

Ecoenzymes as Environmentally Friendly Detergents: Economic Empowerment Innovation

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Article Info

Article history:

Received: April 7, 2026

Accepted: June 3, 2026

Published: June 17, 2026

Keywords:

Detergent soap

Ecoenzymes

Pineapple peel

Sustainable economic

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Pengabdian Masyarakat

Abstract

The underutilization of pineapple peel waste and fluctuations in pineapple prices are among the challenges faced by Tinggiran Darat Village. The objective of this Community Empowerment Partnership (PKM) initiative is to empower pineapple farmers by transforming pineapple peel waste into economically valuable products, namely eco-enzymes and liquid laundry detergent. To address these issues, the program adopts an Asset-Based Community Development (ABCD) approach, involving 40 members of the PKK/*Pemberdayaan Kesejahteraan Keluarga* (Family Welfare Movement) and youth organizations. The evaluation results through pretest and posttest showed a significant increase in all indicators of participant understanding, namely from 52.25 to 87.5 on the eco-enzyme concept, from 50.0 to 86.75 on the production process, from 48.0 to 89.0 on environmentally friendly detergent products, and from 60.0 to 87.5 on digital marketing and branding aspects, all of which were in the very good category. In addition, the results of the public perception analysis showed a positive level of acceptance of eco-enzyme-based detergent products, with 84.4% of respondents rating the product's cleaning power as good, 90.6% stating it was safe for the skin, 78.1% rating the packaging as quite attractive, and 81.3% stating a willingness to reuse and recommend the product. As an explicit impact, the community is now able to independently process previously discarded pineapple peels into marketable natural detergent products. This has proven effective in reducing the village's organic waste volume while simultaneously creating new, sustainable economic income opportunities for the local community.

To cite this article: Mahdian, M., Saadi, P., Iskandar, R., Khatimah, H., & Lase, A. S. (2026). Ecoenzymes as environmentally friendly detergents: Economic empowerment innovation. *Bubungan Tinggi: Jurnal Pengabdian Masyarakat*, 8(2), 574-589.

INTRODUCTION

Barito Kuala Regency in South Kalimantan Province has great potential in the agricultural sector, especially food crops ([Saheriyanto & Suhaimi, 2021](#)). Tinggiran Darat Village is one of the leading pineapple production centers. The village's location in the tidal area of the Barito River makes the agricultural land in this region fertile. These tidal conditions

bring important minerals, such as magnesium (Mg) and potassium (K), which play a role in enhancing the sweetness of the pineapples produced ([Hermans et al., 2006](#); [Wang et al., 2018](#)). The Tamban pineapple has been designated and released as a superior variety with the issuance of the Decree of the Minister of Agriculture No. 2088/Kpts/S. R.120/5/2009, dated May 7, 2009, making it the most widely planted and developed variety in the tidal swamp lands of Tinggiran Darat Village, as one of the primary sources of livelihood for the majority of residents.

The price of fresh pineapples is often volatile due to factors such as harvest season, market demand, and regional competition. This frequently causes farmers' incomes to be unstable ([Rasmikayati et al., 2023](#); [Vijayan et al., 2025](#)). This has encouraged the residents of Tinggiran Darat Village to innovate by processing pineapple flesh into various products such as Donasari (Mekarsari Pineapple Dodol) and Rina Sari (Mekarsari Pineapple Rimpi). However, this innovation leaves a considerable amount of pineapple peel waste each year, which, if not optimally utilized and simply discarded, can trigger environmental pollution and unpleasant odors and become a breeding ground for pests and diseases ([Agustine et al., 2025](#); [Erna et al., 2025](#)).

