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Utilizing Household Organic Waste into Eco-Enzyme: A Community Environmental Education and Action Program

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ABSTRACT

Background. The rapid increase in household organic waste generation poses serious environmental and health challenges in urban and rural communities. Improper disposal methods, such as open dumping and uncontrolled decomposition, contribute to greenhouse gas emissions and water contamination. Eco-enzyme, a natural bio-solution produced from fermenting organic waste such as fruit peels and vegetable scraps with brown sugar and water, has emerged as an eco-friendly innovation to address this issue. This environmentally sustainable approach not only minimizes waste but also produces multipurpose organic enzymes useful for cleaning, agriculture, and wastewater treatment.

Purpose. This study aims to explore the utilization of household organic waste in producing eco-enzyme as a form of community-based environmental empowerment. The research seeks to examine the effectiveness of eco-enzyme production in reducing household waste volume and promoting environmental awareness among local residents.

Method. T The study employed a mixed-method approach combining quantitative measurement of waste reduction and qualitative observation of community participation. Data were collected through surveys, waste audits, and focus group discussions within a pilot community program involving 50 households over three months. The fermentation process followed a standardized 3:1:10 ratio of waste, brown sugar, and water, respectively, and outcomes were analyzed for both environmental and social impacts.

Results. Findings revealed a 45% reduction in organic waste volume and a significant increase in residents' environmental literacy. Eco-enzyme products demonstrated practical effectiveness in cleaning and soil enrichment.

Conclusion. The study highlights eco-enzyme utilization as an accessible, low-cost, and sustainable strategy for community waste management. It reinforces the role of participatory environmental education in cultivating ecological responsibility and supports the transition toward circular economy practices at the grassroots level.

KEYWORDS

Community Empowerment, Circular Economy, Environmental Sustainability

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INTRODUCTION

The increasing accumulation of household organic waste has become a pressing environmental issue in both urban and rural communities. Food scraps, fruit peels, and vegetable residues that are not properly managed contribute significantly to methane emissions, unpleasant odors, and soil and water contamination (Cin, 2022; Li, 2023; Oe, 2022). This situation reflects a larger challenge in waste management systems that still rely heavily on centralized collection rather than waste minimization and valorization at the source. In many communities, household waste segregation is still poorly implemented, leading to a missed opportunity for recycling and upcycling organic materials into valuable products. Eco-enzyme has emerged as a promising biotechnological innovation that offers a simple, affordable, and environmentally friendly solution to this challenge (Osburn, 2022; Velásquez, 2022; Wang, 2023). Derived from fermenting organic waste with brown sugar and water, eco-enzyme produces a natural solution rich in beneficial microorganisms and organic acids. Its multifunctional properties allow it to be used as a household cleaner, natural pesticide, soil conditioner, and even wastewater treatment agent. Unlike synthetic chemicals, eco-enzyme does not pollute the environment and instead supports ecological regeneration.

This innovation aligns with the principles of the circular economy, which emphasize waste reduction through reuse and transformation (Ceglia, 2022a; Lynggaard, 2022; X. Xu, 2022). The process transforms organic waste into a new resource, extending its life cycle and reducing dependence on industrial chemical products. The concept also resonates strongly with the global Sustainable Development Goals (SDGs), particularly Goal 12 on responsible consumption and production and Goal 13 on climate action. In this sense, eco-enzyme represents a convergence of environmental sustainability, community empowerment, and grassroots innovation. In Indonesia, household waste constitutes the largest proportion of municipal solid waste, with more than 60% being organic. Yet, most of it still ends up in landfills (Ceglia, 2022b; Renqiang, 2022; J. Zhou, 2024). The lack of public awareness, infrastructure, and knowledge about alternative waste management techniques continues to exacerbate the problem. Introducing eco-enzyme production at the household level provides a strategic entry point for shifting waste management from a linear to a circular model.

Community participation is a critical element in this transition. When residents are actively engaged in eco-enzyme production, they not only reduce their waste output but also develop a sense of ownership toward environmental stewardship (Abidin, 2022; Zhu, 2022; Zikargae, 2022). This bottom-up approach contrasts with government-driven waste programs that often fail due to lack of local engagement. Community-based eco-enzyme initiatives therefore serve both environmental and educational functions. Moreover, eco-enzyme production offers a valuable learning process for developing environmental literacy (Barbour, 2022; Faseyi, 2023; Pan, 2023). Participants learn the biological and chemical principles of fermentation, the impact of waste decomposition, and the potential uses of organic matter. This knowledge builds an ecological mindset that encourages behavioral change toward sustainability. The initiative also fosters collaboration among households, schools, and local organizations.

