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Development of Practical Guidelines for Waste Processing Based on Liquid Organic Fertilizer Formulation Research for High School Biology Learning

Shafa Chamilatush Sholihah, Ismul Mauludin Al Habib*, Dwi Sucianingtyas Sukamto
Biology Education Department, Faculty of Teacher Training and Education,
Universitas PGRI Argopuro Jember, Indonesia.
*Corresponding Author. Email: habibismul71@gmail.com

Abstract: This research aims to formulate a liquid organic fertilizer (LOF) based on banana corm, moringa leaves, and pineapple peel, providing a practical guide for organic waste processing in high school biology learning. The study used samples of organic waste (banana corm, moringa leaves, and pineapple peel) collected from Suci Village, Panti District, Jember Regency, which were then formulated into liquid fertilizer through a fermentation process lasting 14 days with the addition of bioactivators and other supporting materials. Data collection was conducted by observing the nutrient content of the LOF analyzed in the laboratory of Jember State University and validating the practical guide using validation sheets by three experts who assessed material, media, and language aspects on a Likert scale of 1–5. The validation data were analyzed descriptively and quantitatively by calculating the average percentage score to determine the product's validity level. Laboratory analysis showed that the resulting LOF contained Nitrogen (N) at 0.05%, Phosphorus (P) at 0.0032%, Potassium (K) at 0.005%, organic carbon at 0.62%, iron (Fe) at 0.00053%, and a pH of 3.4. The macro- and micronutrient content in this LOF is still below the minimum standards set by the Ministry of Agriculture; however, this formulation still provides an alternative for the value-added utilization of agricultural organic waste. The practical guide developed in this research has been validated by three expert validators with an average assessment percentage of 79.90%, indicating that this guide is valid for use in grade 10 high school biology learning on the topics of environmental change, waste, and recycling. The results show that this practical guide for making LOF is feasible to implement, contributing to organic waste management and contextual learning media that supports project-based environmental education. This study's outcomes have implications for developing innovative learning materials and promoting sustainable waste management practices in educational settings, ultimately enhancing environmental awareness and literacy among high school students.

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Introduction

Fertilizer is a material that contains one or more essential nutrients. In general, fertilizers are classified into inorganic and organic types (Yanti *et al.*, 2022). The use of inorganic fertilizers can accelerate plant growth, but in the long term, it often leads to soil degradation, decreased water quality, and a decline in the natural fertility of the soil (Khotimah *et al.*, 2020; Sifaunajah *et al.*, 2022). Liquid Organic Fertilizer (LOF) is created through the breakdown of organic materials such as plant, animal, and human waste, providing essential nutrients that promote healthy plant growth and development. (Waris *et al*., 2023). Liquid organic fertilizer serves as a sustainable substitute for traditional fertilizers, being recognized as eco-friendly, more readily taken up by plants, and rich in essential macronutrients. (Herlinawati *et al*., 2019).

In Indonesia, agricultural waste such as banana stems, moringa leaves, and pineapple peels are often simply discarded. Organic waste has the potential to be processed into Liquid Organic Fertilizer, which not only reduces waste but also helps improve soil quality and provides essential nutrients for plants (Marasabessy & Tanasale, 2020). Plants need a lot of macronutrients, including potassium (K), phosphorus (P), and nitrogen (N). Plants need a lot of macronutrients like potassium (K), phosphorus (P), and nitrogen (N). Deficiency in any of these macronutrients can cause symptoms like yellowing leaves, stunted growth, or flower drop (Infarm, 2024). Micronutrients are also crucial for plants, although they are needed in smaller quantities.

Liquid Organic Fertilizer (LOF) is derived from organic materials, such as plant residues and kitchen waste, which are fermented under anaerobic conditions with the help of microorganisms. LOF is more easily absorbed by plants and can improve the physical, chemical, and biological properties of the soil. Liquid Organic Fertilizer (LOF) can also reduce the use of chemical fertilizers, which have negative impacts on the soil if used continuously. The use of LOF is environmentally friendly because it does not cause environmental pollution and provides beneficial soil microorganisms. Furthermore, liquid organic fertilizer includes binding agents that help the fertilizer solution, when applied to the soil surface, to be quickly absorbed and efficiently used by plants. (Ersadi *et al*., 2023). An example of Liquid Organic Fertilizer (LOF) is a fertilizer solution produced from agricultural waste materials like banana stems, moringa leaves, and pineapple peels.

