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Implementation of eco-enzyme technology: An innovative solution for organic waste management

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ABSTRACT

Waste management remains a pressing challenge in modern society, largely due to limited public awareness regarding its importance. This study offers a transformative approach by redefining waste—particularly organic waste—not as mere refuse, but as a potential economic asset. Although biodegradable, organic waste is often left untreated, leading to missed opportunities for resource recovery. This research highlights the utilization of eco-enzyme, a product of organic waste fermentation over a three-month period, as an innovative and sustainable waste treatment method. The resulting eco-enzyme liquid functions effectively as a natural cleaning agent and soil enhancer, contributing to environmental restoration by reducing heavy metal content and stabilizing soil pH. From an economic standpoint, the use of eco-enzyme reduces dependence on conventional cleaning products, thereby lowering household expenses. Overall, the findings advocate for a paradigm shift in organic waste handling—demonstrating its dual value in environmental improvement and economic efficiency—while laying the groundwork for more sustainable waste management models.

ABSTRAK

Pengelolaan limbah masih menjadi tantangan yang mendesak dalam masyarakat modern, terutama karena terbatasnya kesadaran masyarakat mengenai pentingnya limbah. Studi ini menawarkan pendekatan transformatif dengan mendefinisikan ulang limbah—khususnya limbah organik—bukan hanya sebagai sampah, tetapi sebagai aset ekonomi yang potensial. Meskipun dapat terurai secara hayati, limbah organik sering kali tidak diolah, sehingga menyebabkan hilangnya peluang untuk pemulihan sumber daya. Penelitian ini menyoroti pemanfaatan eko-enzim, produk fermentasi limbah organik selama periode tiga bulan, sebagai metode pengelolaan limbah yang inovatif dan berkelanjutan. Cairan eko-enzim yang dihasilkan berfungsi efektif sebagai agen pembersih alami dan penambah tanah, berkontribusi pada pemulihan lingkungan dengan mengurangi kandungan logam berat dan menstabilkan pH tanah. Dari sudut pandang ekonomi, penggunaan eko-enzim mengurangi ketergantungan pada produk pembersih konvensional, sehingga menurunkan pengeluaran rumah tangga. Secara keseluruhan, temuan tersebut menganjurkan perubahan paradigma dalam penanganan limbah organik—yang menunjukkan nilai gandanya dalam perbaikan lingkungan dan efisiensi ekonomi—sambil meletakkan dasar bagi model pengelolaan limbah yang lebih berkelanjutan.

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1. Introduction

Waste management has emerged as a critical issue in many parts of the world, including Indonesia. The rapid increase in population and the intensification of community activities have contributed to a surge in waste generation. Without appropriate management, this condition poses a serious threat to public health and environmental sustainability. According to the United Nations Environment Programme (UNEP, 2021), Indonesia ranks as the second-largest waste producer globally, after China, and contributes significantly to global environmental pollution [1]. Most waste handling systems in

Indonesia still rely on conventional approaches such as collection, transportation, and disposal at final processing sites. This linear waste management model leads to various negative environmental impacts, including the emission of methane gas from landfill sites, which accelerates global warming [2]. In light of these challenges, there is an urgent need to shift the paradigm from viewing waste merely as refuse to recognizing it as a potential economic resource, as mandated in Law No. 18 of 2008 concerning Waste Management.

To support this shift, the Thematic Student Community Service (KKM) program of Sultan Ageng Tirtayasa University (Untirta) has initiated community empowerment efforts by introducing eco-enzyme production as an innovative solution in organic waste management. This program was implemented by Group 81 in Kampung Cirukap, Cibarani Village, with the goals of raising public awareness on sustainable waste practices, promoting environmental stewardship, and supporting local efforts to preserve cleanliness and ecological balance.

Eco-enzyme refers to a liquid produced through the fermentation of organic kitchen waste, molasses, and water in specific proportions over a period of three months. The fermentation progresses through three main stages: alcohol formation in the first month, acetic acid production in the second month, and enzyme generation in the third. The final product, obtained by filtering the mixture, has distinct features such as a sour aromatic scent (alcoholic or vinegar-like), bright coloration influenced by the types of waste used, and white fungal growth known as pitera [3]. Wide-mouthed containers are used during fermentation to prevent pressure buildup and reduce the risk of explosions due to alcohol formation.

Eco-enzyme is a sustainable, non-toxic liquid with multifunctional benefits for household and environmental use. Astra et al. (2021) note that eco-enzyme can serve as an effective substitute for chemical cleaners in cleaning floors, clothes, kitchenware, and toilets, while also acting as a deodorizer, indoor humidifier, fertilizer, and pest repellent [4]. Additionally, eco-enzyme has demonstrated its capability in reducing water pollution levels, functioning as a natural disinfectant and contributing to water purification processes. Given its wide range of applications and eco-friendly nature, eco-enzyme offers a practical and sustainable solution for addressing the organic waste problem while supporting environmental conservation efforts.