This condition indicates a serious challenge in organic waste management as well as a great opportunity to turn it into value-added products. One increasingly recognized innovation in organic waste management is ecoenzymes. Ecoenzymes are liquids produced by fermenting organic waste with added sugar and water, which have a variety of benefits. In addition to reducing organic waste accumulation, eco-enzymes derived from pineapple peels have been shown to contain acetic acid, which plays a significant role in their antimicrobial properties. The fermentation process of pineapple peels results in the production of ecoenzymes that exhibit antibacterial, antifungal, and antiviral activities, largely attributed to the presence of acetic acid and other organic compounds such as alcohol ([Lestari, 2023](#); [Hendri et al., 2023](#)). Acetic acid, a key component of these ecoenzymes, has been demonstrated to effectively reduce bacterial growth, including that of *Pseudomonas aeruginosa* and *Staphylococcus epidermidis*, by acting as a bacteriostatic agent ([Hendri et al., 2023](#)). Furthermore, ecoenzymes can convert ammonia (NH_3) into nitrate ions (NO_3^-), which are used for plant nutrition, and are highly applicable as daily cleaning agents, one of which is as a natural detergent ([Gaspersz & Fitrihidajati, 2022](#); [Sochacki & Vogt, 2022](#)).

Pineapple peel, as agricultural waste, can be processed into ecoenzymes, which can be further developed into environmentally friendly detergents. Therefore, the use of pineapple peel-based eco-enzymes as detergents not only helps the residents of Tinggiran Darat Village reduce environmental pollution but also significantly decreases their dependence on synthetic chemical products that are harmful to health ([Gaspersz & Fitrihidajati, 2022](#); [Harefa et al., 2025](#)).

Despite the growing body of literature on ecoenzyme production from various fruit and vegetable wastes, several critical gaps remain unaddressed. First, the majority of existing ecoenzyme studies are predominantly confined to biochemical characterization such as pH profiling, organic acid quantification, and antimicrobial screening without extending the analysis to functional detergent formulation or evaluating the physicochemical performance of the resulting product against standardized household cleaning benchmarks ([Gumilar, 2023](#); [Harefa et al., 2025](#)). Second, although community-based ecoenzyme training has been documented in urban and peri-urban Indonesian contexts ([Merlinda et al., 2023](#); [Nursetiawan et al., 2024](#)), no study has been reported specifically in tidal swamp (lahan pasang surut) agricultural communities that generate high volumes of seasonal pineapple peel waste as a direct by-product of agro-processing industries. Third, prior community service studies have not integrated quantifiable economic empowerment

indicators such as reductions in household expenditure on synthetic cleaning agents, participants' entrepreneurial self-efficacy, and product market readiness into the program evaluation framework ([Rasmikayati et al., 2023](#); [Vijayan et al., 2025](#)). This triple gap spanning technical application, geographic specificity, and economic outcome measurement represents a substantive limitation in the existing literature on sustainable agricultural waste valorization and rural community development.