The nutrient nitrogen (N) plays an important role in plants during the vegetative growth phase, such as in leaves, stems, and roots, helping to enhance plant growth. The nutrient phosphorus (P) also plays a crucial role in plant growth. If a plant is deficient in phosphorus (P), symptoms appear as dark green leaves with a shiny reddish surface, and the plant becomes stunted. The edges of the leaves, branches, and stems of the shallot plant shrink and turn reddish-purple, eventually turning yellow over time. Potassium content functions to harden the woody parts of plants, improve the quality of seeds and fruits, and enhance the plant's resistance to pests and diseases. Plants deficient in potassium (K) show symptoms of dryness at the leaf tips, especially on older leaves. Potassium is very important in the formation and transfer of carbohydrates, photosynthesis, water regulation, and protein synthesis (Triadiawarman *et al.*, 2022). Iron (Fe) is one of the micronutrients required by plants for the formation of amino acids, chlorophyll, and energy (ATP and ADP) (Andriani & Habibah, 2019). pH levels greatly affect plant growth and health because they influence nutrient availability, microorganism activity, and soil structure. Most plants prefer a neutral pH of 6-7 since this is where macronutrients like potassium (K), phosphorus (P), and nitrogen (N) are most readily absorbed.

The research by Anzila & Asngad, (2022) showed that moringa leaves contain 4.02% nitrogen (N), 1.17% phosphorus (P), and 1.80% potassium (K); banana stems contain 1.05% nitrogen (N), 0.04% P2O5, and 0.76% K2O; while pineapple peels are rich in bioactive compounds and the enzyme bromelain, which accelerates fermentation and increases the mineral content in the fertilizer. Processing organic waste into Liquid Organic Fertilizer (LOF) is also highly relevant as a contextual learning medium in 10th-grade high school biology, especially in topics related to environmental changes, waste, and recycling.

Jurnal Paedagogy:
Jurnal Penelitian dan Pengembangan Pendidikan
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Email:paedagogy@undikma.ac.id

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

Environmental education is one of the solutions to increase students' knowledge and understanding of preserving the functions of the environment. Utilizing the environment as a learning resource serves as an anticipation or response to the impacts of environmental changes, one of which is waste (Saparuddin *et al*., 2022). The topics included in waste recycling education are the types of waste and the processes for recycling them. Currently, practical guidelines for making organic fertilizer are not based on the results of research on organic waste processing formulations.

Previous studies on liquid organic fertilizer (LOF) have been carried out with various focuses. Research conducted by (Aditya *et al.*, 2018) focused on the production of LOF from banana corms through a fermentation process. Meanwhile, (Susi *et al*., 2018) emphasized the analysis of nutrient content in LOF derived from pineapple peel waste. Furthermore, research by (Reyni & Binawati, 2023) examined the effects of applying LOF made from a combination of banana corms and moringa leaves on the growth of mustard greens (*Brassica juncea* L.).

Based on these comparisons, a research gap is identified, namely the lack of studies specifically addressing the nutrient content of LOF formulated from a combination of banana corms, moringa leaves, and pineapple peels, as well as its utilization as a practical guide in high school biology learning, particularly in the sub-chapter on waste processing. The novelty of this study lies in two aspects: focusing on the nutrient content of LOF formulated from banana corms, moringa leaves, and pineapple peels, and developing a practical guide that can assist students in understanding learning materials through structured, contextual, and experiential learning.

Therefore, this research is important to determine the nutrient content of LOF (Liquid Organic Fertilizer) with formulations of banana stems, moringa leaves, and pineapple peels. It is also needed to determine whether the resulting liquid organic fertilizer formulation can be used as a reference for practical guidelines in the 10th-grade high school biology subject, specifically in the sub-chapter on waste processing.

Research Method

This study employed the Research and Development (R&D) method to produce a practical guide for waste processing based on the formulation of liquid organic fertilizer (LOF). The method integrates scientific research—through laboratory analysis of nutrient content in LOF formulated from banana corms, moringa leaves, and pineapple peels—with product development in the form of a practical guide for 10th-grade high school Biology learning. The product was validated by experts in material, media, and language to assess its content, presentation, and clarity. Thus, this study not only generated scientific data on LOF but also produced an educational product that was validated as feasible for supporting practical-based learning. This study took place in Suci Village, Panti District, Jember Regency, as well as in the Laboratory of Jember State University, and was conducted between November 2024 and January 2025.

