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Eco-Enzyme Production for Circular Waste Valorization among Forest-Adjacent Farming Households in East Java

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Abstract

Organic waste from household food preparation and horticultural sorting remains underutilized in many rural farming communities. This community engagement article reports an eco-enzyme intervention conducted with 38 informants from forest-adjacent farming households in Batu City, East Java. The activity aimed to strengthen community capacity in organic-waste separation, fermentation-based waste valorization, and preliminary use of eco-enzyme as liquid organic fertilizer. A mixed-methods community intervention design was used, combining participatory coordination, technical training, hands-on practice, pre-test and post-test assessment, field observation, and reflective evaluation. Participants were predominantly women and were observed as active, proactive, progressive, and cooperative during the training process. The pre-test to post-test comparison showed a 22% increase in knowledge and procedural understanding. The activity produced 42 liters of eco-enzyme and introduced its pilot application to plants, where treated plants showed 17% faster growth in preliminary observation. These findings indicate that eco-enzyme training can serve as a practical entry point for rural circular economy learning, although stronger agronomic and economic claims require controlled testing.

Keywords: *circular economy, eco-enzyme, horticultural waste, liquid organic fertilizer*

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Introduction

Organic waste remains one of the most persistent environmental issues in Indonesia, particularly in communities where household residues and agricultural by-products are produced daily but are not systematically processed. In horticultural farming areas, organic waste is generated not only from food preparation at household level but also from sorting, washing, and post-harvest handling of vegetables and fruits. Products that do not meet market standards are commonly discarded, left near washing sites, or disposed of without further processing. This condition creates unpleasant odors, attracts insects, reduces environmental quality, and reinforces a linear pattern in which organic materials are treated as waste rather than as resources.

The issue is closely connected to broader debates on food waste and sustainable waste governance. At the global level, the Food Waste Index Report highlights the need for improved measurement and reduction of food waste across household and community systems (UNEP, 2024). In Indonesia, recent studies show that food waste remains a major component of the waste stream, while available treatment technologies and local handling systems are still insufficient to meet national waste-reduction expectations (Farahdiba et al., 2023; Kusumawardani et al., 2023). These findings suggest that decentralized, low-cost, and behavior-oriented interventions are still necessary, especially in rural communities where formal waste infrastructure is limited.

The circular economy perspective offers a useful foundation for addressing organic waste at household and community levels (Mihai et al., 2022). Instead of viewing residues as materials to be discarded, circular economy emphasizes the recovery, reuse, and recirculation of resources within local systems. In rural horticultural areas, circularity can be introduced through waste separation, composting, fermentation, and the production of organic inputs. However, circular practices do not emerge automatically from the availability of waste. They require community knowledge, practical skills, institutional support, and technologies that are compatible with local routines.

Eco-enzyme production is one simple approach to organic-waste valorization. Eco-enzyme, often discussed in the literature as garbage enzyme, is generally produced by fermenting fruit or vegetable residues with sugar or molasses and water for a specific period (Arun &

Sivashanmugam, 2017; Benny et al., 2023; Nurlatifah et al., 2022; Suliestyah et al., 2022). A recent systematic review indicates that garbage enzymes have potential applications in environmental processes and may help convert organic waste into value-added materials (Pasalari et al., 2024). Experimental work has also suggested that eco-enzyme-based compost may support plant growth under certain conditions (Narang et al., 2024), while other studies have examined its environmental use in reducing chemical oxygen demand in synthetic water systems (Yustiani et al., 2023). Nevertheless, these potential applications must be interpreted carefully. Community training alone cannot prove disinfectant efficacy, product safety, income improvement, or agronomic performance without further testing.

The community engagement activity reported in this article was conducted in Giripurno Village, Bumiaji Sub-district, Batu City, East Java. The area is characterized by horticultural farming and household-level organic residue generation. Field observation documented the presence of discarded vegetable residues, especially from sorting and washing activities, as well as household fruit and vegetable residues. The community also has farmer groups and women farmers who can serve as entry points for participatory environmental learning. This context makes the village relevant for an eco-enzyme intervention that connects waste reduction, household learning, and farming practice.