Accordingly, Team 81 of the Untirta Thematic KKM 2025 seeks to implement a targeted community service initiative that promotes the processing of organic fruit peel waste using the eco-enzyme method. Conducted in Kampung Cirukap, Cibarani Village, Cisata District, Pandeglang Regency, this activity aims to inspire a behavioral transformation within the community—from discarding organic waste to utilizing it as a valuable ecological and economic resource. Through participatory education and hands-on practice, the program aspires to build local capacity in sustainable waste management while enhancing the well-being and environmental awareness of residents.

2. Method

This community training activity was carried out at the Community Service Post (KKM) of Group 81, located in Kampung Cirukap, Cibarani Village, Cisata District, Pandeglang Regency, Banten. The training participants primarily consisted of local housewives and farmer groups, selected due to their role as the main producers of household organic waste and their potential as end users of eco-enzyme liquid products. This activity was conducted as part of the Thematic Student Community Service (KKM) program on January 20, 2025. The implementation of the activity was divided into four main phases.

2.1. Preparation Phase

The initial phase focused on preparing all necessary aspects of the training. The KKM team conducted a field assessment to identify suitable participants based on their relevance to household waste generation and interest in sustainable practices. Once the target group was identified, the team prepared educational materials in the form of PowerPoint slides and organized the logistics for the demonstration. These included materials such as organic waste (mainly fruit and vegetable scraps), palm sugar, clean water, and gallon-sized plastic containers for fermentation.

Figure 1. Materials and equipment preparation.

2.2. Socialization Phase

In this phase, the KKM team introduced the concept of eco-enzyme through a structured presentation. The session began with a pretest designed to measure participants' prior knowledge related to eco-enzyme, its benefits, and production methods. The data gathered from the pretest allowed the facilitators to adapt the material delivery according to the participants' existing understanding and ensure more targeted knowledge transfer.

2.3. Practical Implementation Phase

The core of the activity was a hands-on demonstration of the eco-enzyme production process. The process began with the preparation of raw materials, which consisted of three main ingredients: palm sugar, organic waste derived from fruits and vegetables, and clean water. These ingredients were essential for initiating the fermentation process. The eco-enzyme was produced using a specific mixing ratio of 1:3:10, meaning one part sugar, three parts organic waste, and ten parts water. The procedure started by pouring clean water into a fermentation container. Palm sugar was then dissolved into the water, followed by the addition of chopped organic waste. Once all components were combined, the container was sealed tightly and placed in a shaded, well-ventilated location to ferment for 90 days. During the first week, the container's lid needed to be opened to release the accumulating gases, and this step

was repeated on the 30th day to ensure safety and support the fermentation process. After 90 days of fermentation, the eco-enzyme mixture was ready for harvesting. The final step involved filtering the liquid to separate it from the solid residue. The filtered liquid was then transferred into bottles, resulting in a ready-to-use eco-enzyme product suitable for various household and environmental applications.

Figure 2. (a) eco-enzyme socialization, and (b) eco-enzyme production practice.

2.4. Evalution Phase

To assess the impact of the training, the KKM team conducted an interactive evaluation session. This included a Q&A segment to reinforce key concepts and address any remaining questions. In addition to the verbal assessment, the team monitored the participants' fermentation containers periodically to observe their progress and offer further guidance if needed.

Figure 3. Eco-enzyme monitoring and evaluation.

Table 1. Training activity question indicators**.**

No	Question Indicators
1	Understand the fundamental concept of Eco-Enzyme
2	Recognize the various applications of Eco-Enzyme
3	Identify the physical characteristics of Eco-Enzyme
4	Comprehend Eco-Enzyme's environmental benefits
5	Utilize organic materials effectively in Eco-Enzyme production
6	Master the Eco-Enzyme production process
7	Identify the essential ingredients needed for Eco-Enzyme production
8	Demonstrate independent Eco-Enzyme production capabilities
9	Understand Eco-Enzyme's role in household waste reduction
10	Express interest in furthering their knowledge about Eco-Enzyme

3. Results and Discussion

The management of organic waste continues to pose a major challenge in rural regions, including Cirukap Village, Cibarani. The introduction of eco-enzyme utilization presents a strategic alternative that not only addresses environmental concerns but also empowers the local community. As part of the Student Community Service (KKM) program, the implementation of eco-enzyme training was initiated through early coordination with the Cibarani Village government. This included obtaining official permits and approvals during the student placement period. Subsequent phases focused on the dissemination of program details—such as objectives, schedules, and venues—through established neighborhood structures (RT and RW), ensuring that the target participants, primarily housewives and farmer groups, received accurate and timely information.

