Jurnal Biolokus: Jurnal Penelitian Pendidikan Biologi dan Biologi
Vol. 8, Issue 1, June 2025
Pages : 160 – 175

p-ISSN: 2621-3702
e-ISSN: 2621-7538

Formulation of Jakaba fertilizer from banana peel, pineapple peel, tea dregs for enhanced *pak choi* (*Brassica rapa* subsp. Chinensis) growth

Salwa Zainum Muttaqin[1], Jendri Mamangkey[1*], Marina Silalahi[1], Lucas William Mendes[2]
[1]Department of Biology Education, Faculty of Education and Teacher Training, Universitas Kristen Indonesia, East Jakarta 13630, Jakarta, Indonesia
[2]Center for Nuclear Energy in Agriculture (CENA), University of São Paulo (USP), Av. Centenário, 303 – São Dimas, Piracicaba – SP, 13400-970, Brazil
*corresponding author: jendri.mamangkey@uki.ac.id

ABSTRACT

Excessive use of chemical fertilizers can lead to environmental degradation and increase the financial burden on farmers. As a sustainable alternative, liquid organic fertilizer (LOF) derived from Jakaba (also known as *jamur keberuntungan abadi*) was fermented using common organic wastes. This study aimed to evaluate the effects of different organic waste substrates on the characteristics of Jakaba-based LOF (JLOF) and the growth performance of *pak choi* (*Brassica rapa* subsp. Chinensis). A completely randomized design (CRD) was used, consisting of nine treatments with three replications each. The concentration variations of banana peel waste, pineapple peel, and tea grounds used in fermentation include 100 g, 200 g, and 300 g. Observations were conducted in three time intervals on days 0, 14, and 30. Parameters measured included the physical and biological characteristics of the LOF (i.e., pH and fungal growth), as well as plant height, leaf number, and fresh weight of *pak choi*. The data obtained were analyzed statistically using ANOVA analysis. The results showed that tea dregs provided the most favorable conditions for Jakaba growth and maintained the most stable pH. In contrast, pineapple and banana peels inhibited fungal growth, likely due to the presence of inhibitory compounds such as tannins and bromelain. Field application on *pak choi* indicated that JLOF derived from tea dregs promoted the best plant growth among all groups. These findings suggest that Jakaba-based LOF formulated with tea dregs holds promise as an effective organic fertilizer and may be further developed for commercial use.

Keywords: Fermentation, fungal consortia, Jakaba, organic waste, plant growth

INTRODUCTION

The excessive use of chemical fertilizers has been widely recognized as a major contributor to soil degradation, water pollution, and potential health risks (Rashmi et al., 2020). Beyond environmental concerns, the economic burden on farmers continues to grow due to the high costs of chemical fertilizers, which are often not offset by a proportional increase in crop yield (Rahman & Zhang, 2018). As a sustainable alternative, organic fertilizers derived from household waste offer an environmentally friendly solution to mitigate these negative impacts. The decomposition of organic waste into nutrient-rich fertilizers not only promotes plant growth but also helps reduce waste accumulation (Chew et al., 2019; Virginia et al., 2023).

Some microorganisms involved in the fermentation of rice washing water are *Pseudomonas fluorescens*, pectinolytic bacteria, and *Xanthomonas mailophilia*. The three types of microorganisms play a role in breaking down complex compounds into simple ones during the fermentation of Jakaba fertilizer (Risman, 2022). Microorganisms such as *Pseudomonas fluorescens* and *Xanthomonas maltophilia* naturally colonize rice washing water and begin to break down polysaccharides into monosaccharides. While pectinolytic bacteria produce the enzyme pectinase and increase the rate of decomposition by breaking down pectin contained in organic matter such as fruit peels into sugars.

One promising liquid organic fertilizer (LOF) is Jakaba (*Jamur Keberuntungan Abadi*), which was accidentally discovered during the fermentation of rice washing water (*air leri*) (Fadilah et al., 2024). Jakaba is primarily composed of carbohydrates (90%), along with vitamins, minerals, and proteins (Ndese et al., 2024). Its high carbohydrate content plays a crucial role in stimulating the production of plant growth hormones such as gibberellins and auxins, thereby enhancing plant development (Yusminan et al., 2022). Previous studies have sought to improve the quality of *Jakaba* by incorporating organic waste materials such as rice bran, fish pellets, and banana peels (Yusminan et al., 2022).

Building upon these findings, this study further modifies the fermentation process by incorporating pineapple peels (*Ananas comosus* L.), banana peels (*Musa paradisiaca*), and tea dregs (*Camellia sinensis*) as additional organic substrates. These waste products are important sources of nutrients that could speed up microbial development during fermentation and increase Jakaba's potency as a biofertilizer. Jakaba ferments naturally as a result of microbial activity occurring on its own. In order to improve soil fertility and encourage plant growth, beneficial bacteria like *Pseudomonas fluorescens* are essential for nutrient solubilization and plant hormone synthesis (Panpatte et al., 2016).

Conventional biotechnology applications, such Jakaba fermentation, are still underrepresented in school courses despite their potential advantages. Due to a curriculum that focuses mostly on food biotechnology, a lack of suitable learning tools, and restricted access to laboratory facilities, students frequently struggle to understand biotechnology ideas (Orhan & Sahin, 2018). Students' understanding and enthusiasm for biotechnology could be improved by incorporating Jakaba fermentation into the curriculum. The purpose of this study was to examine the qualitative and quantitative properties of Jakaba fermented with tea dregs, pineapple peels, and banana peels. It also assesses how applying Jakaba affects the *pak choi* (*Brassica rapa* subsp. Chinensis) plant growth characteristics, such as fresh weight, leaf count, and plant height.

A biotechnology practicum guide will be created using the study's findings to aid in both academic learning and the advancement of sustainable farming methods. The project intends to link theoretical knowledge to real-world application by linking scientific research with educational applications. Students can gain practical experience in microbial fermentation and the creation of organic fertilizer by using Jakaba as a case study in conventional biotechnology. In the end, it is anticipated that this research would advance sustainable agriculture, make biotechnology education more relevant and interesting, and offer insightful information on maximizing liquid organic fertilizers.

METHOD

Materials

The materials used in this study included *pak choi* (*Brassica rapa* subsp. Chinensis) seedlings obtained from a local farm in Jakarta, and organic household waste in the form of pineapple peels (*Ananas comosus* L.), banana peels (*Musa paradisiaca*), and tea dregs (*Camellia sinensis*). Rice washing water (*air leri*) was used as the primary fermentation substrate. Additional materials included rice bran, a Jakaba starter culture, and distilled water. The equipment used in the experiment consisted of a digital pH meter (Hanna Instruments), a precision digital balance (±0.01 g accuracy), 20 × 20 cm polybags, a ruler, a camera for documentation, and fermentation containers with airtight lids.