The research samples include banana stems, moringa leaves, and pineapple peels collected from the surrounding environment or local sources that meet the research criteria. The population of this research consists of organic waste used as the base material for liquid organic fertilizer, originating from plants such as banana stems, moringa leaves, and pineapple peels.

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

The main materials: banana stems, moringa leaves, pineapple peels. Additional materials: molasses, rice washing water, bioactivator (EM4), coconut water, and clean water. Equipment: fermentation container, strainer, measuring tools, and stirring tools.

Steps to Create Liquid Organic Fertilizer (LOF):

The research samples consisted of banana corms, moringa leaves, and pineapple peels, collected from locally available organic waste. Banana corms were obtained from non-productive plants, moringa leaves from nearby residential areas, and pineapple peels from household waste and local vendors. All materials were selected in good condition, free from chemical contamination or inorganic residues. The samples were then weighed, washed with clean water, and chopped or ground to facilitate fermentation into liquid organic fertilizer.

The materials needed for making liquid organic fertilizer are: 3 kg of banana stems, 3 kg of moringa leaves, 1.5 liters of coconut water, 1.5 liters of rice washing water, 0.5 liters of molasses, and EM4 bioactivator.

Steps: Chop the banana stems and pineapple peels into small pieces, grind the moringa leaves using a blender, then mix them into a fermentation container. Then add 1.5 liters of coconut water, 1.5 liters of rice washing water, and 0.5 liters of EM4 molasses. Next, close the container and let it ferment for 14 days, stirring twice a week. The finished liquid fertilizer, characterized by a fragrant, tape-like smell, is filtered and placed into bottles. Then, the liquid fertilizer is prepared to be tested for its nutrient content.

Identification of Research Variables: Independent Variable: The composition of the base materials used to make liquid organic fertilizer, namely banana stems, moringa leaves, and pineapple peels. Dependent Variable: The quality of the produced liquid organic fertilizer, including parameters such as nutrient content (N, P, K), Fe, organic carbon, and pH. The effectiveness of the practical guidelines in assisting the learning process of organic waste processing for students. Control Variables: The process of making liquid organic fertilizer, as well as the proportions and measurements of the materials used to ensure consistent research results.

Data were collected from observations of the nutrient content in liquid organic fertilizer made from banana stems, moringa leaves, and pineapple peels, which had been tested for nutrient content by the laboratory staff at Jember State University. Laboratory testing was carried out using standard chemical analysis methods (nutrient content tests and pH meter).

Based on the results of the nutrient content observations, the practical guide for the waste processing subject was then developed. After the practical guide was created, validity testing was conducted by a validation team using a prepared format to determine whether the practical guide is suitable for implementation in 10th-grade biology learning.

Validation data were collected by providing the validation sheet instrument and the developed practical guide to the validation team. The results of the validity testing included suggestions and feedback used as a basis for improving or revising the practical guide that the researcher developed. The instruments used in this research were observation results and validation sheets.

Research Instruments

Observation sheets are data obtained after conducting observations during the process of making liquid organic fertilizer (LOF) and the results of observations on the nutrient content contained in the liquid organic fertilizer (LOF). The Validation Sheet is a form used to test the validity of the developed media, including language, material, and media aspects, by appointing a validation team or experts for these three aspects. The evaluation results for

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Jurnal Penelitian dan Pengembangan Pendidikan
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Email:paedagogy@undikma.ac.id

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

all aspects are measured using a Likert scale. In this research, the instrument item responses are classified into five options. Each measured indicator is given a score on a scale of 1 to 5, as shown in the table below: (Salmiati, 2023)

Table 1. Likert Scale Indicators

Criterion	Value/Score
Very poor	1
Poor	2
Less than good	3
Good	4
Very good	5

The data analysis technique used in this research is quantitative data analysis. Data obtained from the validators were analyzed descriptively and quantitatively. The data analysis technique in this research is as follows:

