerment and skill development.

Pesantren Terpadu Al Falah Abu Lam U in Aceh Besar, Indonesia, is a modern Islamic boarding school that accommodates 484 students and more than 20 teachers. The *pesantren* provides three daily meals, resulting in the generation of approximately 50 kg of waste per day, of which 30 kg is organic waste such as fruit and vegetable scraps. Although the campus features green spaces with vegetable gardens and beneficial plants used for ecological education, the organic waste generated remains largely underutilized.

This community service initiative was designed to introduce eco-enzyme technology as a practical and science-based solution for organic waste valorization within the *pesantren*. Through a series of participatory workshops, students (*santriwan* and *santriwati*) and teachers (*ustadzah*) were trained to sort organic waste, conduct the fermentation process, and use the resulting EE in environmentally friendly dishwashing soap production. The program also aimed to foster basic biotechnological skills and entrepreneurial thinking among participants.

Despite the *pesantren*'s potential for circular waste management, the lack of systematic practices highlights a critical gap. Immediate action is needed to integrate sustainable waste management solutions that are both contextually relevant and scientifically grounded.

The objective of this initiative is to empower students and teachers through the introduction of eco-enzyme production as a sustainable waste management solution. This article aims to document the process, outcomes, and implications of the initiative as a replicable model for integrating environmental biotechnology into Islamic education.

The findings contribute to science and technology in the field of waste-to-resource biotechnology and support progress toward multiple Sustainable Development Goals (SDGs), including SDG 6 (Clean Water and Sanitation), SDG 12 (Responsible Consumption and

Production), SDG 13 (Climate Action), and SDG 15 (Life on Land), by reducing chemical pollutants, minimizing methane emissions, and promoting organic fertilization for soil health.

2. Methods

This community service program employed a product-based intervention model to address the issue of organic waste accumulation within the pesantren environment. The initiative was designed with two core focus areas: (1) production and (2) marketing, implemented through structured training, hands-on activities, and continuous mentoring.

2.1 Target Community and Participant Profile

The primary beneficiaries of the program were 20 individuals, including junior and senior high school students (*santrivan* and *santrivati*) and female dormitory mentors (*ustadzah*) residing in the pesantren. Participants were selected based on their interest and availability, and participation was voluntary. Most had no prior experience in organic waste processing. Their involvement ranged from initial training to post-program follow-up activities.

2.2 Community Service Approach and Implementation Stages

The program adopted a participatory and capacity-building approach, emphasizing local empowerment through knowledge transfer and product development. Activities were divided into two sectors:

a. Production Sector. Activities in this sector included:

- **Awareness sessions** on the potential of organic waste, emphasizing its transformation into eco-enzyme (EE) as a sustainable, value-added product.
- **Hands-on training** on selecting and preparing quality organic waste (primarily fruit and vegetable scraps) for fermentation.
- **Fermentation process**, conducted over a period of 3 months and 10 days using the standard ratio of 1 part organic waste : 3 parts brown sugar : 10 parts water in an anaerobic environment.
- **Post-fermentation processing**, where EE was extracted, filtered, and stored in clean containers for use.
- **Product development workshops**, in which participants were guided to formulate dishwashing liquid and liquid organic fertilizer using the produced EE.
- **Consultation and monitoring**, allowing participants to access technical support, quality control guidance, and ongoing mentoring.

b. Marketing Sector. This sector focused on:

- **Product packaging and labeling design**, to enhance product readiness for distribution and public presentation.
- **Logistical and technical support** during training implementation, including venue provision, equipment, and materials.
- **Participant engagement**, encouraging active involvement in every stage of training and production, fostering ownership and sustainability.

2.3 Technology and Materials Used

The fermentation process used common materials such as fruit and vegetable scraps, brown sugar, and water. Tools included airtight plastic containers, measuring instruments (graduated cylinders, digital scales), and sieves for filtering. Educational media such as slides, posters, and demonstration videos supported learning delivery. Bottles and printed labels were provided for packaging final products.

2.4 Monitoring and Evaluation Strategy

Program effectiveness was assessed through continuous monitoring during and after the intervention. Evaluation focused on:

- **Sustainability**, measured by the continuity of EE production (e.g., the number of batches produced post-program).
- **Product quality**, assessed through sensory evaluation (color, odor, clarity) and pH testing.
- **Participant feedback**, collected through structured questionnaires and informal interviews to assess satisfaction, learning outcomes, and likelihood of continued adoption.

Monitoring was carried out through on-site visits and follow-up communication via WhatsApp groups, ensuring sustained engagement and technical support.

2.5 Indicators of Success

Indicators of program success included:

- Independent production of EE by participants after program completion.
- Development of at least two derivative products (dishwashing liquid and fertilizer).
- Participant satisfaction level above 80%, as recorded in post-activity feedback.
- Evidence of interest in promoting EE-based products to the broader community.