Experimental design and research variables

This study employed an experimental approach to evaluate the effects of household organic waste variations on the qualitative and quantitative characteristics of Jakaba-based liquid organic fertilizer (JLOF). It also assessed the impact of the JLOF application on the growth performance of *pak choi*. To ensure a comprehensive evaluation, both qualitative and quantitative analyses were conducted. The independent variables included the type and concentration of organic waste, specifically pineapple peel, banana peel, and tea dregs, applied at concentrations of 100 g, 200 g, and 300 g during the Jakaba fermentation process. Additionally, the dosage of JLOF applied to *pak choi* plants was considered as an independent variable. The dependent variables comprised both qualitative and quantitative parameters. The qualitative parameters of JLOF included color, aroma, texture, pH, and fungal growth. The quantitative parameters for *pak choi* growth included plant height, number of leaves, and fresh weight. The study was conducted at the Plant Anatomy and Physiology Laboratory and the Greenhouse of the Biology Education Program, Faculty of Teacher Training and Education, Universitas Kristen Indonesia (UKI), Jakarta.

Experimental setup

A completely randomized design (CRD) was employed, comprising nine treatments with three replications each, resulting in a total of 27 (9x3) experimental units for Jakaba fermentation. Organic waste was incorporated at varying concentrations (100 g, 200 g, and 300 g) and subjected to fermentation for 30 days. Observations were conducted on days 0, 14, and 30, evaluating the following parameters: color, aroma, texture, fungal growth, and pH of JLOF. For the *pak choi* growth experiment, a single application dose of JLOF (40 mL/L) was used across 11 groups with three replications, totaling 33 plant samples. *Pak choi* plants were cultivated in polybag systems, and growth observations were recorded at regular intervals.

Fermentation of organic wastes using *Jakaba* starter

The fermentation of JLOF began with the preparation of organic waste materials: pineapple peels, banana peels, and tea dregs. These materials were thoroughly washed, chopped into small pieces, and weighed according to the designated treatment concentrations of 100 g, 200 g, and 300 g. Each organic waste sample was then combined with 1 L of rice washing water, 10 g of rice bran, and 100 mL of the Jakaba starter culture in a sealed fermentation container. The mixtures were stored in a shaded area at room temperature for 14 days to allow spontaneous microbial fermentation. Observations were conducted on days 0, 14, and 30, during which qualitative parameters, including color, aroma, texture, fungal growth, and pH, were recorded to monitor changes throughout the fermentation process.

Field application of JLOF on *pak choi*

The impact of JLOF on pak choi growth was assessed by monitoring key growth parameters throughout the experimental period. *Pak choi* seeds were first germinated in a nursery and then transplanted into 20 × 20 cm polybags filled with sterilized soil to ensure optimal growth conditions. JLOF was applied at a concentration of 40 mL/L, with each plant receiving the treatment at seven-day intervals. Growth parameters, including plant height, number of leaves, and fresh weight, were recorded on days 7, 14, and 30 after planting (DAP), with a final measurement taken at the end of the observation period to assess the effect of JLOF on plant development. Quantitative data collected from the experiment were analyzed using one-way Analysis of Variance (ANOVA) to determine the effects of the different JLOF treatments and application rates on *pak choi* growth. A radar plot was used to visualize the sensory attributes (aroma, color, and texture) of liquid organic fertilizers fermented using Jakaba starters using Microsoft Excel ver. 2016. To identify statistically significant differences between treatments, Duncan's Multiple Range Test (DMRT) was performed at a 5% significance level. This statistical approach provided a comprehensive evaluation of JLOF's effectiveness in promoting plant growth.

RESULTS AND DISCUSSION

Formulation of Jakaba-based LOF using different orgaic wastes

Following fermentation, each Jakaba-based formulation exhibited distinct visual and physicochemical characteristics (Figure 1). The pineapple peel-based JLOF ranged in color from light to dark brown, with viscosity increasing as the concentration of organic waste increased. The banana peel-based JLOF appeared darker and showed significant sediment accumulation, especially at the highest concentration of 300 g. In contrast, the tea dregs-based JLOF developed a dark brown to reddish hue, with increasing turbidity observed at higher waste concentrations. Spontaneous fermentation of Jakaba-based liquid organic fertilizers (JLOF) typically takes one to two months to complete. However, in this study, the addition of a Jakaba starter culture significantly accelerated the fermentation process, reducing the time to just 14 days. The fermentation process involved several key stages: substrate preparation, mixing, anaerobic fermentation, hydrolysis, gas production, microbial growth during the logarithmic phase, idiophase, and formation of the final product. Household organic waste, particularly rice washing water, served as the primary fermentation substrate. In addition, pineapple peels (*Ananas comosus* L.), banana peels (*Musa paradisiaca*), and tea dregs (*Camellia sinensis*) were incorporated to supply essential nutrients and enhance the quality of the final JLOF. The addition of these organic waste materials aimed to stimulate microbial activity and accelerate the logarithmic growth phase of beneficial microorganisms.

There are differences in color between the liquid and sediment during the fermentation process that can be related to biochemical reactions and the degradation of pigments that occur during fermentation. The color of the liquid is usually influenced by soluble metabolites, such as phenolic compounds and pigments produced by microbes, while the sediment is the result of the precipitation of insoluble particles, such as settling organic residues and insoluble pigments. The main difference between floating sediment and sinking sediment is their relative position in the solution. Floating sediment usually consists of lighter and smaller particles that tend to float due to their higher buoyancy, while sinking sediment consists of heavier and larger particles that settle at the bottom of the container. Factors contributing to this variation include particle size and weight, density, as well as the chemical and physical properties of these particles.

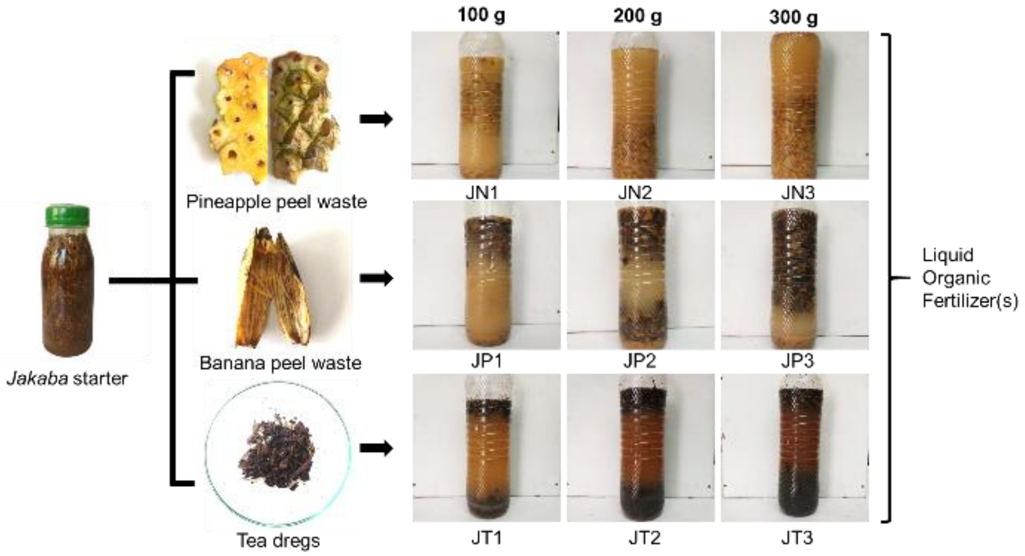

Figure 1. Liquid organic fertilizer(s) formulated using three different organic wastes and *Jakaba* starter. Note: liquid organic fertilizer (LOF) using banana peels (JP1–JP3), pineapple peels (JN1–JN3), and used tea leaves (JT1–JT3) with Jakaba starter at varying concentrations (100 g, 200 g, and 300 g).