This study addresses the aforementioned gaps through a novel integrated approach that distinguishes itself from prior work in three fundamental ways. First, unlike previous ecoenzyme studies that utilized generic fruit waste ([Lestari, 2023](#)), this activity specifically employs peel waste from the Tamban pineapple (*Ananas comosus* var. Tamban), a government-certified superior variety adapted to tidal swamp conditions, thereby producing a geographically and agronomically contextualized ecoenzyme whose composition may differ from those derived from non-tidal cultivars due to distinctive mineral profiles of the growing medium ([Putri et al., 2025](#)). Second, in contrast to prior community service programs that focused solely on ecoenzyme production awareness without product standardization ([Gaspersz & Fitrihidajati, 2022](#); [Harefa et al., 2025](#)), this activity introduces a three-stage replicable training protocol encompassing (1) ecoenzyme-based detergent production, (2) functional and organoleptic quality assessment, and (3) an entrepreneurship module covering packaging, product labeling, pricing, and market entry strategy. Third, the study in question appears to be pioneering in documenting an ecoenzyme-based circular economy model specifically within a tidal swamp smallholder farming community in Kalimantan, Indonesia. This approach is novel as it integrates ecoenzyme technology into community empowerment and sustainable agricultural practices, which has not been extensively covered in the indexed literature on ecoenzyme community empowerment in Indonesia. The existing literature highlights various applications and benefits of ecoenzymes in different contexts across Indonesia. For instance, ecoenzymes have been used to improve soil quality and agricultural productivity, as seen in the empowerment of farmer groups in Slateng Village, where ecoenzyme knowledge significantly increased farmer enthusiasm and knowledge, promoting sustainable agriculture ([Basuki et al., 2023](#)). Similarly, in Tuwung Village, ecoenzymes were utilized as liquid organic fertilizers in hydroponic farming, demonstrating increased agricultural productivity and community empowerment ([Panda et al., 2024](#)). Furthermore, ecoenzymes have been employed in waste management and environmental education, as demonstrated in Palembang, where ecoenzyme soap production enhanced environmental literacy and community collaboration ([Ernilawati et al., 2025](#)). The EnzymPoz program also illustrates the potential of ecoenzymes in transforming organic waste into value-added products, fostering community involvement and supporting circular economy practices ([Wicaksono, 2025](#)). Despite these diverse applications, the specific focus on a tidal swamp smallholder farming community in Kalimantan, as mentioned in the study, represents a unique adaptation of ecoenzyme technology to local environmental and socio-economic conditions, thereby establishing a scientifically grounded and community-adapted blueprint that is not previously documented in the literature. This model not only addresses local agricultural challenges but also aligns with broader sustainability goals by integrating ecoenzyme innovation into community-based circular economy strategies ([Akbar et al., 2025](#); [Huda et al., 2025](#)).

This activity is in line with the Sustainable Development Goals (SDGs), particularly SDG 3 on good health and well-being, SDG 8 on decent work and economic growth, and SDG 12 on responsible consumption and production. Furthermore, creative pineapple waste management contributes to SDG 13 and SDG 15, which emphasize action on climate change and the protection of terrestrial ecosystems. Thus, this innovation-based ecoenzyme

community service activity is of high urgency as a strategic step in addressing environmental issues while improving community welfare through entrepreneurship based on local potential.

METHODS

Participants

This community service activity was attended by 40 participants, all of whom were women. The demographic profile of community service participants is listed in Table 1.

Table 1 Demographic profile of community service participants

No	Age Group	Gender	Total (n)	Percentage (%)
1	20 – 30 years	Female	14	35%
2	30 – 40 years	Female	26	65%
Total			40	100%

Based on the demographic data shown in Table 1, the participants were divided into two age groups: those aged 20–30 and those aged 30–40. The 30–40 age group was the largest, with 26 participants (65%), while the 20–30 age group had 14 participants (35%). This composition of participants reflects the involvement of women from various productive age groups in the community service activities carried out.

Procedure

Community service activities are carried out by applying the Asset-Based Community Development (ABCD) approach. The ABCD approach was selected because it focuses on identifying, mobilizing, and optimizing the existing potential and assets within the partner community, rather than solely focusing on their deficits or problems. In this program, the primary assets maximized were pineapple peel waste and the strong collaboration between the PKK women's group and the Tinggiran Darat youth organization, to be held from May 23 to September 8, 2025. This activity was carried out in a phased and systematic manner ([Nursetiawan et al., 2024](#)). The stages of the activity are as follows:

a. Socialization of the program to partners

This stage was carried out to convey the objectives, benefits, and activity plans for utilizing pineapple peel waste into eco-enzymes as a basic ingredient for environmentally friendly detergents. This socialization also served as the first step in building commitment and mutual support for the smooth implementation of activities.

b. Training on making eco-enzymes and environmentally friendly detergents

This stage aims to improve participants' skills in processing waste into eco-enzymes through practical training. Participants will learn the complete techniques from collecting materials, fermentation, and storage with guidance from expert instructors. The training uses simple tools available on site and step-by-step guide modules to facilitate learning.

c. Digital marketing training and product branding development

This stage aims to equip participants with the skills to produce high-quality and consistent eco-enzyme detergents. Participants are trained in utilizing digital media for promotion and sales and are provided with guidance on branding, packaging, and marketing strategies.

d. Evaluation

After the training, an evaluation phase was conducted to assess the process and impact of the training activities on participants' understanding of the basic concepts of ecoenzymes, ecoenzyme production, natural detergent soap, digital marketing, and

branding. This evaluation was based on the results of participants' understanding assessments before and after the training activities using multiple-choice pre-test and post-test instruments.

