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Pineapple Liquid Waste Indigenous Bacteria Consortium for Improving the Quality of Sediment-Based Organic Fertilizers for Shrimp Ponds

Beny Saputra[1*], Agus Sutanto[2], Hening Widowati[3]

[1,2,3]Program Studi Pendidikan Biologi, FKIP, Universitas Muhammadiyah Metro, Kota Metro, Indonesia.
**Corresponding author*: benysaputra@ummetro.ac.id

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ABSTRACT

Shrimp pond sediment is a biosolid waste that can degrade water quality but contains organic matter and nutrients that can be reused as organic fertilizer. Liquid pineapple waste or limbah cair nanas (LCN) harbors indigenous bacteria that can serve as composting starters. This study evaluated the effectiveness of LCN-derived consortia in improving the quality of shrimp pond sediment–based organic fertilizer. A completely randomized design with six treatments (control, P1–P5) and five replications was used. The consortia were aerobically fermented for 30 days with sediment, leaf litter, rice husk charcoal, and LCN. Total N, P_2O_5, K_2O, organic C, C/N ratio, pH, and moisture content were analyzed using one-way ANOVA and Tukey's test ($\alpha = 0.05$). The consortia significantly affected ($p < 0.05$) most parameters, except moisture content. Treatment P5 (15 isolates) produced the highest total N (3.44%), K_2O 2.70%, C/N ratio 9.47, pH 6.2, and organic C around 32–33%, whereas P3 (9 isolates) showed the highest P_2O_5 (2.39%); these values generally met or approached the Indonesian standard for organic fertilizer (Permentan No. 261/2019). LCN-based consortia thus have potential as local starters to improve shrimp pond sediment–based organic fertilizer, although further studies on salinity, heavy metals, and field performance are needed.

INTRODUCTION

Biosolid waste, in the form of shrimp pond sediment, is a key challenge in coastal environmental management. Feed residues, feces, dead plankton, and other organic matter accumulate at the bottom of the pond during shrimp farming, especially in intensive and semi-intensive systems. This accumulation can reduce water quality, increase organic matter loading, and, under certain conditions, be detrimental to aquatic organisms if not managed properly. Shrimp pond sediment can not only be seen as waste because it still contains organic matter and nutrients that have the potential to be reused as raw materials for organic fertilizer if the processing, decomposition, and maturation process is carried out in a controlled manner (Hou et al., 2021a; Sutanto et al., 2024; Suwoyo et al., 2016).

Shrimp pond sediment cannot be directly used as organic fertilizer material without going through a characterization and stabilization process. Sediment discharged directly into the environment can increase the pollutant load because it carries organic matter and nutrients to water bodies, while its use as fertilizer requires processing to make it more stable and safe for plants (Thanh et al., 2023a; Tie et al., 2024). Organic matter that has not fully decomposed can still contain compounds from fermented products, organic acids, ammonia, salts, or have unstable pH conditions and C/N ratios, so they have the potential to cause phytotoxicity and interfere with plant growth (Jagadabhi et al., 2019; Ji et al., 2023). Therefore, fermentation or composting is necessary to stabilize organic matter, adjust the pH to more suitable conditions, reduce the C/N ratio, and increase the maturity and quality of organic fertilizers before applying them to the field (Aguilar-Paredes et al., 2023; Tie et al., 2024).

The quality of the organic fertilizer produced is largely determined by the activity of microorganisms involved in decomposition during the composting process. Microbes, especially bacteria, play a role in transforming complex organic compounds into simpler forms that are more available to plants (Duan et al., 2020; Raza et al., 2023a). Naturally, shrimp pond sediments harbor communities of indigenous bacteria that contribute to the decomposition of organic matter, nutrient transformation, and nitrogen and sulfur cycling in pond ecosystems. However, the community composition and stability of the sediment bacterial network are not fixed, but are influenced by the environmental conditions of the pond, such as sediment sulfate content, pH, total nitrogen, feed load, organic matter accumulation, water quality, and sediment dynamics during the cultivation period (Alfiansah et al., 2018; Hou et al., 2021; Wu et al., 2023; Zhou et al., 2022).

The natural decomposition process in composting is often slow and non-uniform because it is influenced by the material's composition, moisture, pH, aeration, C/N ratio, and the initial microbial community. These factors determine microbial activity, the rate of organic matter decomposition, the humification process, and the level of compost maturity (Aguilar-Paredes et al., 2023; Ge et al., 2022; Ji et al., 2023). Therefore, the use of bioactivators or microbial inoculants is an approach for improving composting efficiency, accelerating organic matter degradation, and enhancing the stability of the final product (Duan et al., 2020; Feng et al., 2024).

The use of bacterial consortiums on the compound substrate, such as pond sediments, leaf waste, and husk charcoal, is considered more potent than the use of single isolates because each isolate has different enzymatic and hydrolytic capabilities in decomposing proteins, amylum, fats, cellulose, hemicellulose, and other organic fractions (Lin, 2022; G. Zhang & Dong, 2022). The combination of microbes with complementary functions has the potential to generate synergies in the decomposition process, thereby enabling the more effective transformation of organic matter into more mature, stable, and high-quality organic fertilizers (Feng et al., 2024).

Pineapple liquid waste (*Limbah Cair Nanas*, LCN) is one of the agroindustrial wastes with potential as a source of indigenous bacteria to support the composting process. LCNs are rich in simple organic compounds and are acidic, thereby providing an environment conducive to the growth of decomposer microbes with specific hydrolytic capabilities (Sidik et al., 2020; Sukirah et al., 2023; Sutanto, 2012). On the other hand, LCN can also become a pollutant if disposed of without adequate treatment, as its high organic matter content can degrade the quality of aquatic ecosystems (Fouda-Mbanga & Tywabi-Ngeva, 2022). Waste from the pineapple processing industry is generally reported to generate high loads of BOD, COD, and suspended solids, so its management needs to be directed not only toward pollution reduction but also toward the reuse of organic resources (Hossain et al., 2022). In addition, pineapple waste contains various organic components, including residual sugars, pectin, hemicellulose, cellulose, and other bioactive compounds, making it a potential bioresource for developing value-added products (Kumar et al., 2024; Perez-Cabrera et al., 2024). Previous research has also demonstrated that fruit-derived organic waste can be transformed into organic fertilizer through microbial fermentation. However, the resulting macronutrient content and compliance with fertilizer quality standards remain strongly influenced by the characteristics of the raw materials and the processing conditions (Sinaga et al., 2023).