Pineapple peels are rich in carbohydrates and sugars that are readily decomposed by microbes, thereby enhancing the nutrient content of LOF (Aruna, 2019). Similarly, banana peels contain high levels of carbohydrates that influence enzymatic activity during fermentation (Arekemase et al., 2020). The high carbohydrate content in banana peels affects enzymatic activity such as the hydrolysis of amylase and pectinase enzymes. The amylase enzyme breaks down polysaccharides like starch into simpler monosaccharides, while the pectinase enzyme breaks down pectin in plant cell walls into smaller components, thus facilitating microbes in decomposing organic materials. Tea dregs, on the other hand, contribute organic matter that supports microbial growth and accelerates the fermentation process (Li et al., 2021).

Fermentation was carried out under anaerobic conditions by sealing the containers with cloth covers to prevent contamination, particularly from fly larvae. During the hydrolysis stage, microbial activity facilitated the breakdown of complex compounds such as polysaccharides and proteins into simpler molecules, including monosaccharides, amino acids, and fatty acids. The addition of organic wastes optimized the logarithmic growth phase, during which microbes actively consumed nutrients and proliferated exponentially (Abatenh et al., 2017; Ambardini et al., 2025). In this phase, microorganisms produce primary metabolites essential for their growth and reproduction (Ali et al., 2018).

As fermentation progressed, microbial populations entered the idiophase, characterized by the synthesis of secondary metabolites. These secondary metabolites, although not directly involved in microbial growth, play a crucial role in enhancing the quality of the LOF. Moreover, they contribute to the biosynthesis of plant growth hormones, thereby increasing the effectiveness of LOF in promoting plant development (Ismail et al., 2021). The specific types of secondary metabolites produced depended on the organic waste materials used during fermentation. For instance, banana peels are rich in flavonoids, saponins, phenolics, and tannins (Kibria et al., 2019), while pineapple peels contain polyphenols, alkaloids, flavonoids, bromelain, and gallic acid (Hikal et al., 2021). Tea dregs present a more complex composition, including alkaloids, flavonoids, tannins, vitamins, and minerals, which not only improve the quality of LOF but also support plant growth regulator (PGR) mechanisms (Maryana et al., 2023).

The JLOF fermentation process uses facultative anaerobic bacteria and is conducted in anaerobic conditions. These microbes used the available oxygen during the early stages of fermentation through aerobic respiration to quickly generate energy. As oxygen levels decreased, microbial metabolism transitioned to obligate anaerobic pathways to maintain fermentation activity (Lu & Imlay, 2021).

In the fully anaerobic stage, obligate anaerobes thrived by utilizing organic compounds that had been partially decomposed by facultative microbes. These anaerobic microorganisms played a key role in further breaking down organic matter into final fermentation products, such as methane, acetic acid, and carbon dioxide, which contributed to the overall nutrient composition of LOF (Kurniawan et al., 2024). Fermentation also produces carbon dioxide (CO_2) as a byproduct. At elevated concentrations, CO_2 can create extremely anaerobic conditions that inhibit microbial activity. Excess CO_2 accumulation lowers the pH of LOF, disrupts microbial ion balance, and interferes with enzymatic functions (Yu & Chen, 2019). Additionally, high CO_2 levels can induce osmotic stress, leading to microbial cell death, and altering membrane interactions, thereby impairing nutrient transport mechanisms (Guan et al., 2017). Elevated CO_2 also intensifies microbial competition for limited resources, enabling more tolerant species to dominate while less adaptive species populations decline (Heiborn et al., 2023). To prevent these adverse effects and maintain stable fermentation conditions, the process was limited to 14 days. This duration ensured CO_2 levels remained within an optimal range to support microbial growth and promote the production of beneficial secondary metabolites.

Sensory qualities (aroma, color, and texture) of formulated JLOF

The sensory quality assessment of *Jakaba*-based liquid organic fertilizer (JLOF) revealed variation in acceptance levels depending on the type of organic waste used and the attribute evaluated (Figure 2). The aroma was assessed using a five-point scale, where a score of 1 indicated a strong, unpleasant odor and a score of 5 represented a mild, pleasant scent. The highest aroma rating was observed for JN1 (4.3), which exhibited a fermented tapai-like aroma, followed by JP1 (4.0), suggesting that the fermentation process of these formulations produced more favorable olfactory characteristics.

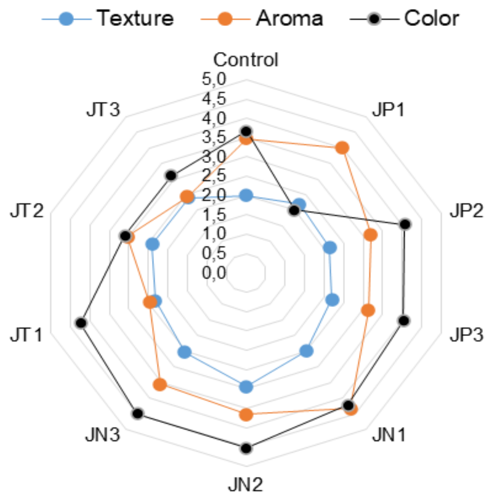

Figure 2. Radar plot showing the sensory attributes (aroma, color, and texture) of liquid organic fertilizers fermented using Jakaba starter, evaluated on a five-point scale. Jakaba formulations: JN = Jakaba + pineapple peel waste: 100 g (JN1), 200 g (JN2), 300 g (JN3); JP = Jakaba + banana peel waste: 100 g (JP1), 200 g (JP2), 300 g (JP3); JT = Jakaba + tea dregs: 100 g (JT1), 200 g (JT2), 300 g (JT3); Control = Jakaba without waste substrates

The aroma of JLOF derived from different organic wastes is influenced by the chemical and biological composition of the raw materials, as well as by microbial activity during fermentation. Microorganisms involved in the fermentation process break down organic compounds into volatile metabolites, which shape the final aroma profile of the LOF (Ranadheera et al., 2017). JLOF produced from pineapple peels initially emitted a sweet and fresh aroma. However, after 14 days of fermentation, the JN1 formulation developed a more pungent and putrid odor, while JN2 and JN3 retained a faint pineapple-like scent. This variation is attributed to the higher concentration of pineapple peels in JN2 and JN3, which led to an increased presence of volatile aromatic compounds. Nonetheless, the pineapple peels also contain antibacterial compounds such as tannins, steroids, saponins, flavonoids, and phenols, which may inhibit microbial activity, slow fermentation, and prevent the full development of a desired aroma (Minarni & Riga, 2024). In banana peel-based JLOF, aroma changes were more pronounced over time. Initially, the formulations emitted a characteristic sweet banana scent. However, after 30 days of fermentation, each sample exhibited distinct olfactory profiles.