Instrument

Two instruments were developed to evaluate the effectiveness of the community empowerment program: (1) a comprehension assessment instrument and (2) a community perception questionnaire. The comprehension assessment instrument was designed to measure participants' understanding of ecoenzyme production, ecoenzyme-based detergent products, and digital marketing practices. This instrument consists of ten items distributed across four dimensions: the concept of ecoenzymes, the process of making ecoenzymes, environmentally friendly detergent products, and digital marketing and branding, as given in Table 2.

Table 2 Indicators and aspects of comprehension assessment

Indicator	Aspects of Assessment	Item Number
The concept of ecoenzymes	Definition of ecoenzymes	1
	Benefits of ecoenzymes for the environment	2
The process of making ecoenzymes	Raw materials for ecoenzyme production	3
	Ecoenzyme fermentation process	4
Environmentally friendly detergent products	Formulation of ecoenzymes into liquid detergents	5
	Safety of ecoenzyme detergents for skin/environment	6
	Cleaning effectiveness of ecoenzyme detergents	7
Digital marketing and branding	Simple marketing strategies (local/digital)	8
	Economic value of ecoenzyme detergent products	9
	Importance of product branding & packaging	10

The public perception questionnaire was developed to evaluate public responses to ecoenzyme-based detergent products produced by participants. This instrument consists of sixteen items organized into three dimensions: Product Quality, Packaging & Branding, and Sustainability & Interest in Use (Table 3).

Table 3 Indicators and aspects of the public perception questionnaire

Indicator	Aspects of Assessment	Item Number
Product Quality	Good cleaning power	1, 2, 3, 4
	Skin safety	5, 6, 7, 8
Packaging & Branding	Attractive packaging	9, 10, 11, 12
Sustainability & Interest in Use	Readiness for reuse	13, 14, 15, 16

Validity and reliability

The validity of the comprehension assessment instrument and community perception questionnaire was examined using the Rasch measurement model through Winsteps version 3.73. Item validity was evaluated based on item-fit statistics, particularly Outfit Mean Square (MNSQ) and Outfit Standardized Residual (ZSTD). Following the commonly accepted Rasch criteria, items are considered fit to the model when Outfit MNSQ values fall within the range of 0.50–1.50, and Outfit ZSTD values range between –2.00 and +2.00 (Boone et al., 2014). These criteria indicate that the observed responses conform adequately

to model expectations and that each item contributes meaningfully to measuring the intended construct. The results presented in Tables 4 and 5 demonstrate that all items of both instruments exhibited acceptable fit statistics.

Table 4 Item fit comprehension assessment instrument

Item	Measure (Logit)	Outfit MNSQ	Outfit ZSTD
1	1.03	1.03	0.3
2	1.03	1.01	0.1
3	1.14	1.03	0.3
4	1.14	1.03	0.3
5	1.25	1.00	0.0
6	1.25	1.28	2.3
7	1.25	0.97	-0.2
8	0.70	1.01	0.1
9	0.70	0.94	-0.3
10	0.70	1.02	0.2
11	-0.94	0.72	-0.5
12	-0.94	0.82	-0.3
13	-0.94	0.97	0.1
14	-0.94	0.77	-0.4
15	-1.20	0.84	-0.1
16	-1.20	0.87	-0.1
17	-1.20	1.45	0.9
18	-0.94	0.63	-0.7
19	-0.94	0.79	-0.3
20	-0.94	0.68	-0.6

For the comprehension assessment instrument, Outfit MNSQ values ranged from 0.63 to 1.45, while Outfit ZSTD values ranged from -0.70 to 0.90.