3. Result and Discussion

In general, the community service activities were carried out in several sequential stages. The program began with educational sessions on the utilization of organic waste for eco-enzyme (EE) production, followed by the selection of appropriate organic waste materials—primarily fruit and vegetable residues—for fermentation over a period of three months. Once the fermentation process was complete, the EE was harvested and subsequently used in training sessions focused on processing EE into derivative products, specifically dishwashing liquid and liquid fertilizer.

In addition to these activities, the service team established a consultation channel via WhatsApp to assist community partners with technical issues and product quality monitoring, ensuring continuity and support throughout the implementation phase.

In the implementation of this community service program, two key applications of science and technology were highlighted: biotechnological transformation and organic chemical transformation. The biotechnological transformation refers to the fermentation process of organic waste, particularly fruit peels, carried out over a period of three months using naturally occurring microorganisms. This process produces EE, a fermented liquid rich in bioactive compounds such as acetic acid and enzymes (e.g., amylase and lipase), which function as natural antibacterial and cleaning agents. It reflects the use of microbial biotechnology to convert organic waste into environmentally beneficial products through a low-cost, sustainable approach.

Meanwhile, the organic chemical transformation occurs during the conversion of the EE filtrate into liquid dishwashing soap. This involves combining the fermented EE with additional ingredients such as natural surfactants, emulsifiers, and stabilizing agents, enabling mild organic chemical reactions that produce a functional cleaning product with improved consistency, stability, and scent. This transformation demonstrates how naturally derived organic compounds can be processed and enhanced for practical household applications. Together, these two forms of transformation represent an effective integration of environmentally friendly technology into

community-based waste management, supporting circular economy principles and contributing to sustainable development goals.

The technological concepts and processes applied throughout the project are illustrated in Figure 1 below.

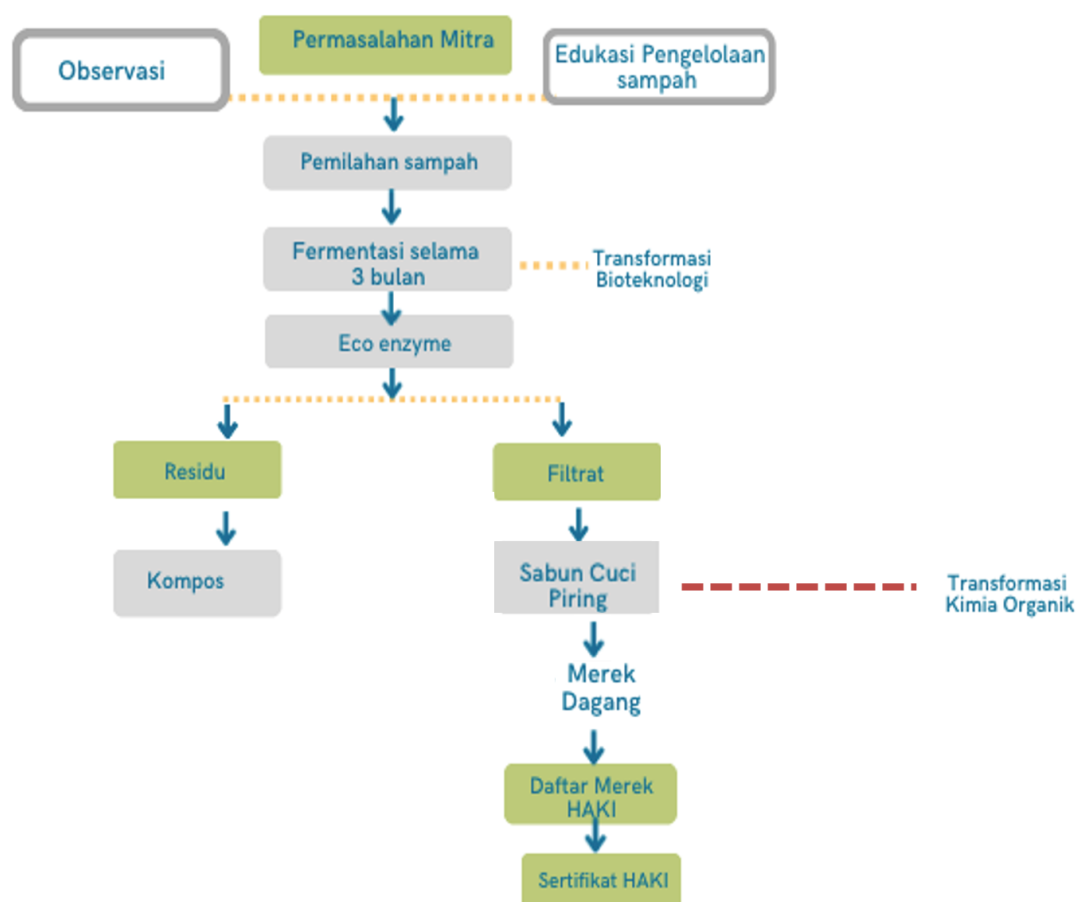


Figure 1. Application of Science and Technology (IPTEK) in the Community Service Program