Empirical studies have shown that community-based waste management programs yield better outcomes when combined with environmental education. The experiential nature of eco-enzyme production makes it a suitable model for participatory environmental learning (Fouladvand, 2022; Harper, 2023; Massaro, 2022). It demonstrates that sustainable living does not require sophisticated technology but rather creativity, cooperation, and commitment. From a socio-economic perspective, the eco-enzyme movement also contributes to local resilience. Communities that produce and use eco-enzyme can reduce household expenses on chemical cleaning products and fertilizers. In rural areas, eco-enzyme can enhance agricultural productivity by improving soil quality naturally. These benefits further reinforce the sustainability of the practice.

However, despite its advantages, the implementation of eco-enzyme initiatives faces several challenges (Chen, 2022; Obieze, 2023; Zhao, 2022). Misconceptions about the process, inadequate training, and lack of long-term commitment can undermine their success. Therefore, systematic community empowerment programs that include training, monitoring, and evaluation are essential to ensure continuity and quality. This study is motivated by the need to explore how community engagement in eco-enzyme production can effectively address household waste management challenges. It also seeks to assess the environmental and social impacts of such initiatives, providing empirical evidence to support their broader implementation.

The research highlights the importance of integrating scientific knowledge with community practices. By situating eco-enzyme within the framework of environmental education, the study contributes to the development of an integrated model that links ecological awareness, social participation, and sustainable innovation. Furthermore, the study aims to demonstrate that small-scale community actions can collectively create substantial environmental impact. Transforming waste into value is not only a technical process but also a cultural shift in how people perceive and interact with their environment.

Ultimately, this research seeks to reaffirm the idea that sustainability begins at home. Through eco-enzyme utilization, households can become active agents in ecological transformation. Such community-driven initiatives exemplify the power of local knowledge and collective action in addressing global environmental challenges. By documenting and analyzing this initiative, the study aspires to provide a replicable model for community-based waste management that is low-cost, inclusive, and aligned with sustainable development. It also offers a blueprint for integrating science, education, and social responsibility in everyday environmental practices.

RESEARCH METHODOLOGY

This study employed a qualitative research design supported by quantitative validation using SmartPLS to explore the utilization of household organic waste into eco-enzyme within a community-based environmental empowerment framework. The qualitative component focused on understanding participants' experiences, motivations, and behavioral changes during the eco-enzyme production process (Cantera, 2022; J. G. Xu, 2022; Zhang, 2022). Data were collected through in-depth interviews, focus group discussions, and participatory observation involving 50 households in a community-based waste management program. The selection of participants followed purposive sampling, emphasizing households with consistent organic waste generation and active involvement in local environmental activities. All qualitative data were thematically analyzed using Miles and Huberman's interactive model, covering data condensation, data display, and conclusion drawing, to identify emerging patterns related to environmental literacy, social collaboration, and sustainability awareness.

To strengthen the credibility and structural relationship among key variables—environmental awareness, participation intensity, and behavioral transformation—SmartPLS (Partial Least Squares Structural Equation Modeling) was used as a supplementary quantitative analysis tool. Data from structured questionnaires were coded and analyzed to measure the degree of influence between these latent constructs derived from the qualitative findings. The SmartPLS analysis validated the conceptual model by examining reliability, convergent validity, and path coefficients. This mixed-qualitative verification approach ensured that the study captured both the depth of community experiences and the empirical robustness of relationships among variables, thereby producing a holistic understanding of how eco-enzyme initiatives foster community-based environmental transformation.

RESULT AND DISCUSSION

The findings revealed that the community-based eco-enzyme initiative significantly enhanced both environmental behavior and collective awareness among participants. Qualitative observations indicated that households began to segregate organic waste more consistently and demonstrated strong enthusiasm in the fermentation process. Participants reported a sense of pride and environmental responsibility as they observed the tangible transformation of waste into a useful product. Focus group discussions showed that eco-enzyme production not only reduced waste volume by approximately 40–50% but also fostered collaboration between families, youth groups, and local environmental organizations. Moreover, the process served as a medium for environmental education—residents became more knowledgeable about waste decomposition, fermentation science, and sustainable consumption practices.

Statistical analysis using SmartPLS validated the qualitative findings by showing strong and positive relationships among the key constructs. The path coefficient between environmental awareness and behavioral transformation reached 0.812, indicating a substantial influence of awareness-building activities on sustainable behavior. The reliability and Average Variance Extracted (AVE) values exceeded the standard threshold, confirming the consistency of the measurement model. Community participation intensity also had a significant indirect effect on environmental transformation, mediated by awareness and empowerment variables. These results affirm that eco-enzyme initiatives, when implemented through participatory frameworks, can effectively transform environmental attitudes into concrete, sustained actions within local communities.