The consortium of LCN indigenous bacteria isolated by Sutanto (2012) is known to degrade various fractions of organic matter and has been used as a bioactivator for the treatment of solid organic waste (Ariyani et al., 2021; Sutanto, 2012). The use of indigenous bacteria from LCN in the composting of shrimp pond sediments is relevant because it integrates two types of local waste, namely aquaculture waste in the form of pond sediment and agroindustrial waste in the form of LCN, which are conceptually included in the category of local resource-based waste that is available around the production area and has the potential to be reused (Ghisellini et al., 2016; Kirchherr et al., 2017). In this study, local waste is interpreted as organic waste that is available predominantly around the research area or production area, has not been utilized optimally, and has the potential to be converted into a product of use value through biological processes. This approach aligns with the circular economy principle, which positions organic waste as a resource for producing products of use value (Dhar et al., 2024; Paz-Arteaga et al., 2024). Thus, the use of the LCN indigenous bacterial consortium not only serves as a biotechnology strategy for improving the quality of organic fertilizers but also as a form of local waste valorization with the potential to support more sustainable environmental management.

However, the specific application of the LCN indigenous bacterial consortium to improve the quality of shrimp pond sediment as a solid organic fertilizer has been studied only rarely, especially in relation to variations in the composition of the isolates in the consortium and their conformity with the quality parameters of organic fertilizers. Previous studies have extensively discussed the potential of microbes in the decomposition of organic waste, sediment bioremediation, or the use of bioactivators in composting, but the LCN consortium's multi-stage testing of shrimp pond sediments still requires further proof(Ariyani et al., 2021; Jasmin et al., 2020; Thanh et al., 2023).

Parameters such as C-organic, N-total, P_2O_5, K_2O, C/N ratio, pH, and moisture content are important to analyze because they describe the nutrient content, the stability of organic matter, the maturity level, and the basic feasibility of the product as a solid organic fertilizer. Therefore, this study aims to assess whether differences in the composition of the LCN indigenous bacterial consortium can affect the chemical quality of pond sediments, thereby improving organic fertilizer standards.

In terms of policy, the use of pond sediment and LCN as organic fertilizer materials is in line with national regulations regarding solid organic fertilizer quality standards regulated in Ministerial Regulation No. 261/KPTS/SR.310/M/4/2019 as well as with the direction of industrial liquid waste management that emphasizes reducing pollutant burdens through an environmentally friendly approach (Meirdana & Utomo, 2020). At a broader level, the conversion of aquaculture waste and agroindustrial waste into organic fertilizer supports the Sustainable Development Goals (SDGs) agenda, specifically goal 12 on sustainable consumption and production and goal 14 on aquatic ecosystems.

Based on this background, this study aims to evaluate the influence of various compositions of LCN indigenous bacterial consortiums on changes in the content of C-organic, N-total, P_2O_5, K_2O, C/N ratio, pH, and moisture content of fermented shrimp pond sediments. The results of the study are expected to identify the most effective consortium formulations for improving sediment quality, so that they meet or approach applicable solid organic fertilizer standards and have the potential to be used as inputs in cultivation systems or integrated agriculture.

RESEARCH METHODS

Study Design

This study used a laboratory experimental design with a one-factor Complete Randomized Design (*Rancangan Acak Lengkap*, RAL). The treatment factor in this study was the variation in the formulation of the indigenous bacterial consortium (LCN) from pineapple liquid waste, rather than the number of isolates as a single factor. Each level of treatment is a consortium formulation package differentiated by the number of isolates and the hydrolysis ability profile of the constituent isolates.

The treatment consisted of six levels, namely P0 as a control without consortium, P1 containing 3 isolates with dominant fat degradation capabilities, P2 containing 6 amylum-degrading isolates, P3 containing 9 protein degradation isolates, P4 containing 12 isolates with a combination of protein and amylum degradation capabilities, and P5 containing 15 isolates with protein, amylum, and fat degradation capabilities. Each treatment was replicated five times (30 experimental units) to evaluate the effects of different LCN indigenous bacterial consortium formulations on the chemical quality of shrimp pond sediment-based organic fertilizers.

Research Location

Shrimp pond sediment was collected from a vannamei shrimp farm in Pasir Sakti District, East Lampung Regency, Lampung Province. Material preparation, fermentation, and compost maintenance were conducted at the Integrated Science Laboratory and the Pumakkal PPs UM Metro Fertilizer House, University of Muhammadiyah Metro. Chemical analyses were performed at the Analytical Chemistry Laboratory, University of Muhammadiyah Malang. The study was completed over approximately three months.

Materials and Bacterial Consortiums

The main material used is shrimp pond sediment, while additional materials consist of leaf waste, husk charcoal, and pineapple liquid waste. Shrimp pond sediment serves as the main material to be converted into organic fertilizer; leaf waste is used as a source of additional organic matter; and husk charcoal is used to help improve media structure, porosity, and aeration during the fermentation process. The composition of the compost media was determined as part of the research work, namely shrimp pond sediment, leaf waste, and husk charcoal, in a ratio of 50%:37.5%:12.5 %.

The comparison is used to maintain shrimp pond sediment as the main component while providing additional organic matter and structural improvement materials, so that the aerobic fermentation process can occur more evenly. The determination of this composition is based on the approach of processing pond sediment waste as an organic fertilizer material and on the Pumakkal formulation developed in previous research, with adjustments to the materials used in this study (Ariyani et al., 2021; Sutanto et al., 2024).

The consortium of indigenous bacteria is composed of 15 isolates from LCN from Sutanto (2012), which have previously been characterized based on the hydrolysis ability of proteins, amylum, and fats. The formulation of the P1–P5 formula is based not only on the difference in the number of isolates, but also on the variation in the composition of the isolate and its hydrolysis ability profile. Thus, each treatment is positioned as a consortium formulation package, rather than as a single-isolate treatment.

The P1 formula consists of 3 isolates with the dominant ability to degrade fat, P2 consists of 6 isolates with the ability to degrade amylum, P3 consists of 9 isolates with protein degradation ability, and P4 consists of 12 isolates with a combination of protein and amylum degradation ability. In comparison, P5 comprises 15 isolates capable of degrading protein, amylum, and fat. The multi-level arrangement was used to compare the quality response of organic fertilizers to consortium formulations with different hydrolysis capabilities, ranging from formulations with specific hydrolysis capabilities to formulations containing entire isolates with more complete hydrolysis capabilities.

Procedure

The compost medium is prepared by mixing pond sediment, leaf waste, and husk charcoal until homogeneous, according to the set composition. The leaf waste used is in the form of dried leaf litter that has been cleaned of inorganic materials and chopped, while husk charcoal is in the form of rice husks that have been laid out, dry, porous, and not mixed with raw husks or excess ash. Each treatment unit is inoculated with 5% (v/w) LCN indigent bacteria consortium starter that has been activated for 24 hours. Fermentation is carried out aerobically for 30 days at a room temperature of about 30

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°C. During fermentation, the material is covered with plastic and turned over every three days to maintain aeration, reduce compaction, and even out microbial activity throughout the media.