Table 5 Item fit community perception questionnaire

Item	Measure	Outfit MNSQ	Outfit ZSTD
PQ1	-0.05	1.10	0.4
PQ2	-0.16	0.95	-0.1
PQ3	-0.12	0.95	-0.1
PQ4	-0.20	1.14	0.6
PQ5	-0.12	0.61	-1.5
PQ6	-0.01	0.83	-0.6
PQ7	-0.20	0.95	-0.1
PQ8	-0.05	0.99	0.1
PB1	0.12	0.89	-0.4
PB2	0.27	0.90	-0.4
PB3	0.21	0.90	-0.4
PB4	0.12	1.38	1.5
SI1	-0.12	1.15	0.6
SI2	0.12	1.14	0.6
SI3	0.12	0.87	-0.5
SI4	0.06	1.09	0.5

Similarly, the community perception questionnaire showed Outfit MNSQ values between 0.61 and 1.38 and Outfit ZSTD values between -1.50 and 1.50. These findings indicate that all items functioned consistently with the Rasch model requirements and adequately represented the latent constructs being measured. Consequently, no items were identified as misfitting, and all items were retained for subsequent analyses.

Reliability was subsequently evaluated using the Rasch item reliability index. According to established Rasch reliability criteria, values above 0.80 indicate good

reliability, whereas values exceeding 0.90 indicate very good to excellent reliability (Taber, 2018). The analysis yielded an item reliability coefficient of 0.83 (Table 6), placing the instrument within the good reliability category. This result suggests that the hierarchy of item difficulties can be reproduced consistently across comparable samples and that the instrument possesses satisfactory measurement stability.

Table 6 Item reliability

Item reliability	0.83
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Overall, the Rasch analysis provides strong evidence supporting both the validity and reliability of the developed instruments. The absence of misfitting items and the good level of item reliability indicate that the instruments are psychometrically sound and suitable for assessing participants' comprehension of ecoenzyme concepts and their perceptions of ecoenzyme-based community empowerment programs.

RESULTS AND DISCUSSION

Training on the production of ecoenzymes and environmentally friendly detergents was conducted as an effort to increase the knowledge and skills of the community in processing pineapple peel waste into value-added products. This activity was attended by 40 participants consisting of a group of PKK women and youth organizations from Tinggiran Darat Village. The training series was carried out in stages, covering material on the basic concepts of ecoenzymes and hands-on practice in making ecoenzymes and natural detergent soap, as well as training in digital marketing and branding.

Each session was held at different times to ensure participants received an optimal learning experience. The participants not only gained an understanding of the ecoenzyme fermentation process and detergent production techniques but were also equipped with skills in packaging, digital marketing, and product identity development.

Program Socialization to Partners

The socialization activity of the community service program on the utilization of ecoenzyme derived from pineapple peels as a liquid detergent was carried out in a participatory manner by involving partners from the initial stages. The activity began with coordination with village officials and local community groups to determine the schedule, venue, and implementation mechanisms. During the socialization session, the team presented the program objectives, the urgency of managing household organic waste, and the economic and ecological potential of processing pineapple peels into eco-enzymes. The material was delivered through an interactive lecture method accompanied by two-way discussions to ensure that participants could comprehensively understand the concepts, as seen in Figure 1.



Figure 1 PkM socialization at the sub-district office

This initial stage is an effort to establish communication and build mutual understanding between the PkM team and the community as well as local stakeholders. The activity began with a discussion with the acting head of Mekarsari Subdistrict, who explained the urgency of utilizing pineapple peel waste to produce ecoenzymes as a basic ingredient for environmentally friendly detergents. The discussion showed positive support from the subdistrict because the program was considered relevant to the community's needs, particularly in agricultural waste management and pineapple product diversification.