3.1. Community Awareness and Participation Levels

The socialization results revealed that community awareness regarding organic waste management in Cirukap Village, Cibarani, remains relatively low. This low awareness level can be attributed to several key factors, particularly the limited education regarding the importance of organic waste segregation and its benefits for the environment and daily life. Many residents have not yet grasped that organic waste can be processed into compost beneficial for agriculture, reduce waste volume in landfills, and help maintain environmental cleanliness. More intensive efforts are needed in the form of outreach campaigns and sustainable education programs. These activities may include socialization, training in composting organic waste, and providing household-level waste segregation facilities.

3.2. Major Challenges in Organic Waste Management

Organic waste management in Cibarani Village faces significant structural challenges, particularly in terms of limited supporting infrastructure. This is reflected in the absence of standardized Final Processing Sites (TPA) and insufficient transportation facilities for effective organic waste collection. These problems are exacerbated by suboptimal implementation of waste management policies at the village level. Based on the identification of these challenges, a comprehensive approach is needed, encompassing improvements in waste management infrastructure quality and the formulation of policies more adaptive to local conditions and needs.

3.3. Eco-Enzyme Production Process

Eco-enzyme is produced through organic waste processing techniques, converting materials like fruit peels and vegetable scraps into environmentally friendly liquid. The initial production phase begins with washing and finely chopping organic waste for easy container placement. The basic components consist of molasses/palm sugar, fruit or vegetable waste, and clean water. Fermentation begins after mixing water and sugar [5]. The material composition follows a 3:1:10 ratio, for example, mixing 600g organic material, 200g palm sugar, and 2 liters of clean water. This mixture is then placed in a gallon container at room temperature. The fermentation process continues for 3 months, with container opening in the first week to release gases. Research by Sitogasa and Rosariawari (2023) shows variations in fermentation results, with some producing white fungus while others do not.

Figure 3. Eco-Enzyme before Fermentation Process.

After the fermentation period concludes, the mature eco-enzyme is filtered and transferred to smaller containers for ease of use. The remaining pulp can be reused with new material addition following the same procedure. For fertilizer application, eco-enzyme usage is sufficient 2-3 times per week, with a dosage of 1 bottle cap of eco-enzyme diluted in 5-7 liters of water [6]. Eco-enzyme characteristics can be observed after filtering the 3-month fermentation results. Fermentation itself is the decomposition process of organic compounds by microorganisms such as fungi, yeast, or bacteria to produce energy [7]. These microorganisms primarily obtain energy from glucose, supplied through palm sugar addition. During fermentation, reactions occur producing gases $CO_2 + N_2O + O_2$, which then form $O_3 + NO_3 + CO_3$ [8]. The eco-enzyme's acidity level is highly influenced by its organic acid content, particularly acetic and lactic acids formed during the 3-month fermentation process [9].

3.4. Environmental Impact of Eco-Enzyme Utilization

Eco-enzyme offers various advantages, including its ability to balance soil pH and control harmful microorganisms through its antimicrobial properties [10]. These advantages make eco-enzyme an effective solution, particularly in post-disaster situations such as volcanic eruptions, floods, and fires. In these conditions, eco-enzyme plays a crucial role in environmental impact mitigation and supporting ecosystem recovery processes. The benefits of eco-enzyme extend to both environmental and economic aspects. Environmentally, its fermentation process produces ozone (O_3) and acetic acid, effective in controlling pathogenic microorganisms [11]. Enzyme content such as lipase, trypsin, and amylase provides inhibitory effects against harmful bacteria growth [12]. By-products including nitrogen (NO) and carbon monoxide (CO) contribute as soil nutrients [13]. From an economic perspective, eco-enzyme usage can reduce expenses for commercial insecticides and cleaning materials.

Eco-enzyme applications are diverse in daily life, ranging from cleaning kitchen utensils, floors, and bathrooms to washing vegetables and fruits. This liquid also functions as a natural insect repellent and benefits soil fertility enhancement. According to Rochyani et al. (2020), eco-enzyme possesses disinfectant properties due to its acetic acid and alcohol content [14]. Although acetic acid (CH_3COOH) in eco-enzyme effectively kills germs, its use is more recommended for plants due to the sugar content from molasses added during the production process.

3.5. Utilization of Residue as Fertilizer

The eco-enzyme fermentation process yields not only liquid but also valuable residue. The sediment formed at the bottom of the fermentation container has potential as a natural fertilizer that can enrich soil quality. Its chemical components, including nitrites and various enzymes (amylase, lipase, and trypsin), serve as important biocatalysts capable of reducing harmful substance levels in waste [15].