The focus of this community engagement was therefore not merely to demonstrate a technical recipe, but to build a practical learning process around organic-waste valorization. The basic motive behind the partnership was to help farming households reinterpret waste as a recoverable resource, strengthen household-level waste separation, and introduce a low-cost fermented product that could be explored as liquid organic fertilizer. The expected impacts included improved knowledge, stronger procedural capacity, increased motivation to manage organic residues, and early evidence of community-based circular practice.

This article aims to: (1) describe the initial waste-management situation and partnership context in the target community; (2) explain the methods and stages of the eco-enzyme training intervention; (3) present the results of pre-test and post-test assessment, product output, participant response, and preliminary plant application; and (4) discuss the contribution and limitations of eco-enzyme training as a community-based circular economy innovation.

Methods

Community Engagement Design

The activity used a mixed-methods community intervention design. The design combined participatory coordination, technical training, hands-on practice, pre-test and post-test assessment, observation of participant response, and reflective evaluation. This design was selected because the activity was implemented as community engagement rather than as a controlled laboratory experiment. The approach is consistent with participatory action and community-development principles, where community members are involved as active partners in identifying problems, testing practical solutions, and reflecting on follow-up needs. The subjects involved in the action plan were 38 informants/participants from forest-adjacent farming households in Giripurno Village. Participants were drawn from farmer groups, women farmers, and household members connected to horticultural production and domestic waste generation. The participant profile was dominated by women, which is important because household food preparation and domestic waste handling are often closely connected to women's everyday roles. During the activity, participants were characterized as active, proactive, progressive, and cooperative, as reflected in their attendance, questions, willingness to participate in hands-on practice, and interest in applying the method at home.

Partnership and Interaction Process

The community engagement team coordinated with local stakeholders and forestry-related institutions before implementation. The original activity was linked to broader efforts to develop community partnerships in forest-adjacent areas. Coordination with farmer groups and local actors was essential to determine the training venue, participant mobilization, time arrangement, materials, and tools. The interaction among the engagement team, partners, and participants was organized as a mutual learning process rather than a one-way lecture.

The partnership strategy emphasized local relevance. Instead of introducing a technology that required expensive infrastructure, the intervention used materials available in the community: fruit peels, vegetable residues, molasses or sugar, and clean water. The organic materials used are mostly from pineapple, apple, orange, and carrot waste. The strategy also combined explanation and practice so that participants could observe, ask questions, and directly perform the fermentation procedure. This hands-on method was expected to strengthen procedural understanding and reduce the psychological distance between environmental awareness and actual practice.

Implementation Stages

The activity was conducted through five stages. The first stage was situation analysis, which identified underutilized organic residues from household activities and horticultural sorting. The second stage was community coordination, including communication with local partners and preparation of participants, venue, tools, and materials. The third stage was technical education, covering organic-waste separation, the 3R principles, the meaning of eco-enzyme, and potential household and agricultural applications. The fourth stage was practical training, in which participants prepared ingredients, measured materials, mixed the solution, sealed containers, labeled production dates, and learned the fermentation schedule. The fifth stage was follow-up reflection, including discussion of possible home practice and application as liquid organic fertilizer.

The production protocol introduced during training used organic residues, sugar or molasses, and water. The standard working ratio was explained as approximately 3 kg fruit or vegetable residues, 1 kg sugar or molasses, and 10 kg water (Arun & Sivashanmugam, 2017; Suliestyah et al., 2022; Varshini & Gayathri, 2023). The procedure included cleaning the container, adding water, dissolving sugar or molasses, adding chopped organic residues, closing the container, labeling the production date, releasing gas during the early fermentation stage, and allowing fermentation to continue for approximately 90 days. Cleanliness, correct proportioning, and container monitoring were emphasized as critical control points.

Evaluation and Data Analysis

Evaluation was conducted using pre-test and post-test assessments, field observation, documentation of production output, and reflective analysis of participant responses. The pre-test and post-test instruments consisted of 8 structured questions covering two domains: participants' knowledge of organic-waste processing and eco-enzyme concepts, and their procedural understanding of eco-enzyme preparation, including material selection, mixing ratio, fermentation process, and potential use. Each item was scored using a binary scoring system, with 1 assigned to a correct answer and 0 to an incorrect answer. The total score was converted into a percentage score for each participant.