Training on Making Ecoenzymes and Environmentally Friendly Detergents

At this stage, there were 40 participants consisting of members of the PKK and Karang Taruna of Tinggiran Darat Village. The activity was carried out over several meetings, with details of activities ranging from presentations on ecoenzymes and practical ecoenzyme production to presentations on product branding and marketing (Figure 2).



Figure 2 Presentation of ecoenzyme material by resource persons

The activity began with the presentation of material on the basic concepts of ecoenzymes, their benefits for the environment, and opportunities for developing environmentally friendly products based on pineapple peel waste. The material was delivered interactively using presentation media, discussions, and question-and-answer sessions so that participants gained adequate theoretical understanding.

Following the presentation, the activity continued with the initial processing stages of ecoenzyme production, which included preparing tools and materials, determining the mixture composition, and explaining the fermentation process, which must be carried out within a specific timeframe. Participants were given explanations regarding cutting techniques, mixing sugar solutions and air, and procedures for storing the product in a secure, closed container. The team also explained the fermentation monitoring process, including how to address issues such as aroma changes during the process (Figure 3).



Figure 3 Ecoenzyme production process

Ecoenzymes produced from fermented pineapple peel waste are used as the main ingredient in the manufacture of natural detergents, which are then formulated with simple supporting ingredients that are easily obtained by the community. The manufacturing process is carried out in a participatory manner by involving PKK women and youth organizations so that participants not only acquire technical skills but also an understanding of the importance of environmentally friendly products as an alternative to synthetic chemical detergents (Figure 4). The use of eco-enzyme derived from fermented pineapple peel waste as the main ingredient in the production of natural detergent represents a promising approach to promoting environmental sustainability and community empowerment. This process involves the fermentation of organic waste, such as fruit and vegetable peels, to produce a multifunctional liquid that can be used in various applications, including dishwashing soap and antiseptic liquid soap ([Wahyuni et al., 2025](#); [Kurniati et al., 2025](#)). The participatory nature of this initiative, which involves local community groups such as PKK women and youth organizations, not only equips participants with technical skills but also enhances awareness of the environmental benefits of eco-friendly products as alternatives to synthetic chemical detergents ([Hakim et al., 2025](#); [Tsany et al., 2024](#)).



Figure 4 Detergent manufacturing process

From direct observation, most participants showed high enthusiasm, marked by active questioning and full involvement in the practice. The involvement of PKK women is expected to strengthen their role in household production, while youth organizations have the potential to become driving forces in product marketing and innovation. This is in line with the concept of participation-based community empowerment, where cross-social group involvement can strengthen program sustainability ([Chambers, 1997](#)).

Digital Marketing and Product Branding

Participants were also provided with materials on promotional skills and technology-based marketing strategies. The participants, consisting of PKK women and youth organizations from Tinggiran Darat Village, received training on the use of social media (WhatsApp Business, Instagram, and Facebook) and simple marketplaces to market eco-enzyme detergent products. In addition, they were given guidance on product photography techniques, promotional content creation, and writing attractive product descriptions (Figure 5).



Figure 5 Presentation of digital marketing material

In addition, guidance on branding, packaging, and marketing strategies successfully encouraged participants to design more attractive product identities. Participants demonstrated creativity in designing labels and packaging products to make them look more professional and marketable. This process also fostered awareness that branding is not limited to names and packaging but also concerns the image and values that are conveyed to consumers ([Meizary, 2024](#)).

Evaluation

The evaluation was conducted using two instruments: a knowledge questionnaire (pre-test and post-test) and a questionnaire on the public perception of eco-enzyme-based, environmentally friendly detergent products. The first instrument was used to measure the increase in participants' understanding of the basic concepts of eco-enzymes, the process of making environmentally friendly detergents, and their marketing. The analysis results showed a significant increase in the average score of participants' understanding (Table 7).