Data Collection

The data collected were the chemical characteristics of sedimentary organic fertilizers after fermentation. The parameters measured included total nitrogen (N-total), phosphorus as P_2O_5, potassium as K_2O, organic carbon (C-organic), C/N ratio, pH, and moisture content. C-organic is defined using the Walkley–Black method (Walkley & Black, 1934), while N-total was analyzed using the Kjeldahl method. P-total is determined by spectrophotometry, K-total using a flame photometer, pH potentiometrically using a pH meter, and moisture content by gravimetry. Procedure for the analysis of N-total, P-total, K-total, pH, and moisture content (Eviati et al., 2023).

Data Analysis

Data for each parameter were analyzed using one-way ANOVA at a significance level of 5%. The normality of the data was assessed using the Shapiro-Wilk test, and homogeneity of variance was assessed using Levene's test. If the ANOVA results show a significant difference, the analysis is continued with the Tukey HSD test at $\alpha = 0.05$ to determine which treatments differ. The measure of the eta squared effect (η^2) was also calculated to assess the magnitude of the effect of the treatment on each observed parameter. The composition of the LCN consortium of native bacteria is presented in Table 1.

RESULTS AND DISCUSSION

The sediments analyzed in this study came from vannamei shrimp (Litopenaeus vannamei) cultivation ponds in Pasir Sakti District, East Lampung Regency, which is one of the coastal pond centers on the east coast of Lampung Province. Intensive and semi-intensive cultivation systems promote the accumulation of feed residues, feces, dead plankton, and other organic matter, making pond sediments the primary reservoir of organic matter and nutrients.

Table 1. LCN consortium of native bacteria

No	Bacterial Consortium	Total Bacterial Isolate	Bacterial Isolates	Hydrolysis Ability
1	P1	3	Isolates 2, 3, 5	Fat degradation
2	P2	6	Isolates 4, 5, 6, 7, 12, 14	Amylum degradation
3	P3	9	Isolates 1, 2, 3, 8, 10, 11, 12, 14, 15	Protein degradation
4	P4	12	Isolates 1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15	Protein and amylase degradation
5	P5	15	Isolates 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	Degradation of proteins, amylum and fats

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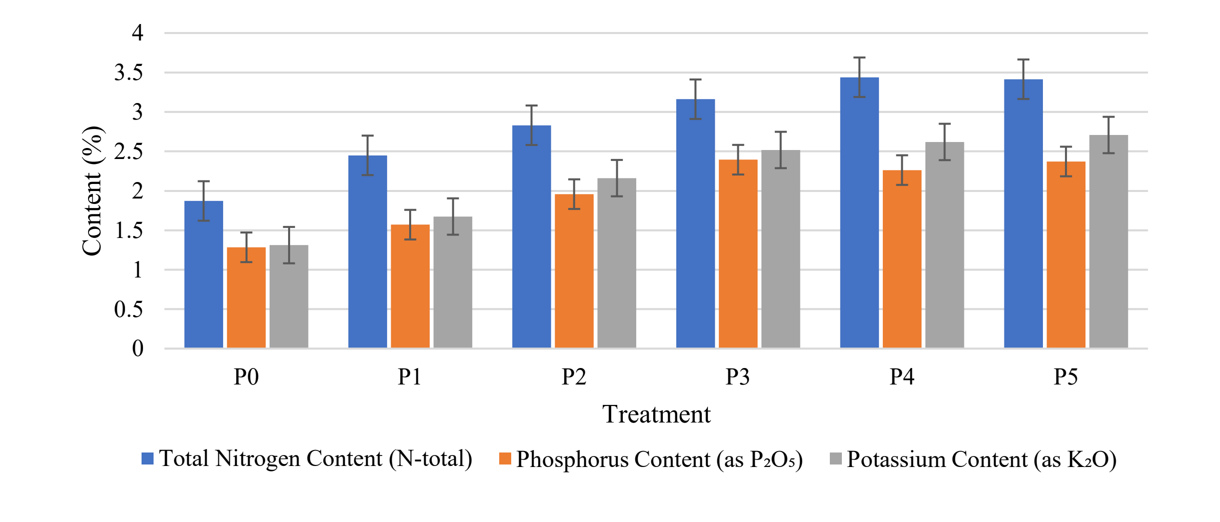

Figure 1. Macronutrient content (N-total, P_2O_5, K_2O) of shrimp pond sediment-based organic fertilizers in various treatments of LCN indigent bacteria consortium.

Unmanaged sediment can become a source of pollution if discharged directly into surrounding waters. However, it still contains nutrients that can be used as raw materials for organic fertilizers. This section presents the results of the analysis of changes in the chemical characteristics of sediments after 30 days of fermentation with leaf waste, husk charcoal, and a consortium of indigenous bacteria from Pineapple Liquid Waste (LCN). The results of the analysis were used to assess the quality of sedimentary organic fertilizers and their compliance with the solid organic fertilizer standards set out in Ministerial Regulation No. 261/KPTS/SR.310/M/4/2019.

Macronutrient content (N-total, P_2O_5, K_2O)

The results of the variety-based analysis showed that treatment with the LCN indigenous bacterial consortium had a highly significant effect on the N-total, P_2O_5, and K_2O contents of shrimp pond sediment-based organic fertilizers ($p < 0.05$). The mean pattern in Figure 1 shows an increase in N-total from about 1.8–1.9% in the control (P0) to more than 3% in all treatments with the consortium, with the highest values in P4 and P5 (±3.4%).

The P_2O_5 content increased from ±1.28% at P0 to 2.39% at P3 as the highest value, while P4 and P5 remained in the range of ≥ 2%. The K_2O level also moved up from about 1.31% (P0) to ±2.7% in P5, and the P2–P5 treatment has all reached $K_2O \geq 2\%$. These findings show that the P3–P5 consortium formulation has produced sedimentary organic fertilizers that meet the minimum thresholds for N-total, P_2O_5, and K_2O in accordance with PERMENTAN No. 261/KPTS/SR.310/M/4/2019. Figure 1 presents the macronutrient contents (total N, P_2O_5, and K_2O) of shrimp pond sediment-based organic fertilizers under different treatments of the LCN native bacterial consortium.

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Table 2. The value of η^2 effect of treatment on N-total, P_2O_5, K_2O, C-organic, C/N ratio, and pH

No	Parameters	Eta_squared	Categories
1	N_total	0.984	Very large
2	P2O5	0.966	Very large
3	K2O	0.984	Very large
4	C_organik	0.379	Weak to moderate
5	C/N Ratio	0.942	Very large
6	pH	0.922	Very large

The increase in these three elements is inseparable from the role of the LCN indigenous bacterial consortium formulation in accelerating the decomposition of sedimentary organic matter, leaf waste, and husk charcoal through microbial activity during fermentation (Ariyani et al., 2021; Duan et al., 2020; Sutanto, 2012). In this study, P1–P5 differed not only in the number of isolates but also in the composition of the isolates and the scope of their hydrolytic ability, as shown in Table 1. Therefore, the increase in N-total, P_2O_5, and K_2O cannot be interpreted solely as a result of an increase in the number of isolates, but rather as a response to the overall formulation difference of the consortium, i.e. the combination of the number of isolates, the composition of the isolates, and the hydrolysis ability of the constituent isolates (Feng et al., 2024; Lin, 2022).