JP1 developed a strong putrid odor, JP2 emitted an aroma resembling fermented cassava (*tapai*), and JP3 retained a sweet, banana-like scent, likely due to the higher concentration of banana peels. The development of a putrid odor in LOF is commonly linked to the activity of acid-producing bacteria such as *Pseudomonas, Escherichia, Flavobacterium*, and *Alcaligenes*, which generate volatile fatty acids during fermentation (Andraskar et al., 2021). Under anaerobic conditions, additional volatile compounds such as methane and hydrogen sulfide may also be produced, contributing to a stronger and more unpleasant odor (Czatzkowska et al., 2020). The fermented *tapai*-like aroma observed in JP2 suggests a well-progressed and balanced fermentation process. This aligns with the criteria for mature LOF, as described by Sekaringsih & Asngad, (2023), who noted that successful fermentation is typically characterized by a reduction in unpleasant odors and the emergence of a *tapai*-like scent. Among the different formulations, the tea dregs-based JLOF demonstrated greater aroma stability compared to other treatments.

Initially, these samples exhibited an earthy scent with a slight putrid odor, likely due to the Jakaba starter. However, after 30 days of fermentation, the aroma became more pleasant and non-pungent. This improvement is attributed to the presence of aromatic compounds in tea leaves, such as linalool, geraniol, benzyl alcohol, methyl salicylate, and *n*-hexanal (Inarejos-García et al., 2021). Among the tea-based formulations, JT1 produced a milder aroma, while JT2 and JT3 retained a stronger tea-like scent due to the higher concentration of tea dregs.

The color was evaluated using a five-point scale, ranging from black (score 1) to brown-to-yellow (score 5). The most favorable scores were recorded for JN2 and JN3, both receiving a 4.5, indicating a brown to yellowish-brown coloration. This suggests that these formulations underwent optimal fermentation, resulting in desirable pigmentation that may enhance user acceptance. Variations in the color of JLOF produced from different organic wastes are influenced by the pigments and chemical constituents inherent in each raw material. The final coloration reflects the extent of organic matter decomposition and, consequently, the overall effectiveness of the fermentation process.

Pineapple peel-based JLOF initially displayed a bright brown to yellowish-brown hue. However, post-fermentation, the color darkened to a murky brown, with noticeable sediment resulting from incompletely decomposed materials. This transformation is attributed to microbial degradation of organic compounds during fermentation, which leads to the production of metabolites that alter the visual appearance of the liquid fertilizer (Rofi'i et al., 2021). Additionally, the presence of phenolic compounds and organic acids in pineapple peels contributes to the color shift from yellow to brown during fermentation (Nitami & Asngad, 2023). The degradation of carotenoids in the peels further reduces the intensity of yellow pigments, while the breakdown of organic matter leads to a deeper brown coloration. In contrast, color changes in banana peel-based JLOF were less pronounced.

The JP1 sample, which initially exhibited a light brown hue, transitioned to a grayish tone, whereas JP2 and JP3 darkened slightly after fermentation. The soft texture of banana peels facilitates rapid decomposition into fine particles, which increases turbidity and sedimentation in the LOF. Additionally, enzymatic browning, driven by polyphenol oxidase activity, plays a significant role in color transformation during fermentation (Ismail et al., 2023). Notably, JP1, derived from ripe banana peels, exhibited a more grayish appearance due to the higher pigment content, which had already undergone oxidation prior to fermentation.

Meanwhile, tea dregs-based JLOF exhibited increasingly intense coloration over the course of fermentation. Among the samples, JT3 displayed the darkest hue, characterized by a deep reddish-brown color. This intensified coloration is likely the result of the higher concentration of tea dregs used in JT3 compared to JT1 and JT2. Prolonged fermentation accelerates enzymatic browning reactions, contributing to a more pronounced darkening effect. During fermentation, carbohydrates in tea dregs are broken down into simple sugars, organic acids, carbon dioxide, and thermal energy. The rise in temperature due to microbial activity enhances browning reactions, further deepening the color of the LOF over time (Zhu et al., 2022).

The texture was evaluated based on viscosity and particulate content, using a scale ranging from fine, soil-like consistency (score 1) to thick and sticky (score 5). The texture scores for all JLOF formulations ranged between 2.0 and 2.9, indicating a predominantly liquid consistency with some sediment. This suggests that Jakaba fermentation produced a relatively homogeneous texture across different organic substrates, maintaining similar physical properties regardless of the waste materials used. Typically, JLOF derived from household organic waste exhibits a liquid consistency with varying degrees of sedimentation, influenced by the type of feedstock.

In formulations based on pineapple peels, particularly in JN2 and JN3, floating clumps were observed on the surface of the solution. These clumps, appearing as thin black layers, were hypothesized to act as a substrate for Jakaba fungal growth. However, after 30 days of fermentation, fungal development remained suboptimal. This limitation is likely due to the presence of bromelain enzymes in pineapple peels, which possess antimicrobial properties that can inhibit microbial proliferation (Minarni & Riga, 2024).

Banana peel JLOF exhibited a more uniform liquid texture with finer sediment compared to pineapple peel-based formulations. In JP1, JP2, and JP3, fine sediment accumulated at the bottom of the fermentation container due to the effective degradation of banana peels, resulting in a soft pulp that gradually settled. While a significant portion of the pineapple peels also decomposed, some fibrous fragments remained suspended in the solution. In contrast, LOF produced from tea dregs maintained a stable liquid consistency throughout fermentation, though incomplete degradation led to the formation of coarser sediment compared to other treatments.

Higher concentrations of organic waste were associated with increased sediment accumulation in the fermentation container. Macroscopic observations of Jakaba texture revealed a crumbly consistency, with a soft surface when pressed. The fungal colonies displayed distinctive orange spores and brittle root-like growths extending toward the bottom of the fermentation vessel. Overall, the macroscopic characteristics were consistent across JLOF samples, regardless of the waste material used. Furthermore, the sensory evaluation indicated that fermentation resulted in a consistent texture across treatments, while variations in color and aroma were influenced by the type and composition of the organic waste. The high scores for aroma and color in certain formulations suggest that specific combinations of organic materials may enhance the acceptability and potential application of JLOF in sustainable agriculture.

pH profile and fungal consortia growth in JLOF

Throughout the fermentation process, significant shifts in pH were observed across the different JLOF formulations (Table 1). A marked decline in pH was recorded by day 14, likely attributed to the accumulation of organic acids produced during microbial metabolism. This initial acidification was followed by a gradual increase in pH by day 30, suggesting microbial consumption or neutralization of acidic compounds as fermentation progressed. Among the formulations, the tea dregs-based JLOF exhibited the most stable pH trajectory, ultimately reaching a near-neutral value of 7.07 by the end of the fermentation period. In contrast, JLOFs derived from pineapple and banana peels maintained relatively lower final pH levels, indicating persistent acidification or slower buffering capacity.

Fungal growth dynamics also varied among treatments. The highest fungal biomass was observed in tea dregs- and pineapple peel-based JLOFs (Figure 3, Table 2), reflecting favorable substrate composition for fungal proliferation. Conversely, banana peel JLOF exhibited comparatively lower fungal development, likely due to differences in nutrient availability, antimicrobial compound content, and substrate degradability. These findings highlight the influence of raw material composition on both physicochemical parameters and microbial colonization during fermentation, which are critical for the quality and consistency of liquid organic fertilizer.