Data obtained from the validator assessments were analyzed quantitatively by calculating the percentage score using the following formula:

$$P: \frac{\Sigma x}{\Sigma xi} \times 100\%$$

Description:

P = percentage of the score
Σx = total score obtained from the validators
Σxi = maximum possible score
100 = constant number

The data obtained from the validators are then averaged using the following formula:

$$\bar{x} = \frac{\Sigma P}{n}$$

Note:

$\bar{x}$ = average percentage score
n = number of validators
ΣP = sum of the percentage scores from each validator (Salmiati, 2023)

After obtaining the average percentage score from the validators, the validity level of the practical guide will be determined based on the following assessment criteria:

Table 2. Assessment Criteria for the Validity Level of the Practical Guide (Salmiati, 2023)

No	Percentage	Qualification
1.	<21%	Qualification
2.	21 – 40%	Invalid
3.	41 - 60%	Quite valid
4.	61 – 80%	Valid
5.	81 – 100%	Very valid

Results and Discussion

1. Organic Matter Content in Liquid Organic Fertilizer from Banana Stems, Moringa Leaves, and Pineapple Peels

   The organic matter content in liquid organic fertilizer made from banana stems, moringa leaves, and pineapple peels was tested at the Laboratory of Jember State University. The tested results are known and the data will be presented in Table 3 below.

Jurnal Paedagogy:
Jurnal Penelitian dan Pengembangan Pendidikan
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Email:paedagogy@undikma.ac.id

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

Table 3. Organic Matter Content in Liquid Organic Fertilizer from Banana Stems, Moringa Leaves, and Pineapple Peels

No	Test Parameter	Test Result
1	Nitrogen (N)	0, 05%
2	Phosphorus (P)	0, 0032%
3	Potassium (K)	0,005%
4	Organic Carbon	0,62%
5	Iron (Fe)	0,00053%
6	pH	3,4

According to the laboratory analysis results presented in Table 3, the nutrient content of liquid organic fertilizer produced from banana stems, moringa leaves, and pineapple peels is detailed. Ensuring an adequate supply of nutrients is crucial for promoting optimal plant growth, as each nutrient serves a distinct and vital function in different physiological processes. Macronutrients including nitrogen (N), phosphorus (P), and potassium (K) are needed by plants in significant quantities.

Nitrogen is crucial for the synthesis of chlorophyll and the process of photosynthesis, whereas phosphorus is vital for root development and generating energy for plant metabolism. Insufficient amounts of either of these macronutrients can lead to symptoms like yellowing leaves, stunted growth, or premature flower drop (Infarm, 2024). Potassium is one of the most abundant elements in plants after nitrogen. Potassium helps the plant absorb water and nutrients from the soil, assists in transporting assimilates from the leaves to other plant tissues, and plays a role in starch formation, enzyme activation, stomatal opening (which regulates respiration and transpiration), physiological processes, cellular metabolism, influences the uptake of other nutrients, enhances drought and disease resistance, and also contributes to root development (Rosawanti, 2019).

Micronutrients such as iron (Fe), boron (B), and copper (Cu) are also crucial, although needed in small amounts. These micronutrients, for example, support enzyme and chlorophyll formation and facilitate the photosynthesis process, so without sufficient micronutrients, plants will experience disturbances in growth and disease resistance (Hartatik *et al*., 2015). The pH level greatly influences plant growth and health because it affects nutrient availability, microorganism activity, and soil structure. A neutral pH range of about 6 to 7 is generally considered optimal for most plants, as macronutrients like nitrogen (N), phosphorus (P), and potassium (K) are more readily taken up by plant roots under these conditions. Organic carbon content in the soil also plays several important roles: it serves as an energy source for soil microorganisms, enhances soil structure, and boosts the availability of nutrients for plant uptake.

Among the macronutrients present in the liquid organic fertilizer, nitrogen is found in the highest concentration compared to the other nutrients. However, the nitrogen content is lower than the minimum standard set by the Ministry of Agriculture Regulation No. 261/ KPTS/ SR. 310//M/4/2019. The contents of phosphorus, potassium, iron (Fe), and organic carbon (C-organic) in the liquid organic fertilizer (LOF) are very low and do not meet the minimum standards for liquid fertilizers. According to the Ministry of Agriculture Regulation No. 261/ KPTS/ SR. 310//M/4/2019, the minimum standards for nitrogen, phosphorus, and potassium content in solid organic fertilizers (compost) are at least 2%, iron (Fe) between 0.9% and 0.09%, organic carbon (C-organic) at 0%, and pH ranging from 4 to 9.