Some of the bacteria that make up the LCN consortium, especially the *Bacillus, Pseudomonas, Enterobacter*, and other heterotrophic bacteria, potentially play a role through hydrolytic activity, mineralization of organic matter, phosphate dissolution, and mobilization of nutrients during fermentation (Damathia et al., 2025; Jiang et al., 2024). The *Bacillus* Group plays an important role in the breakdown of proteins, amylum, and complex organic matter through the production of hydrolytic enzymes, so that it can support the mineralization process of organic matter during composting (Duan et al., 2020; Feng et al., 2024; G. Zhang & Dong, 2022).

The *Pseudomonas* group may facilitate phosphate dissolution and nutrient mobilization by producing organic acids, enzymes, and metabolites during decomposition (Damathia et al., 2025; Sonia & Setiawati, 2022). Thus, consortium formulations that have a wider range of hydrolysis capabilities, especially P3–P5, can result in a more effective decomposition and mineralization process of organic matter, thus supporting the increase in N-total, P_2O_5, and K_2O in the organic fertilizers produced (Feng et al., 2024; Y. Jiang et al., 2022; Lin, 2022).

P3 treatment increases N-total content because it contains a dominant isolate degrading protein. The isolate decomposes the protein fraction from shrimp pond sediment and leaf waste during fermentation

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(Duan et al., 2020; L. Jiang et al., 2024; Sutanto et al., 2024). However, the N-total in P4 and P5 tends to be higher than that of P3 because both formulations have a wider range of hydrolysis capabilities. P4 contains a combination of protein- and amylum-degrading isolates, while P5 contains protein-, amylum-, and fat-degrading isolates. Therefore, the difference in N-total between treatments is more accurately attributed to the difference in the overall formulation of the consortium, i.e. the combination of the number of isolates, the composition of the isolates, and their hydrolysis ability, rather than just the presence of a single protein-degrading isolate (Feng et al., 2024; Lin, 2022). This interpretation is consistent with previous research demonstrating that locally derived bacterial isolates with specific functional traits can be selected and developed as candidates for bacteria-based fertilizers (Yuliatin & Faizah, 2023).

P_2O_5 Increase: It can also be explained through microbial activity that plays a role in the dissolution and mineralization of phosphorus. Inoculation of phosphate-soluble bacteria during composting can reportedly affect organic acid production, total acidity, pH, and phosphate dissolution, thereby converting phosphorus originally in a less available form into a more detectable form in compost products (Zhou et al., 2022). This supports the results of this study, particularly for the P3 treatment, which yields the highest P_2O_5.

Meanwhile, the increase in K_2O in treatment with consortiums can be attributed to the release of potassium from organic matter and mineral fractions during decomposition. Microbial activity, organic acid production, and pH changes during fermentation can help the dissolution of mineral elements, including potassium, so that the K_2O levels in organic fertilizers increase.

Shrimp pond sediments fermented with a consortium of indigenous LCN bacteria show agronomic potential as a major source of macronutrients for plants through increased N-total, P_2O_5, and K_2O. The range of N, P, and K content obtained in this study is comparable to the characteristics of some market organic waste composts enriched with EM4 starters, cow manure, and chicken manure (Kaswinarni & Nugraha, 2020), so that the quality of the sediment fertilizer produced is relatively competitive compared to compost fertilizer made from land waste. P3–P5 formulations that can meet or exceed national standards for these three elements are worthy of consideration as candidates for sedimentary organic fertilizers to replace some of the inorganic fertilizer needs in cultivation systems around pond areas and on other agricultural land.

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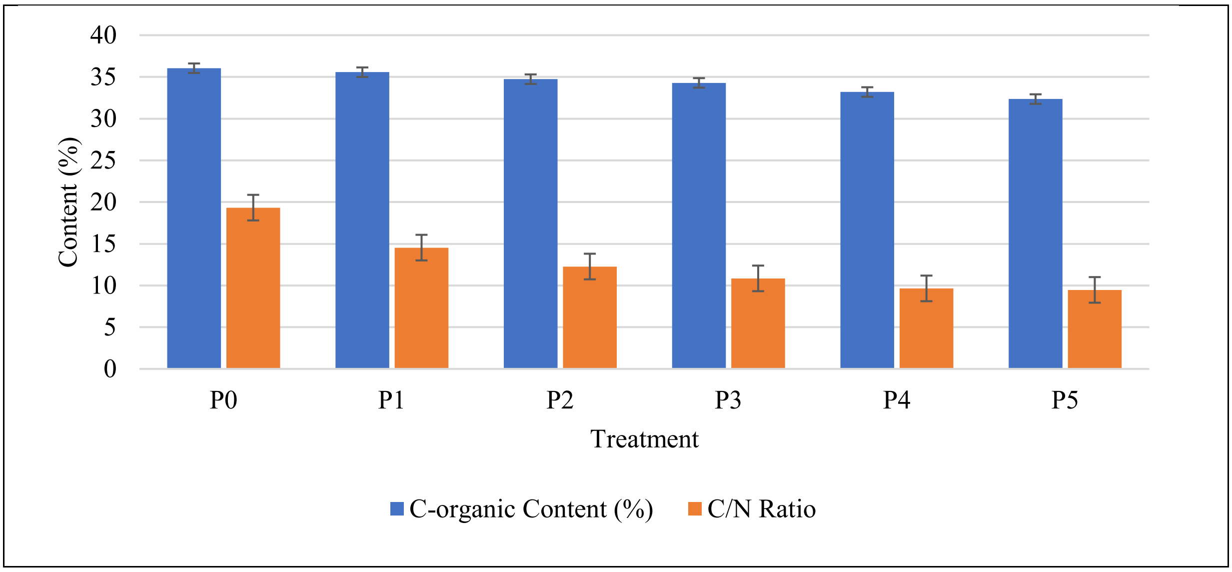

Figure 2. Average C-organic levels and C/N ratios of shrimp pond sediment-based organic fertilizers in various treatments of LCN indigent bacteria consortium

This research also strengthens and expands the use of the LCN consortium, which was previously mostly focused on organic waste treatment, by showing that the same consortium is also effective in improving the quality of solid organic fertilizers based on shrimp pond sediments. Nonetheless, field crop response tests are still needed to ensure fertilization efficiency and long-term impact on soil productivity and health.