Table 1. pH profile of liquid organic fertilizers (LOF) at 0, 14, and 30 days of fermentation

Day	pH ($\bar{x}$)									
	JN1	JN2	JN3	JP1	JP2	JP3	JT1	JT2	JT3	Control
0	4.43[a]	4.52[a]	4.61[a]	4.79[a]	4.88[a]	4.97[a]	4.88[a]	4.79[a]	4.70[a]	4.79[a]
14	4.34[a]	3.26[a]	4.01[a]	4.52[a]	4.70[a]	4.01[a]	6.05[b]	5.42[b]	4.88[a]	6.59[b]
30	5.51[a]	4.52[a]	5.36[a]	6.29[b]	5.15[b]	5.15[b]	7.07[c]	6.46[c]	6.20[b]	6.86[c]

Note:
Jakaba formulations: JN = Jakaba + pineapple peel waste: 100 g (JN1), 200 g (JN2), 300 g (JN3); JP = Jakaba + banana peel waste: 100 g (JP1), 200 g (JP2), 300 g (JP3); JT = Jakaba + tea dregs: 100 g (JT1), 200 g (JT2), 300 g (JT3); Control = Jakaba without waste substrates. Different letters within the same row indicate statistically significant differences at $P < 0.05$ based on DMRT post-hoc analysis.

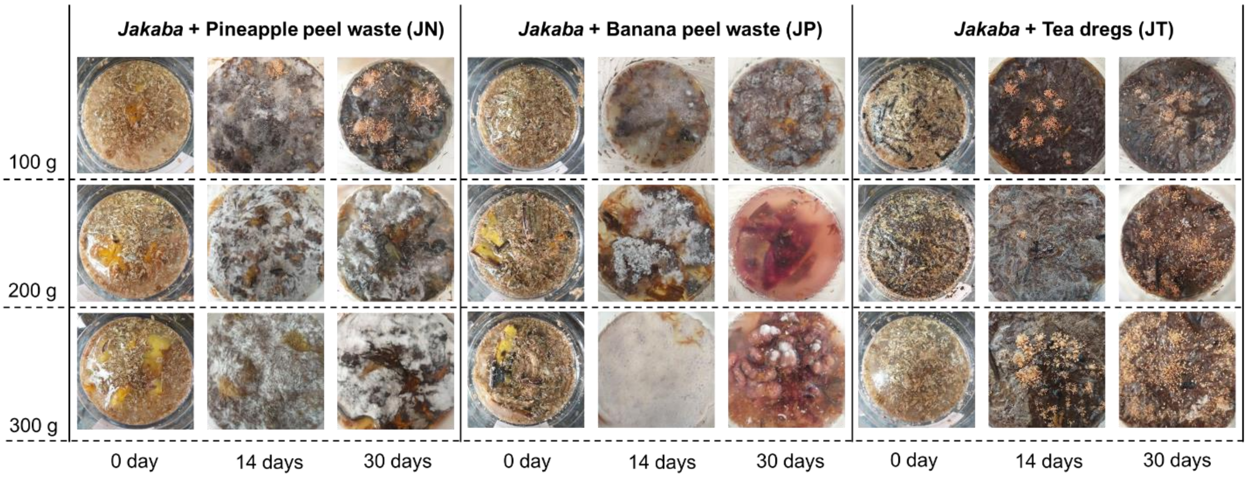

Figure 3. Fungal consortia growth and appearances in different liquid organic fertilizers fermented using Jakaba starter.

Table 2. Radial growth (mm) of fungal consortia in liquid organic fertilizers (LOF) measured at 0, 14, and 30 days of fermentation.

Day	Radial growth ($\bar{x}$ mm)									
	JN1	JN2	JN3	JP1	JP2	JP3	JT1	JT2	JT3	Control
0	-	-	-	-	-	-	-	-	-	-
14	4.0[a]	6.0[a]	7.0[b]	3.0[a]	1.5[a]	-	4.0[a]	4.0[a]	3.5[a]	3.0[a]
30	5.5[a]	5.0[a]	5.0[a]	5.0[a]	3.0[a]	4.0[a]	5.0[a]	6.0[a]	6.0[a]	7.0[b]

Note:
Jakaba formulations: JN = Jakaba + pineapple peel waste: 100 g (JN1), 200 g (JN2), 300 g (JN3); JP = Jakaba + banana peel waste: 100 g (JP1), 200 g (JP2), 300 g (JP3); JT = Jakaba + tea dregs: 100 g (JT1), 200 g (JT2), 300 g (JT3); Control = Jakaba without waste substrates. `-` = no growth. Different letters within the same row indicate statistically significant differences at $P < 0.05$ based on DMRT post-hoc analysis.

Changes in pH values during the fermentation of JLOF from banana and pineapple peels are influenced by microbial activity, particularly anaerobic bacteria and acid-producing bacteria such as *Lactobacillus* and *Lactococcus*. pH fluctuations occur due to methanogenic bacteria, which convert organic acids produced during fermentation into compounds such as methane, ammonia, and carbon dioxide (Yuan & Zhu, 2016). pH measurements indicate a significant decline from day 1 to day 14 of fermentation, primarily due to the accumulation of organic acids generated during the initial stages of fermentation. At this stage, organic matter is broken down into simple organic acids, resulting in a more acidic environment at the beginning of fermentation.

Several factors, including temperature, substrate concentration, environmental conditions, and oxygen availability, contribute to this pH decline. The decrease in pH also coincides with the exponential growth phase of microbial populations, during which rapid cell division depletes available nutrients, thereby altering the chemical composition of the fermentation medium. After day 14, the pH gradually increases until day 30 in all samples containing pineapple and banana peels. Anaerobic fermentation facilitates the breakdown of organic matter by facultative acid-producing bacteria into compounds such as fatty acids and aldehydes.

Methanogenic bacteria convert these fatty acids into methane, ammonia, carbon dioxide, and hydrogen, leading to a rise in pH due to the consumption of organic acids in the solution (Calicioglu et al., 2018). This microbial activity generates hydroxide ions (OH^-), further increasing the alkalinity of the fermentation medium. The pH increase is also associated with the degradation of organic matter into organic acids, nitrogenous compounds, and ammonia, indicating an optimal fermentation process that supports maximum microbial activity (Yu et al., 2019). The conversion of organic acids into stable compounds reduces hydrogen ion concentration in the solution, contributing to the gradual pH rise. Meanwhile, the pH of Jakaba LOF derived from tea dregs exhibited a continuous increase from day 1 to day 30 of fermentation. This trend suggests that fermentation proceeded efficiently, as the final pH approached neutrality.

Microbial communities involved in tea dregs fermentation produce alkaline compounds as metabolic byproducts, which neutralize or even surpass the effects of organic acid production. Therefore, pH fluctuations in JLOF from tea dregs are not solely dependent on organic acid production but also on the presence of alkaline compounds originating from the substrate and microbial metabolism. A One-Way ANOVA statistical analysis revealed that variations in organic waste types significantly influenced the final pH of JLOF, with a significance value (Sig.) of 0.008 (<0.05) at maturation period (30 days). In contrast, variations in organic waste concentrations did not significantly affect pH, as indicated by a significance value (Sig.) of 0.428 (>0.05) at 30 days. This finding suggests that differences in waste concentration did not result in substantial changes in the final pH of JLOF.