3.6. Public Health and Eco-Enzyme Usage

Eco-enzyme represents a safe household cleaning solution that poses no health risks to the community. Its primary advantage lies in its environmentally friendly antimicrobial properties, making it an excellent alternative to traditional cleaning products. Research on eco-enzyme focuses on its potential as a cleaning agent that can be widely applied in daily household activities without creating health risks.

3.7. Economic Aspects of Eco-Enzyme Production

Eco-enzyme production offers diverse and sustainable economic contributions. First, as a household cleaning alternative, eco-enzyme enables communities to reduce operational costs by utilizing simple ingredients such as fruit peels, palm sugar, and water. This not only saves expenses but also reduces dependence on hazardous chemical cleaning products. Furthermore, eco-enzyme creates local economic development opportunities. Producers can market their products through various channels, from local markets and organic shops to regional markets, creating new income sources and fostering community-level economic growth.

Another interesting aspect is eco-enzyme's positive impact on the agricultural sector. The production residue can be utilized as high-nutrient organic fertilizer, helping farmers reduce chemical fertilizer purchase costs. Thus, eco-enzyme is not merely an environmentally friendly product but also an economic empowerment instrument supporting a symbiotic relationship between producers and farmers.

3.8. Evaluation

To measure program effectiveness, the team evaluated participants' understanding of eco-enzyme concepts through questionnaires containing predetermined indicators. Participant enthusiasm remained notably high throughout the evaluation process, reflected in active participation during question-and-answer sessions and accuracy in providing responses. Evaluation results showed very positive responses, with participants successfully absorbing new knowledge despite eco-enzyme concepts being novel to them. More encouragingly, participants expressed their appreciation and committed to immediately implementing eco-enzyme production in their homes, indicating the program's success in motivating communities to adopt more sustainable waste management practices.

Table 2. Training activity evaluation results**.**

No.	Question	Pre-Test		Post-Test	
		Yes (%)	No (%)	Yes (%)	No (%)
1.	Question 1	0	100	77.4	22.6
2.	Question 2	9.7	90.3	83.9	16.1
3.	Question 3	0	100	80.6	19.4
4.	Question 4	0	100	80.6	19.4
5.	Question 5	90.3	9.7	96.8	3.2
6.	Question 6	0	100	83.9	16.1
7.	Question 7	3.2	96.8	83.9	16.1
8.	Question 8	0	100	90.3	9.7
9.	Question 9	16.1	83.9	96.8	3.2
10.	Question 10	80.6	19.4	100	0

Based on pre-test and post-test comparison data, significant improvements were observed across all assessed aspects. Before program implementation, most participants had very limited knowledge about eco-enzyme, with almost all indicators showing comprehension percentages below 20%. However, good potential existed where 90.3% of participants showed interest in utilizing organic materials and 80.6% expressed interest in learning more about eco-enzyme.

After program implementation, an impressive transformation in understanding occurred, with all aspects experiencing substantial improvements, showing average comprehension levels above 80%. The highest achievement was seen in implementation interest, reaching 100%, followed by utilization interest and confidence in eco-enzyme effectiveness, each reaching 96.8%. A significant increase was also observed in participants' confidence to produce eco-enzyme, reaching 90.3%, demonstrating the program's success in building participant capacity and motivation to implement acquired knowledge.

4. Conclusion

The findings of this study highlight that organic waste management in Kampung Cibarani, Cibarani Village, Pandeglang Regency, remains a significant challenge, particularly in terms of public awareness and infrastructural limitations. Nevertheless, the implementation of eco-enzyme production utilizing fruit peel waste demonstrates considerable potential as a sustainable and integrative solution. The controlled three-month fermentation process not only yields a safe, non-toxic alternative for household cleaning but also contributes to environmental restoration by lowering heavy metal concentrations and enhancing soil acidity balance.

The program’s success is further evidenced by the productive reuse of fermentation residues as organic fertilizer, reinforcing a circular approach to agricultural sustainability at the local level. From an economic standpoint, eco-enzyme adoption has been shown to reduce household expenses related to chemical-based cleaning agents, while simultaneously creating new opportunities for small-scale entrepreneurship. These outcomes collectively affirm the eco-enzyme method as a multifaceted intervention capable of addressing environmental degradation, public health concerns, and economic empowerment.

To maximize these benefits, three strategic recommendations are proposed: (1) intensify community education and outreach to improve knowledge and engagement in organic waste practices; (2) invest in the development of supporting infrastructure, including localized composting facilities and waste collection systems; and (3) establish coherent policy frameworks at the local government level to institutionalize and support eco-enzyme initiatives. The implementation of these measures is expected to advance eco-enzyme utilization as a replicable model of sustainable organic waste management applicable across diverse rural and peri-urban communities.

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