C-Organic and C/N Ratio

The application of a consortium of LCN indigenous bacteria had a significant effect on the C-organic content and C/N ratio of shrimp pond sediment-based organic fertilizer ($p < 0.05$). The pattern in Figure 2 shows that C-organic decreased from about 36.04% in the control (P0) to ±32–33% in the treatment with the consortium, with the lowest value at P5 (±32.34%). This decrease in C-organic levels was followed by a sharp decrease in the C/N ratio, from 19.33 (P0) to around 9–12 in the P1–P5 treatment, with the lowest ratio at P5 (9.47). The combination of relatively high C-organic and a C/N ratio < 15 is generally considered an indicator that biodegradable organic matter has been decomposed and that the compost has reached an adequate level of maturity for land application (Trivana et al., 2017).

In other words, the LCN consortium's treatment accelerates the sediment shift from wet waste conditions to a more stable form of organic fertilizer. The significant differences between treatments in C-organic and C/N ratios can be explained by variations in the formulation of the P1–P5 consortium, which differ in isolate counts, isolate composition, and hydrolysis capabilities. Formulations with a wider range of hydrolysis, especially P4 and P5, tend to accelerate the decomposition of more diverse organic fractions, so that organic carbon is used more as a source of microbial energy and partially released as CO_2 during aerobic fermentation (Duan et al., 2020; Raza et al., 2023a).

A decrease in C-organic accompanied by an increase or retention of nitrogen causes the C/N ratio to decrease, thus indicating a further decomposition and maturation process of organic matter (Feng et al., 2024; Jagadabhi et al., 2019; Ji et al., 2023). These changes reflect the decomposition process driven by microorganisms in the LCN consortium. Heterotrophic bacteria use carbon as the primary source of energy and oxidize organic compounds into CO_2 as well as more stable humic compounds, resulting in a decrease in total C-organics. At the same time, relatively more nitrogen persists in the system in the form of microbial biomass and mineral nitrogen (NH_4^+ and NO_3^-) (Duan et al., 2020).

These findings are consistent with the review by Raza et al. (2023), which confirms the key role of microbial consortia in the decomposition of organic matter and the regulation of carbon fluxes in soil and compost ecosystems. The presence of isolates with hydrolysis capabilities, as reported by Sutanto (2012) and further developed by Ariyani et al. (2021) in pond sediments, accelerates the breakdown of proteins, starches, and cellulose, so that the C/N ratio shifts to the range of 10–12, which is widely recognized as the ratio of mature compost. This relatively low C/N ratio is important agronomically because it reduces the risk of nitrogen immobilization in the soil when fertilizers are applied, thereby maintaining the availability of N for plants and making compost safer to use as a soil improver and a nutrient source.

The decrease in C-organic in the consortium treatment indicated that some of the organic carbon was used as an energy source for microbial metabolism during fermentation. The difference in C-organic levels between treatments can be explained by differences in the ability of microbes to produce hydrolytic enzymes, such as proteases, amylase, lipases, and polysaccharide-degrading enzymes, which play a role in breaking down proteins, starches, fats, cellulose, hemicellulose, and other organic fractions into simple compounds (Sutanto et al., 2024; G. Zhang & Dong, 2022).

The compound is then utilized by microbes for metabolism, with some carbon released as CO_2 via aerobic respiration (Duan et al., 2020; Raza et al., 2023). Thus, consortiums with a wider diversity of hydrolytic capabilities tend to accelerate the decomposition of organic carbon, resulting in greater C-organic degradation than consortiums with more limited hydrolytic capabilities (Feng et al., 2024).

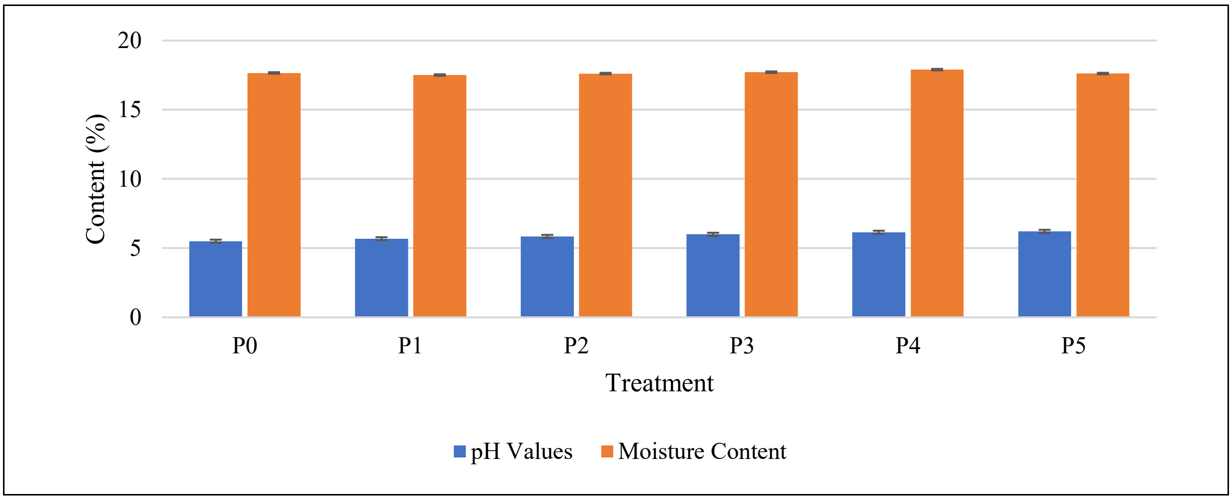

Figure 3. Average pH and moisture content in shrimp pond sediment-based organic fertilizers at various treatments of LCN indigenous bacteria consortium

Studies on compost maturity show that the C/N ratio is one of the important indicators influenced by the dynamics of organic matter decomposition, carbon and nitrogen balance, and the conditions of the composting process (Jagadabhi et al., 2019; Trivana et al., 2017). In this study, the C/N ratio decreased in P1–P5 due to differences in the hydrolytic ability of the microbes comprising the consortium. A consortium with a wider range of hydrolytic capabilities has the potential to decompose more organic fractions, thereby allowing organic carbon to serve as a microbial energy source and be partially released as CO_2 during aerobic fermentation (Raza et al., 2023).

Meanwhile, relative nitrogen is retained in the system through microbial biomass and nitrogen transformation, so the C/N ratio moves to a lower range as a sign of further maturation of organic matter (Ge et al., 2022; L. Jiang et al., 2024). Thus, the difference in C/N ratio between treatments is more precisely attributed to variations in the consortium's hydrolysis ability, rather than solely to the amount of isolates used.

pH Values and Moisture Content

The treatment of the LCN indigenous bacterial consortium had a real effect on the pH of shrimp pond sediment-based organic fertilizers. However, it did not have a significant effect on moisture content. The pattern in Figure 3 shows that the pH at the controls (P0) was in the slightly acidic range, about 5.5, increasing to ±6.0–6.2 in the treatment with the consortium, with the highest value at P5. This shift suggests that the fermentation process using the LCN consortium drives the pH of the sedimentary fertilizer toward neutral conditions. In contrast, the final moisture content of fertilizers in all treatments, including controls, is in a relatively narrow range of around 17–18%, and the difference between treatments is not statistically significant.