3.1 Utilization of Organic Waste

In this stage, educational sessions were conducted on the management of both organic and inorganic waste. The activity also included a socialization session on EE and its various benefits. This session was held on Wednesday, June 5, 2024, and was attended by key stakeholders including the pesantren leadership, school principal, and teachers. The inclusion of this educational component directly contributed to raising environmental awareness and promoting sustainable behavior within the pesantren community. This activity aligns with the Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production), by encouraging the reduction and reuse of waste.

3.2 Eco-Enzyme Production

The eco-enzyme (EE) production phase was conducted on Saturday, June 8, 2024, involving participants from the PKK Women's Group of Gampong Lam Jampok, along with representatives from Pesantren Al-Falah, including the leadership, school principal, male/female teachers (ustadz/ustadzah), and male/female students (santri/santriwati).

The EE production process began with the cleaning of collected fruit peels, which were gathered by the dormitory residents. The peels were then chopped into smaller pieces and placed into sealed containers. Subsequently, molasses (dissolved brown cane sugar) was added to the container filled with fruit peels, stirred evenly, and tightly sealed. These containers were then stored in a dark location away from sunlight.

To prevent potential explosions due to gas buildup during fermentation, the lids were opened briefly on day 2, day 7, day 15, and day 30. After the final opening on day 30, the containers were resealed and left to ferment until the harvest period (three months and ten days), with occasional inspections to monitor the fermentation process. The fermentation conditions and resulting eco-enzyme products are illustrated in Figure 2 below.



Figure 2. (a) Photo of the fermentation process during EE production, and (b) Photo of the eco-enzyme (EE) liquid after fermentation.

This stage contributes to several Sustainable Development Goals (SDGs). It directly supports SDG 12 (Responsible Consumption and Production) by reducing organic waste through community-based recycling and reuse initiatives. It also aligns with SDG 6 (Clean Water and Sanitation) by promoting the use of natural, biodegradable cleaning agents like EE, which help reduce chemical pollutants in water systems. Additionally, the practice of fermenting organic waste instead of allowing it to decompose openly contributes to SDG 13 (Climate Action), by raising awareness on the climate benefits of waste management and minimizing methane emissions from unmanaged decomposition. Furthermore, the use of EE residues as liquid fertilizer supports SDG 15 (Life on Land) by enhancing soil health and reducing dependence on synthetic agrochemicals.

3.3 Production of EE-Based Dishwashing Soap

While awaiting the first harvest of the eco-enzyme (EE), the pesantren community was trained to produce value-added products—specifically, EE-based dishwashing soap. This activity was conducted on Tuesday, August 20, 2024, at Pesantren Al-Falah. Participants in this session included the school principal, teachers, students, as well as students from the thematic

community service program (KKN Tematik). The EE-based dishwashing soap products created during this activity are presented in Figure 3 below.



Figure 3. EE-Based Dishwashing Soap Products Produced

This stage contributes to SDG 6, which aims to improve water quality by reducing pollution, minimizing the release of hazardous chemicals, and substantially increasing safe reuse practices. By promoting the use of EE-based dishwashing soap—an environmentally friendly, non-toxic alternative to conventional chemical detergents—the activity supports safer household sanitation practices and reduces the potential for chemical contamination in wastewater. In doing so, the pesantren community is empowered to adopt and disseminate sustainable hygiene solutions aligned with global water and health goals.

3.4 Partner Feedback on the Implementation of the Community Service Program

The EE-based dishwashing soap successfully produced during the training was distributed to the dormitory canteen staff as well as to ustadz and ustadzah residing within the pesantren environment. Following the distribution, feedback was solicited from the pesantren community through a structured questionnaire to assess their responses to the community service program.

The results of the feedback questionnaire are presented in Table 1 below.