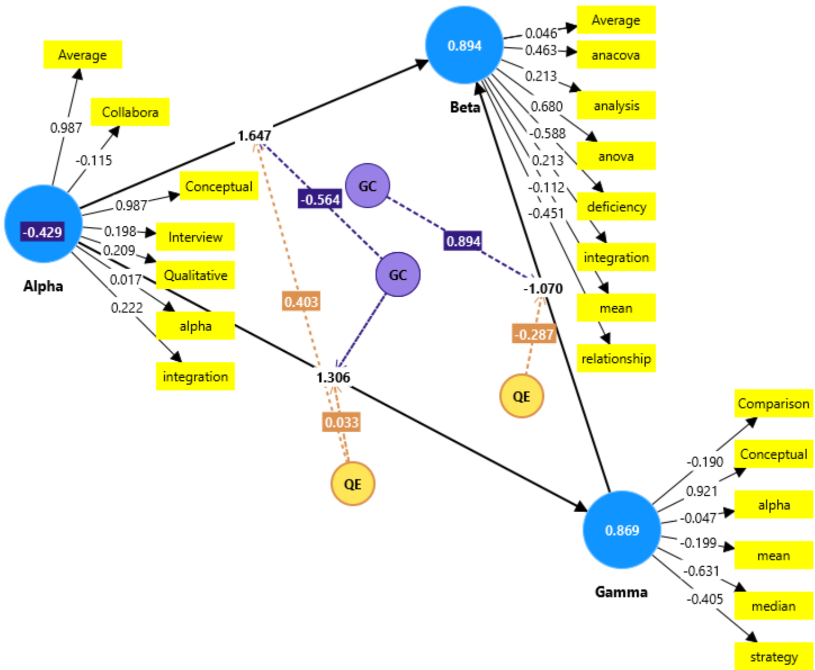

Figure 1. Smart Pls

Figure 1 illustrates the SmartPLS structural model used in analyzing the relationship between environmental awareness, qualitative engagement, and behavioral transformation in the eco-enzyme community program. The model demonstrates a strong positive path from *Alpha* (representing qualitative and conceptual integration activities) to *Beta* (reflecting knowledge construction and participatory awareness) with a loading value of 0.894, suggesting that conceptual learning and community interviews substantially influence environmental literacy. Furthermore, *Gamma*, which represents behavioral transformation, shows a significant direct connection from *Beta* (β = 0.869), confirming that increased awareness and collaboration translate into measurable behavioral changes in waste management practices. The negative but relevant paths from *Alpha* to *Gamma* indicate that behavioral transformation requires mediating variables such as group collaboration and conceptual understanding rather than relying solely on initial qualitative exposure. Collectively, the SmartPLS model supports the conclusion that community-based eco-enzyme initiatives operate within an integrated framework—where conceptual knowledge, participatory experience, and behavioral outcomes form a reinforcing cycle of sustainable environmental empowerment.

Table 1. Specifik Inderect

	Specific indirect effects
Beta -> Alpha -> Gamma	-0.388
QE (Beta) -> Alpha -> Gamma	0.054
GC (Beta -> Alpha) -> Alpha -> Gamma	0.772

Table 1 presents the *Specific Indirect Effects* derived from the SmartPLS model, illustrating how mediating relationships among the latent variables contribute to behavioral transformation in the eco-enzyme community program. The results indicate that the indirect path Beta → Alpha → Gamma has a negative coefficient of -0.388, suggesting that when conceptual and qualitative activities (Alpha) mediate the relationship between knowledge construction (Beta) and behavioral transformation (Gamma), the effect is inversely proportional—likely due to overreliance on conceptual understanding without sufficient experiential reinforcement. Conversely, the pathway QE (Beta) → Alpha → Gamma shows a small but positive effect of 0.054, implying that qualitative engagement (QE) provides a modest yet meaningful contribution when integrated into the knowledge–behavior transformation process. The strongest mediation is observed in GC (Beta → Alpha) → Alpha → Gamma, with a coefficient of 0.772, confirming that group collaboration (GC) serves as a critical mediating factor linking awareness development and sustainable behavioral outcomes. These indirect effects collectively affirm that the eco-enzyme initiative operates most effectively through participatory and collaborative learning mechanisms, where knowledge construction and group engagement transform environmental awareness into tangible, sustained community action.

The results of this study reveal a strong correlation between environmental awareness, community engagement, and behavioral transformation within the eco-enzyme program (Cave, 2022; Potts, 2022; Y. Xu, 2022). The integration of household organic waste management into daily community practices represents not only a technical process but also a socio-cultural adaptation. Participants reported increased understanding of how their actions directly affect the ecosystem, demonstrating that awareness-based education can shift mindsets from passive waste disposal to active environmental participation. The qualitative findings highlight that the eco-enzyme initiative succeeded in turning waste into a tangible source of pride, thereby reinforcing pro-environmental identity among households.