The highest pH value at P5 can be attributed to the consortium formulation, which contains the largest number of isolates and the most complete coverage of hydrolysis capabilities, i.e., degradation of proteins, amylum, and fats. This diversity of hydrolysis capabilities enables more intensive decomposition of organic fractions, as a consortium of microbes with diverse enzymatic functions can work more effectively on complex organic substrates (Feng et al., 2024; Lin, 2022). In the aerobic composting process, the decomposition of organic matter can be followed by the mineralization of nitrogen compounds that produce ammonium, thus contributing to an increase in pH towards a more neutral condition and decreasing the accumulation of organic acids formed in the initial phase of fermentation (Ge et al., 2022; L. Jiang et al., 2024). Thus, a pH of P5 closer to neutral is related not only to the greater number of isolates but also to the composition of the isolates and the completeness of hydrolytic functions in the consortium's formulations.

This change in pH is in line with the general dynamics of composting, where the formation of organic acids in the initial phase usually lowers the pH, followed by ammonium accumulation and a nitrification process that gradually raises the pH towards a near-neutral range (Hoang et al., 2022; Song et al., 2018; Soto-Herranz et al., 2021). The activity of microorganisms in the LCN consortium, which decompose sedimentary organic matter and plant waste, accelerates these two phases, enabling pH stabilization in a relatively short time. A pH of around 6.0–6.2 is not only beneficial for the survival of soil microbes, but also supports the availability of most macro and micronutrients when fertilizers are applied. Meanwhile, the moisture content of around 17–18% helps to suppress the growth of rotting mold and minimize the risk of reheating during storage, while facilitating the handling and transportation of fertilizer (Setiawan et al., 2024; Zuhro et al., 2019). Thus, in terms of pH and moisture content, the organic fertilizer based on shrimp pond sediment fermented with the LCN indigenous bacterial consortium meets key stability criteria and is ready for marketing or field application.

Changes in pH towards a slightly acidic range, or even close to neutral, are one of the signs of the stabilization process during composting. In the initial phase, the decomposition of organic matter can produce organic acids that lower the pH, while in the later phases nitrogen mineralization and ammonium formation can push the pH to rise again. Zhang et al. (2022) show that pH and initial moisture content affect compost quality, the humification process, microbial succession, and the maturity index. Thus, the final pH of about 6.0–6.2 in the consortium treatment indicates that the fermentation process has shifted towards more stable conditions, making it more suitable for soil microbial activity and nutrient availability.

The relatively low final moisture content and the lack of significant differences between treatments showed that differences in the number of isolates and hydrolysis ability among P1–P5 did not necessarily have a direct effect on the final moisture content of the product. This can happen because the moisture content in composting is more controlled by the physical factors of the process, such as the composition of the material, the porosity of the medium, aeration, reversal, fermentation time, and environmental conditions during fermentation (Ge et al., 2022; Ji et al., 2023).

In this study, all treatments used the same media composition, namely shrimp pond sediment, leaf waste, and husk charcoal with a ratio of 50%: 37.5%: 12.5%, and were given the same fermentation, reversal, and incubation period treatments. The husk charcoal used in all treatments also acts as a porous material that helps maintain aeration and reduce media compaction. Therefore, although P1–P5 have different numbers of isolates and hydrolysis capabilities, the relatively uniform physical conditions of the medium can cause the final moisture content to fall within a range that is not significantly different. Thus, differences in consortium formulations are more evident in the chemical transformation of organic matter and nutrients. In contrast, the final moisture content is more influenced by the uniformity of physical conditions and fermentation processes (Aguilar-Paredes et al., 2023).

Overall, the results of the study show that the LCN indigenous bacterial consortium can improve the quality of organic fertilizers derived from shrimp pond sediments across various key parameters. The P3–P5 consortium formulation produces N-total, P_2O_5, and K_2O content that meets or exceeds the minimum threshold of solid organic fertilizers according to PERMENTAN No. 261/KPTS/SR.310 /M/4/2019, accompanied by a decrease in C-organic to the range of ±32–33%, C/N ratio around 9–12, pH close to neutral (±6.0–6.2), and final moisture content of around 17–18%. The combination of these changes indicates that shrimp pond sediments fermented with the LCN consortium have transformed from problematic organic waste into mature, stable organic fertilizers with chemical characteristics that are competitive with those of commercial solid organic fertilizers.

The implication is that using pond sediment and pineapple liquid waste as raw materials for organic fertilizers opens opportunities to implement a circular economy approach in coastal cultivation areas, while reducing full dependence on inorganic fertilizers. A consortium of LCN indigenous bacteria, developed from local resources, has been optimized as a bioactivator to improve the quality of sedimentary fertilizers and has the potential to be adopted by small-scale fertilizer production units around ponds. Nevertheless, further research, including analyses of salinity, heavy metals, and pathogen presence, as well as plant response tests across different soil types, remains necessary to assess environmental safety and long-term agronomic effectiveness before this technology is recommended for widespread application. This direction of development is consistent with the findings of Harefa & Pharmawati (2022), which suggest that treating organic waste with local bioactivators can be a key strategy for sustainable community- based environmental management.

CONCLUSION

Variations in the composition of the pineapple liquid waste indigenous bacterial consortium (*Limbah Cair Nanas,* LCN) affected the chemical quality of shrimp pond sediment-based organic fertilizers, particularly N-total, P_2O_5, K_2O, C-organic, C/N ratio, and pH, but had no significant effect on water content. The P3–P5 formulation is the most promising treatment because it yields higher macronutrient content, a lower C/N ratio, and a pH closer to neutral than that of the controls. Thus, the LCN consortium of indigenous bacteria can serve as a local starter for processing shrimp pond sediment into more stable, higher-quality solid organic fertilizer.