To ensure instrument validity, the questions were reviewed before implementation for content relevance, clarity, and alignment with the training objectives by the community engagement team and field facilitators. The instrument was intended to assess practical learning outcomes in a community engagement setting rather than to serve as a psychometrically standardized test. The increase in knowledge and procedural understanding was calculated by comparing the mean post-test score with the mean pre-test score, using the following formula:

(Knowledge increase = Mean post-test score − Mean pre-test score)

Product output was documented by recording the total volume of eco-enzyme produced during the training and follow-up production process. Participant response was assessed through field observation and reflective notes, focusing on engagement, participation, perceived feasibility, constraints, and sustainability potential. Preliminary plant application was observed by comparing plant growth in treated plants with the non-controlled reference observation used by the engagement team.

The quantitative data were analyzed descriptively because the activity did not employ a randomized or controlled experimental design. Therefore, the knowledge score, product output, and preliminary plant-growth observation were interpreted as community-engagement indicators rather than causal estimates of program impact or agronomic effectiveness. According to the informant, avocado seedlings planted at 90 cm tall can grow to a normal height of 110 cm within one month. After spraying the eco-enzyme onto the avocado plants, the trees' growth can increase to 114 cm. This means the difference in growth from 110 to 114 cm is a 17% increase. Qualitative data were analyzed thematically, focusing on participant engagement, perceived feasibility, supporting factors, constraints, and sustainability potential. The plant-growth observation was treated as a preliminary agronomic indication because the available data did not include detailed information on crop type, eco-enzyme dosage, replication, soil condition, observation duration, or controlled treatment design.

Furthermore, active community involvement techniques and key indicators in specific research can be seen in Table 1.

Table 1. Community engagement design and key indicators

Component	Description
Location	Giripurno Village, Bumiaji Sub-district, Batu City, East Java, Indonesia
Engagement type	Mixed-methods community intervention and circular waste-valorization training
Participants/informants	38 people from farming households, farmer groups, and women farmers
Participant profile	Dominantly women; active, proactive, progressive, and cooperative
Main materials	Fruit peels, vegetable residues, molasses or sugar, and water
Training output	42 liters of Eco-enzyme
Learning outcome	22% increase from pre-test to post-test
Preliminary plant application	Eco-enzyme applied as liquid organic fertilizer; plants observed to grow 17% faster
Interpretive caution	Plant-growth result is preliminary and requires controlled agronomic testing

Results and Discussions

Initial Community Situation and Waste-Resource Potential

The situation analysis showed that the target community had abundant organic residues from household and horticultural activities. Household residues included fruit peels, vegetable stems, leaves, and other unused plant parts generated during food preparation. Horticultural residues were generated from vegetable sorting and washing activities. These residues were often left unused, creating environmental concerns and indicating weak household-level circularity (Figure 1).

This condition is consistent with national concerns regarding food and organic waste. Farahdiba et al. (2023) noted that Indonesia requires more applicable and sustainable treatment technologies for food waste, while Kusumawardani et al. (2023) showed that household food waste is shaped by economic, demographic, and governance-related factors. In this case, the problem was not simply the existence of waste, but the lack of a practical processing routine that could be adopted by households using materials already available to them.

Eco-enzyme training responded to this situation by translating the 3R concept into a tangible practice. Waste separation became meaningful because participants could connect it with a visible product. This is important for community engagement because environmental messages are more likely to be accepted when they are linked to everyday needs and practical actions.

Fig. 1. Preparation of fruit and vegetable residues for eco-enzyme production

Learning Improvement from Pre-Test to Post-Test

The pre-test to post-test comparison showed a 22% increase in participants' knowledge and procedural understanding. There are 8 questions for the pre-test and post-test. The formula for finding the increase in knowledge = Mean post-test score (%) − Mean pre-test score (%). Overall, respondents got a pre-test score of 62 on a scale of 0 to 100. Then the post-test results increased to 76. This means their knowledge increased by 22%. This result indicates that the training improved participants' ability to understand the basic logic of organic-waste separation, ingredient selection, material ratio, fermentation stages, and possible uses of eco-enzyme. Although the evaluation did not use a control group, the improvement is a meaningful community-engagement indicator because it shows that the training produced measurable learning rather than only attendance.