Jurnal Paedagogy:
Jurnal Penelitian dan Pengembangan Pendidikan
https://e-journal.undikma.ac.id/index.php/pedagogy/index
Email:paedagogy@undikma.ac.id

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

The nutrient content obtained from the nutrient testing of liquid organic fertilizer made from banana stems, moringa leaves, and pineapple peels is 0.05% for nitrogen, followed by 0.005% for potassium, while the lowest content is phosphorus at 0.0032%. A pH measurement of 3.4 was also taken, with a C-organic content of 0.62% and a micronutrient content of Fe at 0.00053%.

The levels of nitrogen, phosphorus, potassium, organic carbon, iron (Fe), and pH in the liquid organic fertilizer produced from banana stems, moringa leaves, and pineapple peels are significantly below the minimum requirements specified in the Ministry of Agriculture Regulation No. 261/ KPTS/ SR. 310//M/4/2019.

2. Utilization of Research Results as a Practical Guide for Making Liquid Organic Fertilizer (LOF) in the Biology Subject for Senior High School, Chapter on Environmental Changes, Waste, and Recycling

The Practical Guide for Making Liquid Organic Fertilizer (LOF) for the 10th-grade Biology subject in the chapter "Environmental Changes, Waste, and Recycling" discusses how to make LOF from agricultural organic waste found around us. It also covers supporting materials related to organic waste and the process of making organic fertilizer. This practical guide is specifically designed to utilize banana stems, moringa leaves, and pineapple peels as organic waste materials, providing a detailed process for transforming these agricultural byproducts into liquid organic fertilizer (LOF)..

Below is an image of the practical guide, which will be developed further for use as a practical resource in the 10th-grade Biology curriculum, specifically for the chapter "Environmental Changes, Waste, and Recycling."

a) b)

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Email:paedagogy@undikma.ac.id

Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

c)

Figure 1. Practical Guide: a) Cover; b) Tools and Materials, Procedures; c) Observation Table, Evaluation

The practical guide is initially reviewed by experts to assess its validity and suitability for educational purposes. Validation is conducted by having each expert complete a validation sheet, which includes questions covering aspects of content, presentation, and language. The expert validation sheet is completed by 3 validators who are adjusted to their expertise.

The validation results are as follows: Validator 1 (media) scored 648 points, equivalent to 64.8%; Validator 2 (material) scored 862 points, or 86.2%; and Validator 3 (language) scored 621 points, corresponding to 88.71%. The average percentage score across all validators was calculated to be 79.90%. Based on these findings, it can be concluded that the practical guide for producing liquid organic fertilizer is "valid" and suitable for use in 10th-grade Biology instruction, specifically for the topic “Environmental Changes, Waste, and Recycling.”

The validity testing of the practical guide for making liquid organic fertilizer was conducted by 3 expert validators. According to Salmiati, (2023), a product can be considered valid if it has undergone several stages or processes of validity testing by experts. Validation is an important step in the development of learning tools, including practical guides, to ensure their feasibility before being implemented in schools. Validation is carried out by expert validators on the aspects of media, material, and language.

Validator 1 gave a total score of 648 with a percentage score of 64.8%. This indicates that the media aspect of the practical guide meets the criteria of being fairly good, although it still requires some improvements. he media aspect covers visual design, layout, image and color usage, and the ease of navigating the practical guide. This approach is in line with Putri, (2020), whose research demonstrates that learning

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Email:paedagogy@undikma.ac.id
Vol. 12 No. 4 : October 2025
E-ISSN: 2722-4627
pp. 1140-1151

materials with attractive visuals can boost student motivation, as long as the design remains simple to ensure clarity and prevent confusion.

Validator 2 gave a total score of 862 with a percentage of 86.2%. This indicates that the material in the practical guide is very valid and aligns with the curriculum standards as well as the targeted basic competencies. The content covers explanations of agricultural organic waste (such as banana stems, moringa leaves, and pineapple peels), the fermentation process, and the advantages of using liquid organic fertilizer. This approach aligns with research by Budiarti & Oka, (2017), which highlights the significance of providing accurate and pertinent material to strengthen students' comprehension of environmental biology concepts.