REFERENCES

Aguilar-Paredes, A., Valdés, G., Araneda, N., Valdebenito, E., Hansen, F., & Nuti, M. (2023). Microbial community in the composting process and its positive impact on the soil biota in sustainable agriculture. *Agronomy, 13*(2), 542. https://doi.org/10.3390/agronomy13020542

Alfiansah, Y. R., Hassenrück, C., Kunzmann, A., Taslihan, A., Harder, J., & Gärdes, A. (2018). Bacterial abundance and community composition in pond water from shrimp aquaculture systems with different stocking densities. *Frontiers in Microbiology, 9*, 2457. https://doi.org/10.3389/fmicb.2018.02457

Ariyani, E., Sutanto, A., Sujarwanta, A., Widowati, H., & Achyani. (2021). Pumakkal compost formula for degrading shrimp pond sediment (As a learning source of biology subject). *Journal of Physics: Conference Series, 1796*(1), 012046. https://doi.org/10.1088/1742-6596/1796/1/012046

Damathia, B., Pathania, D., Jha, A., Sable, H., Sonu, Singh, P., Singh, V., Rustagi, S., & Chaudhary, V. (2025). Emergence of potassium-solubilizing microbes-assisted crop processing for sustainable food production and microbial complexities. *Food and Bioproducts Processing, 153*, 521–535. https://doi.org/10.1016/j.fbp.2025.08.003

Dhar, P., Nickhil, C., Pandiselvam, R., & Deka, S. C. (2024). Pineapple waste-based biorefinery for sustainable generation of value-added products. *Biomass Conversion and Biorefinery, 14*(20), 24927–24948. https://doi.org/10.1007/s13399-023-04801-w

Duan, M., Zhang, Y., Zhou, B., Qin, Z., Wu, J., Wang, Q., & Yin, Y. (2020). Effects of *Bacillus subtilis* on carbon components and microbial functional metabolism during cow manure–straw composting. *Bioresource Technology, 303*, 122868. https://doi.org/10.1016/j.biortech.2020.122868

Eviati, Sulaeman, Herawaty, L., Anggria, L., Usman, Tantika, H. E., Prihatini, R., & Wuningrum, P. (2023). *Petunjuk teknis analisis kimia tanah, tanaman, air dan pupuk*. BPSI Tanah dan Pupuk. https://repository.pertanian.go.id/handle/123456789/24650

Feng, X., Qiu, M., & Zhang, L. (2024). Construction of lignocellulose-degrading compound microbial inoculum and its effects on green waste composting. *Journal of Environmental Management, 370*, 122502. https://doi.org/10.1016/j.jenvman.2024.122502

Fouda-Mbanga, B. G., & Tywabi-Ngeva, Z. (2022). Application of pineapple waste to the removal of toxic contaminants: A review. *Toxics, 10*(10), 561. https://doi.org/10.3390/toxics10100561

Ge, M., Shen, Y., Ding, J., Meng, H., Zhou, H., Zhou, J., Cheng, H., Zhang, X., Wang, J., Wang, H., Cheng, Q., Li, R., & Liu, J. (2022). New insight into the impact of moisture content and pH on dissolved organic matter and microbial dynamics during cattle manure composting. *Bioresource Technology, 344*, 126236. https://doi.org/10.1016/j.biortech.2021.126236

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production, 114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Harefa, N. Y., & Pharmawati, K. (2022). Pengolahan sampah organik di Kota Gunungsitoli. *Jurnal Pengelolaan Lingkungan Berkelanjutan (Journal of Environmental Sustainability Management)*, 33–44. https://doi.org/10.36813/jplb.6.1.33-44

Hoang, H. G., Thuy, B. T. P., Lin, C., Vo, D.-V. N., Tran, H. T., Bahari, M. B., Le, V. G., & Vu, C. T. (2022). The nitrogen cycle and mitigation strategies for nitrogen loss during organic waste composting: A review. *Chemosphere, 300*, 134514. https://doi.org/10.1016/j.chemosphere.2022.134514

Hossain, M. F., Akhtar, S., Anwar, M., & Rahman, M. (2022). Application of pineapple waste to the removal of toxic contaminants: A review. *Toxics, 10*(10), 561. https://doi.org/10.3390/toxics10100561

Hou, D., Zhou, R., Zeng, S., Wei, D., Deng, X., Xing, C., Weng, S., He, J., & Huang, Z. (2021). Stochastic processes shape the bacterial community assembly in shrimp cultural pond sediments. *Applied Microbiology and Biotechnology, 105*(12), 5013–5022. https://doi.org/10.1007/s00253-021-11378-9

Jagadabhi, P. S., Wani, S. P., Kaushal, M., Patil, M. D., Vemula, A. K., & Rathore, A. (2019). Physico-chemical, microbial and phytotoxicity evaluation of composts from sorghum, finger millet and soybean straws. *International Journal of Recycling of Organic Waste in Agriculture, 8*(3), 279–293. https://doi.org/10.1007/s40093-018-0240-8

Jasmin, M. Y., Syukri, F., Kamarudin, M. S., & Karim, M. (2020). Potential of bioremediation in treating aquaculture sludge: Review article. *Aquaculture, 519*, 734905.

https://doi.org/10.1016/j.aquaculture.2019.734905

Ji, Z., Zhang, L., Liu, Y., Li, X., & Li, Z. (2023). Evaluation of composting parameters, technologies and maturity indexes for aerobic manure composting: A meta-analysis. *Science of the Total Environment, 886*, 163929. https://doi.org/10.1016/j.scitotenv.2023.163929

Jiang, L., Dai, J., Wang, L., Chen, L., Zeng, G., Liu, E., Zhou, X., Yao, H., Xiao, Y., & Fang, J. (2024). $Ca(H_2PO_4)_2$ and $MgSO_4$ activated nitrogen-related bacteria and genes in the thermophilic stage of composting. *Applied Microbiology and Biotechnology, 108*(1), 331. https://doi.org/10.1007/s00253-024-13167-6

Jiang, Y., Chen, X., Li, J., Zhang, Y., & Wang, H. (2022). Bottom-up synthetic ecology study of microbial consortia to enhance lignocellulose degradation. *Biotechnology for Biofuels and Bioproducts, 15*, 29. https://doi.org/10.1186/s13068-022-02113-1

Kaswinarni, F., & Nugraha, A. A. S. (2020). Kadar fosfor, kalium dan sifat fisik pupuk kompos sampah organik pasar dengan penambahan starter EM4, kotoran sapi dan kotoran ayam. *Titian Ilmu: Jurnal Ilmiah Multi Sciences, 12*(1), 1–6. https://doi.org/10.30599/jti.v12i1.534

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kumar, V., Singh, J., Kumar, P., & Kumar, P. (2024). Pineapple waste-based biorefinery for sustainable generation of value-added products. *Biomass Conversion and Biorefinery*. https://doi.org/10.1007/s13399-023-04801-w

Lin, L. (2022). Bottom-up synthetic ecology study of microbial consortia to enhance lignocellulose bioconversion. *Biotechnology for Biofuels and Bioproducts, 15*, 14. https://doi.org/10.1186/s13068-022-02113-1

Paz-Arteaga, S. L., Cadena-Chamorro, E., Gómez-García, R., Serna-Cock, L., Aguilar, C. N., & Torres-León, C. (2024). Unraveling the valorization potential of pineapple waste to obtain value-added products towards a sustainable circular bioeconomy. *Sustainability, 16*(16), 7236. https://doi.org/10.3390/su16167236

Perez-Cabrera, L. E., Silva-Campos, M. A., & Parra-Saldivar, R. (2024). Unraveling the valorization potential of pineapple waste to obtaining value-added products: A circular bioeconomy approach. *Sustainability, 16*(16), 7236. https://doi.org/10.3390/su16167236