Table 1. Results of the Feedback Questionnaire on the Implementation of the EE and EE-Based Dishwashing Soap Production Program

No	Statement	Assessment Percentage			
		Strongly Agree	Agree	Disagree	Strongly Disagree
1	I am satisfied with the community service activity on the production of eco-enzyme and EE-based dishwashing soap organized by the service team from USK	85.7	14.3	0	0
2	The community service activity conducted by the USK service team through the training on eco-enzyme and EE-based dishwashing soap production met my expectations	85.7	14.3	0	0

No	Statement	Assessment Percentage			
		Strongly Agree	Agree	Disagree	Strongly Disagree
3	The service team involved in the community service activity provided support in accordance with my needs	71.4	28.6	0	0
4	Any complaints, questions, or issues raised were responded to appropriately by the USK service team involved in the program	57.1	42.9	0	0
5	What I gained from this activity is easy to apply in daily life	85.7	14.3	0	0
6	I will continue to use the dishwashing soap produced during this activity	42.9	57.1	0	0
7	I will introduce the dishwashing soap produced in this activity to relatives, guardians of students, and other parties	71.4	28.6	0	0
8	I prefer using this eco-enzyme-based liquid dishwashing soap over other commercial liquid soap products	57.1	28.6	14.3	0
9	I hope similar community service activities will be conducted again in the future	85.7	14.3	0	0
Average		71.41	27.0	1.59	0

The evaluation results of the community service program, which focused on training participants in the production of eco-enzyme (EE) and EE-based dishwashing soap, indicate a high level of acceptance within the pesantren community. Based on structured questionnaire responses, 71.41% of participants selected "Strongly Agree" and 27.0% selected "Agree" for the majority of statements related to the quality of the activity, relevance of the materials, and applicability of the knowledge gained in daily life. No participants selected "Strongly Disagree," and only one item received a "Disagree" response (14.3%), specifically concerning preference for EE-based dishwashing soap compared to commercial products. These findings suggest that the program was highly successful in achieving its objectives of knowledge transfer and skill development in organic waste management.

The highest levels of satisfaction (85.7% "Strongly Agree") were recorded in statements regarding overall satisfaction with the program, its alignment with participants' expectations, the practical usefulness of the knowledge gained, and the desire for similar activities in the future. Based on Table 1, it can be seen that the implementation of the community service program met the expectations of the partner community. However, regarding the preference for using EE-based dishwashing soap over commercial products, 14.3% of participants expressed disagreement. This was primarily due to the natural odor of the EE-based soap, which retained the original scent of the eco-enzyme. As a result, some participants expressed a dislike for the scent and suggested the addition of fragrance to improve product acceptability. The fruit peels most commonly generated from the pesantren kitchen include those of watermelon, orange, papaya, and banana. These peels serve as the primary raw materials in the fermentation process

for EE production. The scent of the resulting EE reflects the characteristics of the fruit peels used, resulting in a natural scent that is a composite of watermelon, orange, papaya, and banana. While this organic scent is an inherent feature of EE, it may not always align with user preferences—particularly for household cleaning products such as dishwashing soap. To enhance the scent of EE-based dishwashing soap, improvements can be achieved through the addition of esters or by using specific fruit peels during EE fermentation. For instance, producing EE exclusively from banana or orange peels may yield a more distinct and pleasant scent, thereby increasing the acceptability and appeal of EE-based soap products.

Additionally, agreement levels regarding the adequacy of technical support and responsiveness to questions or complaints ranged from 57.1% to 71.4%, suggesting that while generally positive, aspects of communication and facilitation could be further strengthened. On a positive note, the program successfully fostered participant enthusiasm for outreach, with 71.4% strongly agreeing they would recommend the EE-based product to others, including parents and members of the surrounding community.

Overall, the program demonstrated effective science and technology transfer, increased environmental awareness, and community-based empowerment. These outcomes support the strategic role of pesantren in promoting responsible consumption and production (SDG 12), clean water and sanitation (SDG 6), climate action (SDG 13), and life on land (SDG 15). The findings emphasize the importance of integrating environmentally friendly technologies into Islamic education frameworks and developing sustainable, participatory capacity-building models.

4. Conclusion

This community service initiative successfully achieved its objective of empowering the pesantren community—particularly students and educators—with practical skills in sustainable organic waste management and biotechnological transformation. Through a series of hands-on training sessions, participants were not only able to produce eco-enzyme (EE) but also process it into value-added products, specifically eco-friendly dishwashing soap. Quantitatively, the program resulted in the fermentation of approximately 100 kg of organic waste into 342.5 liters of EE, which was subsequently utilized in the production of EE-based dishwashing liquid. The outcomes of this activity highlight the significant potential of pesantren as agents of change in promoting community-based sustainability practices.

This initiative demonstrates the active role of Islamic educational institutions in advancing environmental literacy and green entrepreneurship, particularly in rural areas. The program also contributes to the achievement of several Sustainable Development Goals (SDGs), including SDG 6 (Clean Water and Sanitation) through the use of non-toxic cleaning agents; SDG 12 (Responsible Consumption and Production) by reducing and repurposing organic waste; SDG 13 (Climate Action) by mitigating greenhouse gas emissions through proper waste management; and SDG 15 (Life on Land) by utilizing fermentation residues as organic liquid fertilizer. Looking ahead, similar programs may be further developed by improving product quality, such as incorporating natural fragrances to enhance user acceptance, conducting continuous product testing, and expanding distribution channels to maximize the community's economic impact.

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