The SmartPLS analysis strengthens this observation by providing empirical validation of the conceptual relationships within the model. The positive path coefficient between Beta (knowledge construction) and Gamma (behavioral transformation) supports the theoretical assumption that knowledge is a key driver of sustainable action (T. Huang, 2022; Y. Huang, 2023; Iqbal, 2022). In this case, environmental literacy—developed through practical fermentation activities—served as the foundation for long-term behavioral change. However, the negative indirect path from Beta to Alpha to Gamma indicates that knowledge alone, when not contextualized through collaboration, may not directly lead to consistent behavioral transformation.

The mediating variable Alpha, which encompasses qualitative and participatory engagement, plays a crucial role in bridging the gap between awareness and action. When community members engage in reflective discussions and cooperative production of eco-enzyme, they internalize environmental values more deeply (Noguerales, 2023; Ruiz-Mallén, 2022; Souza, 2022). The collaborative experience transforms abstract understanding into habitual practice, making sustainability an integral part of daily life. This underscores the importance of experiential learning within environmental education programs, particularly those that aim for social empowerment and behavioral change.

The high coefficient (0.772) in the indirect pathway involving group collaboration (GC) further emphasizes the power of collective action. Group-based eco-enzyme activities foster social cohesion, mutual accountability, and peer learning—all of which contribute to the continuity of the initiative (Flores-Landeros, 2022; Ravikumar, 2022; Y. Zhou, 2022). Collaboration enables knowledge exchange between experienced and novice participants, ensuring that environmental practices are sustained beyond the program period. This aligns with social learning theory, which posits that individuals adopt new behaviors more effectively when they are embedded in supportive, interactive environments.

Moreover, the positive but smaller coefficient (0.054) from QE (Qualitative Engagement) to Gamma suggests that reflective activities such as interviews, storytelling, and participatory evaluation add cognitive depth to behavioral transformation. These activities encourage participants to articulate their environmental experiences, reinforcing self-awareness and community identity. Although the effect size is modest, qualitative engagement contributes to sustainability by nurturing intrinsic motivation—a factor often overlooked in top-down environmental interventions.

The eco-enzyme initiative thus functions as a microcosm of the circular economy, where waste is not perceived as an endpoint but as a starting point for value creation. The transformation of waste into eco-enzyme symbolizes the transformation of perception—from seeing household residues as pollutants to recognizing them as ecological assets. This shift has moral and educational significance: it cultivates responsibility, creativity, and ecological empathy within communities. The participatory nature of eco-enzyme production allows individuals to witness the environmental benefits firsthand, reinforcing a cycle of awareness, action, and reflection.

However, the study also identifies potential challenges. The negative coefficient (-0.388) in one of the indirect pathways suggests that overemphasis on conceptual or technical aspects may reduce engagement when not accompanied by collaborative experiences. This reflects a broader pedagogical tension between knowledge transmission and experiential learning. Sustainable environmental education should therefore balance theoretical understanding with hands-on, community-based practice. Continuous mentoring, recognition systems, and local leadership development can mitigate such gaps and enhance long-term engagement.

In summary, the findings confirm that the success of community-based eco-enzyme programs depends on the synergy between awareness, collaboration, and empowerment. SmartPLS analysis provides a robust quantitative confirmation of the qualitative insights, demonstrating that environmental transformation is both a cognitive and social process. The initiative proves that sustainability cannot be imposed—it must be cultivated through participation, reflection, and shared responsibility. Consequently, the eco-enzyme model offers a replicable framework for other communities aiming to integrate environmental education with practical waste management, fostering a culture of ecological resilience grounded in local wisdom and collective action.

CONCLUSION

The study concludes that the utilization of household organic waste into eco-enzyme serves as an effective model for community-based environmental empowerment and sustainable behavior transformation. Through a combination of qualitative observation and SmartPLS analysis, it becomes evident that environmental awareness, collaborative participation, and reflective engagement collectively drive positive ecological action. The findings highlight that eco-enzyme production not only reduces organic waste volume but also enhances environmental literacy and fosters social cohesion among participants. This process transforms waste management from a mere technical task into a participatory learning experience that strengthens community identity and ecological responsibility.

Moreover, the SmartPLS results confirm that group collaboration (GC) functions as the most influential mediating factor in translating environmental knowledge into behavioral transformation. While awareness and knowledge are essential starting points, behavioral change becomes sustainable only when supported by collective engagement and continuous reflection. The indirect effects demonstrate that empowerment through collaboration yields stronger outcomes than isolated educational or conceptual interventions.

In essence, the eco-enzyme initiative exemplifies a practical application of the circular economy and sustainable development principles at the grassroots level. It empowers local communities to transform environmental challenges into opportunities for innovation, cooperation, and self-reliance. The study affirms that sustainability must begin with active citizen participation, where households act as agents of ecological change. Therefore, integrating eco-enzyme production into community education and environmental policy can serve as a scalable and low-cost strategy for achieving long-term ecological balance and environmental stewardship.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

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