Raza, T., Qadir, M. F., Khan, K. S., Eash, N. S., Yousuf, M., Chatterjee, S., Manzoor, R., Rehman, S. ur, & Oetting, J. N. (2023). Unraveling the potential of microbes in decomposition of organic matter and release of carbon in the ecosystem. *Journal of Environmental Management, 344*, 118529. https://doi.org/10.1016/j.jenvman.2023.118529

Setiawan, N. A., Witjoro, A., & Prabaningtyas, S. (2024). Analisa kualitas kompos organik dengan penambahan bioaktivator molase dan bakteri pemfiksasi N di Greenhouse Universitas Negeri Malang. *Symbiotic: Journal of Biological Education and Science, 5*(2), 110–120. https://doi.org/10.32939/symbiotic.v5i2.143

Sidik, B. R., Achyani, Sutanto, A., Zen, S., & Noor, R. (2020). Application pineapple liquid waste to increase fruit weight and vitamin C pineapple as biological learning resources. *Journal of Physics: Conference Series, 1567*(2), 022051. https://doi.org/10.1088/1742-6596/1567/2/022051

Sinaga, W. S., Limeranto, D. M., Pangala, E. L. B., & Madyaningrana, K. (2023). Efek pemberian pupuk organik cair berbasis kulit buah (eco enzyme) terhadap pertumbuhan tanaman pakcoy (Brassica chinensis L.). Pro-Life, 10(2), 839–852. https://doi.org/10.33541/pro-life.v10i2.4801

Song, C., Zhang, Y., Xia, X., Qi, H., Li, M., Pan, H., & Xi, B. (2018). Effect of inoculation with a microbial consortium that degrades organic acids on the composting efficiency of food waste. *Microbial Biotechnology, 11*(6), 1124–1136. https://doi.org/10.1111/1751-7915.13294

Sonia, A. V., & Setiawati, T. C. (2022). Aktivitas bakteri pelarut fosfat terhadap peningkatan ketersediaan fosfat pada tanah masam. *Agrovigor: Jurnal Agroekoteknologi, 15*(1), 44–53. https://doi.org/10.21107/agrovigor.v15i1.13449

Soto-Herranz, M., Sánchez-Báscones, M., Antolín-Rodríguez, J. M., & Martín-Ramos, P. (2021). Reduction of ammonia emissions from laying hen manure in a closed composting process using gas-permeable membrane technology. *Agronomy, 11*(12), 2384. https://doi.org/10.3390/agronomy11122384

Sukirah, A. R., Shuhaimi, M., Uswatun, H. Z., Koh, S. P., & Shukor, M. Y. A. (2023). Local pineapple waste as potential bio-ingredient. *Food Research, 6*(Supplementary 3), 35–44. https://doi.org/10.26656/fr.2017.6(S3).002

Sutanto, A. (2012). Degradasi bahan organik limbah cair nanas oleh bakteri indigen. *El-Hayah: Jurnal Biologi, 1*(4). https://doi.org/10.18860/elha.v1i4.1690

Sutanto, A., Sari, K., Santoso, H., Widowati, H., Fidiastuti, H. R., & Rukayadi, Y. (2024). Pumakkal formula for making shrimp pond waste fertiliser. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi, 8*(1), 212–230. https://doi.org/10.22437/jiituj.v8i1.32094

Suwoyo, H. S., Fahrur, M. M., & Syah, R. (2016). Pemanfaatan limbah tambak udang super-intensif sebagai pupuk organik untuk pertumbuhan biomassa kelekap dan nener bandeng. *Media Akuakultur, 11*, 97–110.

Thanh, D. T. D. T., Ty, N. M. N., Hien, N. V. N., Berg, H., Nguyen, T. K. O., Vu, P. T. P., Minh, V. Q., & Da, C. T. (2023). Effects of organic fertilizers produced from fish pond sediment on growth performance and yield of Malabar spinach and amaranth vegetables. *Frontiers in Sustainable Food Systems, 7*, 1045592. https://doi.org/10.3389/fsufs.2023.1045592

Tie, H. O., Che Man, H., Koyama, M., Syukri, F., Yusoff, F. M., Toda, T., Nakasaki, K., & Ramli, N. M. (2024). Integrated nutrient recycling: Ammonia recovery from thermophilic composting of shrimp aquaculture sludge via a self-heated bench-scale reactor and enhancement of mango plant growth by the compost. *Waste Management, 180*, 55–66. https://doi.org/10.1016/j.wasman.2024.03.021

Trivana, L., Pradhana, A. Y., & Manambangtua, A. P. (2017). Optimalisasi waktu pengomposan pupuk kandang dari kotoran kambing dan debu sabut kelapa dengan bioaktivator EM4. *Jurnal Sains & Teknologi Lingkungan, 9*(1), 16–24. https://doi.org/10.20885/jstl.vol9.iss1.art2

Wu, L., Yang, P., Zhang, L., Luo, L., Hong, Y., Zhu, W., Zheng, L., Zhao, G., Tong, C., & Peñuelas, J. (2023). Sediment sulfate content determines assembly processes and network stability of bacterial communities in coastal land-based shrimp aquaculture ponds. *Aquaculture, 563*, 738953.

https://doi.org/10.1016/j.aquaculture.2022.738953

Yuliatin, E., & Faizah, M. (2023). Karakteristik dan potensi bakteri rhizosfer penghasil indole acetic acid yang berasosiasi dengan tanaman kopi (Coffea spp.). Pro-Life, 10(2), 804–816. https://doi.org/10.33541/pro-life.v10i2.4899

Zhang, G., & Dong, Y. (2022). Design and application of an efficient cellulose-degrading microbial consortium and optimization of carboxymethyl cellulase production. *Frontiers in Microbiology, 13*, 957444. https://doi.org/10.3389/fmicb.2022.957444

Zhang, J., Liu, X., Wang, Y., Chen, X., & Li, H. (2022). New insight into the impact of moisture content and pH on dissolved organic matter and microbial succession during composting. *Bioresource Technology, 344*, 126306. https://doi.org/10.1016/j.biortech.2021.126306

Zhou, R., Hou, D., Zeng, S., Wei, D., Yu, L., Bao, S., Weng, S., He, J., & Huang, Z. (2022). Sedimentary nitrogen and sulfur reduction functional couplings interplay with the microbial community of anthropogenic shrimp culture pond ecosystems. *Frontiers in Microbiology, 13*, 830777. https://doi.org/10.3389/fmicb.2022.830777

Zuhro, F., Hasanah, H. U., Winarso, S., Hoesain, M., & Arifandi, D. (2019). Karakterisasi pupuk organik berbahan dasar kotoran hewan. *Agritrop: Jurnal Ilmu-Ilmu Pertanian (Journal of Agricultural Science), 17*(1), 103–114. https://doi.org/10.32528/agritrop.v17i1.2192