The most rapid fungal consortia growth was observed in JLOF formulations supplemented with tea dregs, as evidenced by the greater expansion of fungal colony diameter. In contrast, JLOFs derived from pineapple and banana peels exhibited significantly slower colony development. These differences in fungal proliferation are likely driven by variations in nutrient composition, decomposition dynamics, and the presence of inhibitory compounds inherent to each type of organic waste. Tea dregs provide an optimal nutrient supply and create favorable environmental conditions for microbial development, thereby accelerating Jakaba growth. In contrast, JLOF from pineapple and banana peels was relatively slower due to nutrient limitations and the potential presence of antimicrobial compounds.

Tea dregs accelerate fermentation due to their nitrogen and polyphenol content, which enhances microbial and enzymatic activity in the decomposition of organic matter (Li et al., 2021). A nutrient-rich environment promotes the growth of microbial communities such as *Proteobacteria* and *Firmicutes*, which play a crucial role in the degradation of organic matter and carbohydrates (Liu et al., 2018). Additionally, the near-neutral pH of tea dregs supports enzymatic activity and fungal metabolism, further promoting fungal growth. The moisture-retaining capacity of tea dregs also plays a vital role in sustaining fungal mycelium development (Samanta, 2020). Conversely, fungal growth in JLOF derived from banana peels exhibited the smallest diameter expansion.

The primary inhibitory factor is the presence of tannins, which have antinutritional properties and can hinder microbial nutrient utilization (Salim et al., 2023). Furthermore, the high crude fiber content in banana peels slows down decomposition, requiring a longer fermentation period for these compounds to break down and become bioavailable for microbial assimilation (Zou et al., 2022). The microbial growth in JLOF derived from pineapple peels was inhibited due to the presence of antimicrobial secondary metabolites. Bromelain and tannins in pineapple peels create an inhibitory zone for microbial growth (Jančič & Gorgieva, 2022). Bromelain, a protease enzyme, hydrolyzes peptide bonds in proteins into amino acids (Nanda et al., 2020).

The antibacterial effects of bromelain are linked to its ability to reduce bacterial cell membrane surface tension, disrupting membrane stability and decreasing the efficiency of solute transport within the cell (Jančič & Gorgieva, 2022). Consequently, microbial populations in pineapple peel JLOF were reduced, leading to slower fungal growth compared to other formulations. One-Way ANOVA analysis indicated that organic waste type did not significantly affect fungal growth diameter, with a significance value (Sig.) of 0.398 (>0.05). Furthermore, variations in organic waste concentrations (100 g, 200 g, and 300 g) also did not significantly influence fungal growth, with a significance value (Sig.) of 0.956 (>0.05). These findings suggest that, despite differences in the type and concentration of organic waste used during JLOF fermentation, these factors did not exert a statistically significant impact on fungal growth diameter after maturation period (30 days).

Application of JLOF on *pak choi* growth performances

Following the application of JLOF, significant increases and variations were observed in certain growth parameters of *pak choi*, in terms of plant height ($F_{10,22}$ = 3.19, P = 0.011) and fresh weight ($F_{10,22}$ = 7.30, P = 0.000). However, no significant difference was detected in the number of leaves ($F_{10,22}$ = 0.68, P = 0.732). The superior growth observed in the JT1 treatment, reaching an average height of 11.53 cm, compared to the stagnant development in the control group (5.8 cm), highlights the significant role of JLOF in enhancing plant performance (Table 3). The limited growth in the absence of LOF, as seen in the negative control treatment, suggests significant nutrient deficiencies that hinder optimal vegetative development. Essential macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), are crucial for plant growth and productivity. Nitrogen is integral to vegetative development by promoting leaf expansion and chlorophyll synthesis (Fathi, 2022). Phosphorus supports energy transfer processes and root system establishment, while potassium contributes to the structural reinforcement of tissues and regulates the distribution of carbohydrates and proteins within the plant (Nadeem et al., 2018). Tea dregs contain substantial amounts of these nutrients, which support young tissue formation and root system expansion. Additionally, phosphorus stored in ATP and ADP plays a vital role in cell division and elongation, contributing to increased plant height (Hardie, 2018). Beyond macronutrients, organic carbon (C-organic) content in LOF formulations also significantly influences plant growth. Organic matter decomposition enhances soil fertility by increasing C-organic content, which, in turn, improves cation exchange capacity and facilitates the release of bound phosphorus (Kholifani et al., 2020).

Table 3. Growth profile of *pak choi* (*Brassica rapa* subsp. Chinensis) following the application of liquid organic fertilizers (LOF), measured at 30 days after planting (DAP)

Plant growth	Treatments (x̄)										
	JN1	**JN2**	**JN3**	**JP1**	**JP2**	**JP3**	**JT1**	**JT2**	**JT3**	**C(+)**	**C(–)**
Plant height (cm)	6.0^{c}	5.5^{c}	5.3^{c}	8.5^{b}	8.2^{b}	8.7^{b}	11.5^{a}	9.1^{b}	8.8^{b}	10.6^{a}	5.8^{c}
Number of leaves (*n*)	4^{a}	5^{a}	4^{a}	5^{a}	5^{a}	6^{a}	7^{a}	5^{a}	5^{a}	5^{a}	4^{a}
Fresh weight (g)	0.8^{d}	1.0^{c}	1.0^{c}	1.5^{c}	1.1^{c}	1.3^{c}	4.2^{a}	2.0^{b}	1.4^{c}	2.6^{b}	0.7^{d}

Note:
Jakaba formulations: JN = Jakaba + pineapple peel waste: 100 g (JN1), 200 g (JN2), 300 g (JN3); JP = Jakaba + banana peel waste: 100 g (JP1), 200 g (JP2), 300 g (JP3); JT = Jakaba + tea dregs: 100 g (JT1), 200 g (JT2), 300 g (JT3); C(–) = no fertilizer; C(+) = commercial Jakaba fertilizer. Different letters within the same row indicate statistically significant differences at P < 0.05 based on DMRT post-hoc analysis.

Different organic substrates used in JLOF contribute varying levels of C-organic: pineapple peel LOF (2.77%) (Sutikarini et al., 2023), banana peel LOF (0.55%) (Akbari et al., 2018), and tea dregs LOF (7.3%) (Pujiati & Asngad, 2024). Higher C-organic content, such as in tea dregs, enhances microbial activity and nutrient availability, promoting better plant development (Sari et al., 2023). Although differences in plant height were observed across groups, statistical analysis indicated that variations in JLOF composition did not significantly affect plant height. However, leaf count showed a more significant response, with JT1, JN3, and JP3 treatments producing the highest number of leaves (six per plant), demonstrating greater effectiveness in promoting vegetative growth. The presence of N, P, and K in JLOF directly influences leaf formation, with nitrogen facilitating protein and chlorophyll synthesis (Fathi, 2022), phosphorus supporting leaf expansion and photosynthetic efficiency (Wang et al., 2018), and potassium improving nutrient transport while preventing chlorosis and leaf drop (Nadeem et al., 2018). The significant statistical results further confirmed that variations in JLOF formulations directly impact vegetative growth, particularly in leaf production. The increase in fresh weight observed in JT1 treatment aligns with the higher leaf number, as leaves serve as the primary site for photosynthesis. In particular, the use of tea dregs in JLOF formulations supports higher biomass production, as reflected in the superior fresh weight recorded in the JT1 treatment. This effect is attributed to the relatively high nitrogen content in tea dregs, which plays a vital role in chlorophyll biosynthesis. Statistical analysis confirmed that variations in JLOF significantly influenced fresh plant weight, with tea dregs JLOF demonstrating the highest potential for increasing biomass production in *pak choi*. These findings highlight the importance of substrate selection in optimizing the efficacy of JLOF as a biofertilizer for sustainable vegetable production.