Validator 3 gave a total score of 621 with a percentage of 88.71%, indicating that the language used in the practical guide is very good, communicative, and appropriate for the comprehension level of 10th-grade high school students. The use of clear and easily understood language is very important so that students can follow the practical steps without confusion.

The average validation percentage across the three aspects is 79.90%, which, according to the learning media assessment standards, falls into the “valid” category. This indicates that the practical guide for making liquid organic fertilizer (LOF) is appropriate for use in the 10th-grade Biology learning process. The results demonstrate that the guide fulfills the required quality standards, supports active and independent learning, and is ready for direct implementation in the classroom.

3. Implications for 10th Grade Biology Learning

The development of a practical guide for making liquid organic fertilizer from agricultural waste such as banana stems, moringa leaves, and pineapple peels has significant educational value in 10th grade biology learning, especially on the topics of environmental change, waste, and recycling. Through this guide, students gain direct, contextual learning experience regarding the process of converting organic waste into value-added products through fermentation.

The practicum integrates environmental biology concepts and biochemical fermentation processes, enabling students to understand the roles of macronutrients (N, P, K) and micronutrients (Fe) in plant growth as well as the importance of maintaining ecosystem balance. Considering the nutrient content limitations of the liquid organic fertilizer according to Ministry of Agriculture standards, students are encouraged to discuss the factors influencing the quality of liquid organic fertilizer and how scientific processes and innovations can be utilized to improve product quality.

Validation of the guide by experts, assessing content, media, and language aspects, ensures that the material presented is relevant, communicative, and appropriate for the comprehension level of 10th grade students. This supports active, critical, and independent learning as students can perform hands-on practice, make observations, and conduct evaluations using the available observation tables.

Moreover, this project-based learning increases students’ environmental awareness through practical understanding of waste recycling, which contributes to reducing the negative impact of organic waste on the environment. The practicum also fosters a sense of responsibility in waste management and sustainable resource utilization, aligning with biology learning objectives that emphasize conservation and environmental preservation. Thus, this practical guide not only enriches theoretical learning experiences but also develops practical skills, critical assessment abilities, and socio-ecological awareness among 10th grade students, making biology learning more meaningful and relevant to everyday life

Conclusion

The laboratory analysis results show that produced liquid organic fertilizer (LOF) has the following nutrient contents: Nitrogen (N) at 0.05%, Phosphorus (P) at 0.0032%, Potassium (K) at 0.005%, C-organic at 0.62%, Iron (Fe) content at 0.00053%, and a pH of 3.4. The obtained data indicate that the nutrient content is still below the minimum requirements established bythe Ministry of Agriculture Regulation No. 261/ KPTS/ SR. 310//M/4/2019.

The practical guide developed from this research has undergone validation by three expert validators with an average assessment percentage of 79.90%, indicating that this practical guide is valid for implementation in 10th-grade high school Biology learning in the chapter "Environmental Changes, Waste, and Recycling." This indicates that this research not only contributes to efforts in managing organic waste but also to the development of contextual learning media that supports environmental education.

Recommendation

Based on the research findings, it is recommended that the formula of liquid organic fertilizer (LOF) made from banana corms, moringa leaves, and pineapple peels be continuously improved. This can be achieved by optimizing the fermentation process or experimenting with additional materials and bioactivators to increase nutrient levels, thereby bringing the product closer to the minimum standards set by the Ministry of Agriculture. In addition, direct effectiveness tests of this LOF on various types of plants should be conducted to determine its actual impact on plant growth and productivity.

The validated and feasible practical guide can also be expanded for use in other schools and further developed into a more interactive project-based learning module to enhance students' understanding and environmental awareness. Furthermore, training and outreach for teachers and students are essential so that knowledge and skills in organic waste management can be applied more widely and sustainably in schools and communities.

In addition, the findings of this research can be utilized to increase community awareness and participation in organic waste management through community-based education programs, household-level LOF training, and collaboration with local organizations and government agencies. Thus, the utilization of organic waste can not only support learning in schools but also contribute to more sustainable environmental management at the community level.

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Vol. 12 No. 4 : October 2025
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Vol. 12 No. 4 : October 2025
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