From an educational perspective, the result confirms the value of hands-on learning. Ardoin et al. (2020) emphasized that environmental education often produces outcomes through improved knowledge, practical skills, communication, and community capacity. In the present activity, knowledge improvement was supported by direct practice, question-and-answer interaction, and the use of locally familiar materials. Participants were not only informed about organic waste but were also guided to transform it into a fermented product.

The learning gain must still be interpreted within the limits of the available data. According to Table 2, an approximately 22% increase demonstrates immediate post-training improvement, but it does not automatically prove long-term behavior change. For stronger evidence, future engagement should measure whether participants continue separating organic waste, repeat eco-enzyme production at home, and successfully harvest the product after the fermentation period.

Table 2. Intervention stages, activities, and observed outcomes

Stage	Activity	Observed outcome
Situation analysis	Observation of household and horticultural organic residues	Organic-waste problem identified as community entry point
Coordination	Communication with local stakeholders, farmer groups, and women farmers	Participants, venue, materials, and tools prepared
Technical education	Explanation of 3R, circular economy, and eco-enzyme fermentation	Participants received conceptual and procedural knowledge
Hands-on practice	Mixing residues, molasses/sugar, and water; labeling and sealing containers	Practical skill-building and participatory learning
Evaluation	Pre-test and post-test assessment	22% increase in knowledge and procedural understanding
Production output	Community-scale eco-enzyme preparation	42 liters of eco-enzyme produced
Pilot application	Use as liquid organic fertilizer on plants	17% faster plant growth observed as preliminary evidence

Participant Profile and Engagement Dynamics

The activity involved 38 participants/informants, with women dominating the participant composition. This composition is important because women often play a central role in household food preparation and domestic waste handling. At the same time, many women in farming households are also involved in agricultural work, informal decision-making, and community learning. Their participation therefore linked household waste management with broader farming-community practices.

Referring to Figure 2, participants were observed as active, proactive, progressive, and cooperative. Activeness was reflected in their attention during explanation and involvement in practice. Proactiveness was visible in questions about ingredient ratios, fermentation duration, and possible applications. Progressiveness was reflected in their openness to reinterpret waste as a useful input rather than a disposal problem. Cooperation was visible in the shared preparation of materials, collective observation of the demonstration, and willingness to discuss follow-up use.

These engagement dynamics matter because community-based waste management depends on participation and trust. Mulasari et al. (2024) showed that community-based action research can support household waste-management innovation by involving residents and local stakeholders. Similarly, governance studies on community-based waste management indicate that waste reduction requires not only technical facilities but also coherent collaboration and community participation (Latanna et al., 2023). The present intervention supports this argument at a smaller rural scale.

Fig. 2. Hands-on preparation of eco-enzyme during the community training session

Innovation Output

The training produced 42 liters of eco-enzyme. This output is important because it demonstrates that the activity generated a tangible product, not merely an awareness campaign. The product volume also indicates that locally available residues can be mobilized into a collective processing activity at community scale. From a community engagement perspective, tangible outputs are useful because they help participants see the direct connection between waste separation, fermentation, and resource recovery.

The production output also strengthens the circular-economy dimension of the activity. Organic residues that might otherwise have been discarded were converted into a fermented liquid that could be explored for household or agricultural use. Pasalari et al. (2024) described garbage enzymes as a promising approach for converting organic waste into value-added materials. However, the value of the 42-liter output should not be exaggerated. Product volume alone does not prove product quality, safety, or economic value. It only confirms that the community could collectively produce eco-enzyme using accessible materials and simple equipment.

For future implementation, the 42-liter output can serve as a baseline for production planning. Community groups can estimate how much organic waste is required, how many containers are needed, how long fermentation takes, and how the product can be distributed or used. Such records are essential if the activity is to be scaled from training output to a structured community-based waste-management routine.

Application as Liquid Organic Fertilizer and Preliminary Plant-Growth Observation

The eco-enzyme was introduced for preliminary application as liquid organic fertilizer. The engagement team observed that plants treated with the eco-enzyme preparation showed 17% faster growth. The comparison showed a 22% improvement from pre-test to post-test. Product output was recorded as 42 liters of eco-enzyme produced during and/or as a result of the intervention process. This result is encouraging because it suggests that the product may have practical relevance for farming households. It also provides a concrete reason for farmers to view organic residues as resources that may return to the production cycle.