CONCLUSION

Based on the comprehensive evaluation of all measured parameters , JT1 was determined to be the best Jakaba-based LOF (JLOF) formulation with a composition of 100 grams of tea dregs, which turned out to be the finest treatment for enhancing the growth and quality of *pak choi*. This study demonstrates that JT1, a liquid organic fertilizer based on Jakaba and fermented from 100 grams of tea dregs JLOF, offers the best circumstances for *pak choi* development by boosting plant height, leaf count, and wet weight through pH stability and healthy fungal growth. These results demonstrate the potential of tea waste as a superior organic substrate for the production of efficient biofertilizers, supporting waste management and sustainable agriculture practices.

ACKNOWLEDGMENT

We would like to thank Universitas Kristen Indonesia for facilitating the preparation of this article.

REFERENCES

Abatenh, E., Gizaw, B., Tsegaye, Z., & Wassie, M. (2017). The role of microorganisms inbBioremediation- A review. *Environmental Biology*, *1*(1), 38–46.

Akbari, W. A., Fitrianingsih, Y., & Jati, D. R. (2018). Pemanfaatan limbah kulit pisang dan tanaman *Mucuna bracteata* sebagai pupuk kompos. *Jurnal Teknologi Lingkungan Lahan Basah*, *3*(1), 1–10.

Ali, S., Asma, S. T., Nadeem, S. F., & Samar, M. (2018). Strategies and kinetics of industrial fermentation for the mass production of various primary and secondary metabolites from microbes. *European Journal of Pharmaceutical and Medical Research*, *5*(6), 595–606.

Ambardini, S., Yanti, N. A., Mamangkey, J., Arsyat, E. Y., & Ardiansyah (2025). Biofungicides derived from indigenous microorganisms fermented on *Tagetes erecta* L. flowers for the control of anthracnose in chili pepper (*Capsicum annuum* L.). *Plant Science Today*, *12* (1), 1–9. https://doi.org/10.14719/pst.4130

Andraskar, J., Yadav, S., & Kapley, A. (2021). Challenges and control strategies of odor emission from composting operation. *Applied Biochemistry Adn Biotechnology*, *193*, 2331–2356.

Arekemase, M. O., Omotosho, I. O., Agbabiaka, O. T., Ajide-Bamigboye, N. T., Lawal, A. K., Ahmed, T., & Oroju, J. O. (2020). Optimization of bacteria pectinolytic enzyme production using banana peel as substrate under submerged fermentation. *Science World Journal*, *15*(1), 56-63.

Aruna, T. E. (2019). Production of value-added product from pineapple peels using solid state fermentation. *Innovative Food Science and Emerging Technologies*, *57*, 102193. https://doi.org/10.1016/j.ifset.2019.102193

Calicioglu, O., Shreve, M. J., Richard, T. L., & Brennan, R. A. (2018). Effect of pH and temperature on microbial community structure and carboxylic acid yield during the acidogenic digestion of duckweed. *Biotechnology for Biofuels*, *11*(275), 1–19. https://doi.org/10.1186/s13068-018-1278-6

Chew, K. W., Chia, S. R., Yen, H. W., Nomanbhay, S., Ho, Y. C., & Show, P. L. (2019). Transformation of biomass waste into sustainable organic fertilizers. *Sustainability (Switzerland)*, *11*(8), 1–19. https://doi.org/10.3390/su11082266

Czatzkowska, M., Harnisz, M., Korzeniewska, E., & Koniuszewska, I. (2020). Inhibitors of the methane fermentation process with particular emphasis on the microbiological aspect: A review. *Energy Science and Engineering*, *8*(5), 1880–1897. https://doi.org/10.1002/ese3.609

Fadilah, R. A., Kurnia, M. D., & Putra, I. P. (2024). Jakaba undercover : Taxonomic riddle and potency in Indonesian agriculture. *Caraka Tani: Journal of Sustainable Agriculture*, *39*(2), 411–423. https://doi.org/10.20961/carakatani.v39i2.89049

Fathi, A. (2022). Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency : A review. *Agrisost*, *28*, 1–8. https://doi.org/10.5281/zenodo.7143588

Guan, N., Li, J., Shin, H. dong, Du, G., Chen, J., & Liu, L. (2017). Microbial response to environmental stresses: from fundamental mechanisms to practical applications. *Applied Microbiology and Biotechnology*, *101*(10), 3991–4008. https://doi.org/10.1007/s00253-017-8264-y

Hardie, D. G. (2018). Keeping the home fires burning: AMP-activated protein kinase. Journal of the Royal Society. *Interface*, *15*(138), 20170774.

https://doi.org/10.1098/rsif.2017.0774

Heiborn, D. heidler von, Reinmüller, J., Yurkov, A., Stehle, P., Moeller, R., & Lipski, A. (2023). Fungi under modified atmosphere—The effects of CO2 stress on cell membranes and description of new yeast *Stenotrophomyces fumitolerans* gen. nov., sp. nov. *Journal of Fungi*, *9*(10). https://doi.org/10.3390/jof9101031

Hikal, W. M., Mahmoud, A. A., Ahl, H. A. H. S.-A., Bratovcic, A., Tkachenko, K. G., Kačániová, M., & Rodriguez, R. M. (2021). Pineapple (*Ananas comosus* L. Merr.), waste streams, characterisation and valorisation: An overview. *Open Journal of Ecology*, *11*(09), 610–634. https://doi.org/10.4236/oje.2021.119039

Inarejos-García, A. M., Helbig, I., Klette, P., Weber, S., & Maeder, J. (2021). Authentication of commercial powdered tea extracts (*Camellia sinensis* L.) by gas chromatography. *Food Science and Technology*, *1*(4), 596–604. https://doi.org/10.1021/acsfoodscitech.1c00003

Ismail, H. A., Richard, I., Ramaiya, S. D., Zakaria, M. H., & Lee, S. Y. (2023). Browning in relation to enzymatic activities and phytochemical content in terap peel (*Artocarpus odoratissimus* Blanco) during postharvest ripening. *Horticulturae*, *9*(57), 1–15. https://doi.org/10.3390/horticulturae9010057

Ismail, M. A., Amin, M. A., Eid, A. M., Hassan, S. E. D., Mahgoub, H. A. M., Lashin, I., Abdelwahab, A. T., Azab, E., Gobouri, A. A., Elkelish, A., & Fouda, A. (2021). Comparative study between exogenously applied plant growth hormones versus metabolites of microbial endophytes as plant growth-promoting for phaseolus vulgaris l. *Cells*, *10*(5), 1–26. https://doi.org/10.3390/cells10051059

Janˇciˇc, U., & Gorgieva, S. (2022). Bromelain and nisin: The natural antimicrobials potential in biomedicine. *Pharmaceutics*, *14*(76), 1–39.