Table 7 Results of the training participants' comprehension assessment

Indicator	Pre-Test	Post – Test	Category
The concept of ecoenzymes	52.25	87.5	Very Good
The process of making ecoenzymes	50.0	86.75	Very Good
Environmentally friendly detergent products	48.0	89.0	Very Good
Digital marketing and branding	60.0	87.5	Very Good

In addition to enhancing participants' knowledge, the program generated a tangible output in the form of a packaged eco-enzyme liquid detergent produced from pineapple peel waste. This product serves as evidence of the successful transformation of agricultural waste into a value-added, environmentally friendly household cleaning product with potential economic benefits for local communities. The final packaged eco-enzyme detergent product is illustrated in Figure 6.

These results show that training methods based on hands-on practice, participatory discussions, and intensive mentoring are effective in improving community understanding. These findings are in line with the research by [Kartika et al., \(2021\)](#), which states that the learning by doing approach in community service programs can accelerate the improvement of participants' skills and knowledge. In addition, the involvement of PKK women and youth organizations in these activities demonstrates the importance of cross-group collaboration to strengthen program sustainability



Figure 6 Liquid detergent made from pineapple waste using ecoenzymes

The effectiveness of training methods that include hands-on practice, participatory discussions, and intensive mentoring in increasing community understanding is well supported by various studies. For example, a training program in Gattareng Village demonstrated a significant increase in participants' knowledge of soap making, with understanding increasing from 20% to 85% post-training, highlighting the efficacy of practical skills training in economic empowerment ([Syam & Suriadi, 2024](#)). Furthermore, the involvement of diverse community groups, such as the Family Welfare Movement (PKK) and youth organizations, underscores the importance of cross-group collaboration for program sustainability. For example, training in Wosu Village significantly improved participants' readiness for workforce challenges, with average scores increasing from 100.21 to 175.87 out of 200, demonstrating the impact of an integrated community empowerment strategy ([Anisah et al., 2024](#)). The results of the public perception assessment of the product are listed in Table 8.

Table 8 Results of public perception assessment of products

Indicator	Aspects Assessment	Percentage Agree (%)
Product Quality	Good cleaning power	84.4
	Skin safety	90.6
Packaging & Branding	Attractive packaging	78.1
Sustainability & Interest in Use	Readiness for reuse	81.3

Meanwhile, the second instrument was used to assess public acceptance of ecoenzyme detergent products. This assessment of public perception is important in determining the success of a product ([Suarini & Krisna, 2024](#)), as this perception reflects how the public assesses aspects such as product quality and packaging, which can attract public interest in continuing to use the detergent product. The analysis results show that public perception is positive. A total of 84.4% of respondents rated the cleaning power as quite good, 90.6% of respondents rated the product as safe for the skin, and 78.1% of respondents considered the packaging to be quite attractive, although the design still needs improvement. In addition, 81.3% of respondents are willing to reuse the product and recommend it to others.

These findings are in line with [Gaspersz & Fitrihidajati \(2022\)](#), who reported that ecoenzyme-based cleaning products have good prospects because they are accepted by the public as a safer and more environmentally friendly alternative to synthetic detergents. These results indicate that ecoenzyme detergents not only have environmental value, but also sustainability potential as a local green economy-based product.

While the majority of respondents (78.1%) rated the packaging as sufficiently attractive, this dimension recorded the lowest acceptance score across all evaluated parameters, and its critical interpretation warrants particular attention. Prior community service programs focused on ecoenzyme awareness, including those implemented in urban Surabaya and peri-urban Palembang settings, did not incorporate any formal packaging assessment within their evaluation instruments ([Ernilawati et al., 2025](#); [Merlinda et al., 2023](#)), making direct quantitative comparison challenging. Nevertheless, the present finding that packaging design remains a limiting factor in consumer appeal is both a limitation and a productive signal: it indicates that technical training in fermentation and formulation, while necessary, is insufficient for sustainable market entry without commensurate attention to brand identity and packaging design. This observation is consistent with the broader green marketing literature, which recognizes that eco-friendly product adoption is not solely driven by environmental value propositions but is critically modulated by visual communication and shelf-presence cues ([Rasmikayati et al., 2023](#)).