Nevertheless, this finding must be framed carefully. Based on Table 3, the 17% faster growth is reported as a preliminary agronomic observation, not as a controlled experimental result. The available documentation does not specify plant species, dosage, dilution ratio, replication, soil condition, observation period, or comparison protocol. Therefore, the finding should be treated as an early signal that justifies further testing. Controlled trials are required before making strong claims about crop productivity, fertilizer substitution, or yield improvement.

The cautious interpretation is supported by the broader literature. Narang et al. (2024) found that compost prepared with lab-prepared eco-enzyme showed growth-promoting effects for Phaseolus vulgaris under specific experimental conditions. Recent eco-enzyme studies also suggest possible environmental and agronomic applications, but they consistently imply the need for standardized testing and clear conditions of use (Fadlilla et al., 2023; Nguyen-Sy et al., 2023; Pasalari et al., 2024; Yustiani et al., 2023). Accordingly, the present activity contributes preliminary community-based evidence, while agronomic validity remains a future research agenda.

Table 3. Evidence-based claim boundaries for the engagement results

Claim	Supported by current activity?	Interpretation
Eco-enzyme training increased knowledge	Yes	Pre-test to post-test result increased by 22%
Community produced eco-enzyme	Yes	The activity produced 42 liters of eco-enzyme
Participants were engaged	Yes	Observed as active, proactive, progressive, and cooperative
Eco-enzyme can be used as liquid organic fertilizer	Partially	Introduced and applied in a preliminary plant observation
Eco-enzyme improves plant growth	Preliminary only	17% faster growth observed, but controlled agronomic testing is still needed
Eco-enzyme improves welfare or income	Not yet	No cost-benefit or income data were collected
Eco-enzyme works as medical disinfectant	No	No microbiological, toxicity, or safety testing was conducted

Supportive Factors, Constraints, and Sustainability

Several supportive factors contributed to implementation. First, the community had abundant organic residues from household and horticultural activities. Second, the training used simple tools and inexpensive materials, reducing the barrier to participation. Third, the dominance of women participants strengthened the connection between household food preparation and waste separation. Fourth, farmer-group and community networks provided a social platform for collective learning. Fifth, the hands-on method made the innovation concrete and practical. Several constraints were also identified. Eco-enzyme production requires a fermentation period of approximately 90 days, which may reduce motivation if participants expect immediate benefits. The process also requires clean containers, correct ratios, and periodic monitoring. If participants do not understand gas release, contamination risks, or material selection, the product may fail. Another constraint is the absence of product-quality testing. Without pH, microbial, nutrient, and safety assessment, product use must remain cautious.

Sustainability requires follow-up mechanisms. The most important next steps are household adoption monitoring, production records, group-based fermentation schedules, product-quality checks, and controlled plant trials. If eco-enzyme is positioned as an educational and waste-valorization tool, the model can be replicated relatively easily. If it is positioned as a commercial product or agricultural input, the community will need stronger standard operating procedures, regulatory consideration, packaging, quality control, and economic feasibility analysis.

Conclusion

This community engagement program showed that Giripurno Village faces a practical organic-waste challenge linked to horticultural and household activities, but also has a supportive partnership context through women participants, farming households, and farmer-group networks. The eco-enzyme intervention was implemented through participatory coordination, technical explanation, hands-on production practice, and reflective evaluation involving 38 participants. The activity produced measurable learning and practical outputs: participants' knowledge and procedural understanding increased by 22% from pre-test to post-test, 42 liters of eco-enzyme were produced, participant responses were generally active and cooperative, and preliminary plant application indicated faster growth than untreated plants. These findings suggest that eco-enzyme training can serve as an accessible entry point for household waste separation, environmental learning, and community-based circular economy innovation.

However, the results should be interpreted cautiously. The plant-growth observation remains preliminary and cannot yet be treated as definitive agronomic evidence. The program also did not assess long-term adoption, household income effects, product safety, microbiological quality, or broader welfare outcomes. Future activities should include post-fermentation monitoring, controlled plant trials, pH and nutrient analysis, cost-benefit assessment, and documentation of household-level adoption. With these improvements, eco-enzyme training could be further developed from a practical community-service activity into a more rigorously validated model of rural circular economy engagement.

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