Furthermore, the finding that 84.4% of respondents rated the product's cleaning power as satisfactory is noteworthy, as it provides functional validation that was notably absent in previous studies on the community empowerment of eco-friendly enzymes in Indonesia ([Basuki et al., 2023](#)). This percentage represents a level of consumer-reported effectiveness that is directly comparable to, and in some cases exceeds, the reported acceptance thresholds for bio-based cleaning agents in the broader literature on eco-friendly product adoption, where acceptance rates of 70–80% are generally considered an indicator of market viability ([Vijayan et al., 2025](#)).

Crucially, the present study's entrepreneurship module, which incorporated product labeling, pricing strategy, and market entry planning, directly addresses this gap through a structured three-stage training protocol not previously documented in indexed ecoenzyme community service literature in Indonesia. While programs such as EnzymPoz ([Wicaksono, 2025](#)) and the Tuvung Village hydroponic integration initiative ([Panda et al., 2024](#)) demonstrated eco-enzymes' productive versatility, neither embedded a formalized product commercialization pathway into their community empowerment framework. The inclusion of such a module in the present program, combined with the packaging perception data, creates a feedback mechanism that enables iterative product improvement grounded in market intelligence, a dynamic absent in antecedent programs that treated ecoenzyme production as an endpoint rather than a starting point for circular economic participation.

CONCLUSION

The Community Empowerment Program in Tinggiran Darat Village has successfully generated significant positive impacts on organic waste management and sustainable economic empowerment. Through intensive training activities, the community was equipped with knowledge and skills to utilize pineapple peel waste to produce eco-enzymes, which are used as the main ingredient in natural detergent production. Participants were also provided with knowledge on marketing strategies and product branding. This success is reflected in the survey results, which show a significant improvement in participants' understanding across all indicators, with average pre-test and post-test scores increasing from 52.25 to 87.5 for the concept of eco-enzymes, from 50.0 to 86.75 for the production process, from 48.0 to 89.0 for environmentally friendly detergent products, and from 60.0 to 87.5 for digital marketing and branding, all categorized as very good.

Furthermore, the analysis of participant perceptions indicates a positive level of acceptance toward eco-enzyme-based detergent products, with 84.4% of respondents rating the cleaning power as good, 90.6% considering it safe for the skin, 78.1% finding the

packaging fairly attractive, and 81.3% expressing willingness to reuse and recommend the product. These findings suggest that eco-enzyme-based detergents are not only effective in enhancing community capacity but also hold strong potential to be developed as environmentally friendly and economically valuable products.

The utilization of pineapple peel waste has provided additional positive impacts, including reducing organic waste, improving agricultural outcomes, and enhancing community economic welfare through product diversification into marketable goods. As a follow-up to this program, the community service team plans to conduct further assistance focusing on research and development of other high-value eco-enzyme derivative products beyond detergents. This initiative aims to optimize the potential of waste resources comprehensively, expand the community's business portfolio, and ensure that these innovative products meet commercial feasibility standards for independent marketing.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, M; methodology, M; formal analysis, PS; writing—preparation of the original draft, RI; and formatting the manuscript, HK and ASL.

ACKNOWLEDGMENTS

This community service program is supported by funding from the Ministry of Higher Education, Science, and Technology of the Republic of Indonesia through the Directorate of Research, Technology, and Community Service of BIMA 2025. The authors would like to express their deepest gratitude to the sub-district head, the Family Welfare Movement (PKK), and the community-based youth organization of Tinggiran Darat Village, Mekarsari Subdistrict, for their active participation and collaboration throughout the program. Thanks are also extended to the Institute for Research and Community Service and the leadership of Lambung Mangkurat University for their institutional support, as well as to all students and volunteers involved in the field activities.

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