Kholifani, Y. I., Arbiwat, D., & Peniwiratri, L. (2020). The effects of mycorrhizae and organic matters application on soil p availability of limestone post mining and the growth of maize in Karangdawa Village, Tegal Regency. *Proceeding International Conference on Green Agro-Industry*, *4*, 404-413.

Kibria, A. A., Kamrunnessa, Rahman, M. M., & Kar, A. (2019). Extraction and evaluation of phytochemicals from banana peels (*Musa sapientum*) and banana plants (*Musa paradisiaca*). *Malaysian Journal of Halal Research*, *2*(1), 22–26. https://doi.org/10.2478/mjhr-2019-0005

Kurniawan, L., Maryudi, M., & Astuti, E. (2024). Utilization of tofu liquid waste as liquid organic fertilizer using the fermentation method with activator effective microorganisms 4 (EM-4): A review. *Equilibrium Journal of Chemical Engineering*, *8*(1), 100–112. https://doi.org/10.20961/equilibrium.v8i1.84056

Li, L., Guo, X., Zhao, T., & Li, T. (2021). Green waste composting with bean dregs, tea residue, and biochar: Effects on organic matter degradation, humification and compost maturity. *Environmental Technology and Innovation*, *24*(35), 101887. https://doi.org/10.1016/j.eti.2021.101887

Liu, L., Wang, S., Guo, X., Zhao, T., & Zhang, B. (2018). Succession and diversity of microorganisms and their association with physicochemical properties during green waste thermophilic composting. *Waste Management*, *73*, 101–112. https://doi.org/10.1016/j.wasman.2017.12.026

Lu, Z., & Imlay, J. A. (2021). When anaerobes encounter oxygen: Mechanisms of oxygen toxicity, tolerance and defence. *Nature Reviews Microbiology*, *19*(12), 774–785. https://doi.org/10.1038/s41579-021-00583-y

Maryana, Haryanto, D., & Lifia, R. C. (2023). Role of tea dregs liquid organic fertilizer and plant media composition in increasing tomato results (*Lycopersicon esculentum* Mill.). *Journal Techno*, *9*(1), 1–10.

Minarni, M., & Riga, R. (2024). Phytochemical potentials and antibacterial activity of pineapple peel extract (*Ananas Comosus* L Merr) against Streptococcus mutans. *Migration Letters*, *7*(57), 1833–1838.

Nadeem, F., Hanif, M. A., Majeed, M. I., & Mushtaq, Z. (2018). Role of macronutrients and micronutrients in the growth and development of plants and prevention of deleterious plant diseases - A comprehensive review. *International Journal of Chemical and Biochemical Sciences*, *13*, 31–52.

Nanda, R. F., Rini, B., Syukrti, D., Thu, N. N. A., & Kasim, A. (2020). A review: Application of bromelain enzymes in animal food products. *And. Int. J. Agric. Nat. Sci*, *1*(1), 33–44.

Ndese, T. V. P., Kamagi, D. D. W., Lawalata, H. J., Mokosuli, Y. S., & Taulu, M. L. S. (2024). The effect of biofertilizer (Jakaba) fertilizer on vegettive growth of chili plants (*Capsicum annum* L.). *Advances in Tropical Biodiversity and Environmental Sciences*, *8*(1), 119–124. https://doi.org/10.24843/ATBES.2024.v08.i03.p01

Nitami, A. P. J., & Asngad, A. (2023). Quality of kirinyuh leaf liquid organic fertilizer and coconut water waste with pineapple skin bioactivator. *International Conference on Biology Education, Natural Science, and Technology*, *1*(1), 122–132.

Orhan, T. Y., & Sahin, N. (2018). The impact of innovative teaching approaches on biotechnology knowledge and laboratory experiences of science teachers. *Education Sciences*, *8*(4), 1-24. https://doi.org/10.3390/educsci8040213

Panpatte, D. G., Jhala, Y. K., Shelat, H. N., & Vyas, R. V. (2016). *Pseudomonas fluorescens*: A promising biocontrol agent and PGPR for sustainable agriculture. *Microbial Inoculants in Sustainable Agriculture Productivity*, *1*, 257–270. https://doi.org/10.1007/978-81-322-2647-5

Pujiati, & Asngad, A. (2024). Efektivitas pupuk organik cair jerami padi dan ampas teh terhadap pertumbuhan dan kandungan kalsium tanaman selada (*Lactuca sativa* L.). *Jurnal Pendidikan Biologi Dan Sains*, *7*(1), 284–293. https://doi.org/10.58351/2949-2041.2024.8.3.013

Rahman, K. M. A., & Zhang, D. (2018). Effects of fertilizer broadcasting on the excessive use of inorganic fertilizers and environmental sustainability. *Sustainability (Switzerland)*, *10*(3), 1–15. https://doi.org/10.3390/su10030759

Ranadheera, C. S., Mcconchie, R., Phan-thien, K., & Bell, T. (2017). Strategies for eliminating chicken manure odour in horticultural applications. *Wordl's Poultry Science Journal*, *73*(2), 365–378. https://doi.org/10.1017/S0043933917000083

Rashmi, I., Roy, T., Kartika, K. S., Pal, R., Coumar, V., Kala, S., & Shinoji, K. C. (2020). Organic and inorganic fertilizer contaminants in agriculture: Impact on soil and water resources. *Contaminants in Agriculture: Sources, Impacts and Management*, 3–41. https://doi.org/10.1007/978-3-030-41552-5

Risman, A. (2022). Pertumbuhan dan produksi tanaman cabai katokkon (*Capsicum chinense* Jacq) pada berbagai konsentrasi pupuk jakaba. [Skripsi]. Universitas Bosowa.

Rofi'i, M., Susanti, A., & Zuhria, S. A. (2021). The formulation's technique using microbes to the speed decomposition of biomass fertilizers. *AGARICUS: Advances Agriculture Science & Farming*, *1*(1), 28–36.

Salim, R., Nehvi, I. B., Mir, R. A., Tyagi, A., Ali, S., & Bhat, O. M. (2023). A review on anti-nutritional factors: Unraveling the natural gateways to human health. *Frontuers in Nutrition*, *10*(1215873). https://doi.org/10.3389/fnut.2023.1215873

Samanta, S. (2020). Potential bioactive components and health promotional benefits of tea (*Camellia sinensis*). *Journal* *of the American College of Nutrition*, *41*(1), 1–29. https://doi.org/10.1080/07315724.2020.1827082

Sari, R., Maryam, & Yumah, R. A. (2023). Penentuan C-Organik pada tanah untuk meningkatkan produktivitas tanaman dan keberlanjutan umur tanaman dengan metoda spektrofotometri UV VIS. *Jurnal Teknologi Pertanian*, *12*(1), 11–19.

Sekaringsih, N. J., & Asngad, A. (2023). LOF kirinyuh leaves and liquid waste tempeh with pineapple peel bioactivator : Sensory and macronutrient content. *International Conference on Biology Education, Natural Science, and Technology*, *1*(1), 335–347.

Sutikarini, S., Masulili, A., Suryani, R., Setiawan, S., & Mulyadi, M. (2023). Characteristics of pineapple waste as liquid organic fertilizer and its effect on ultisol soil fertility. *International Journal of Multi Discipline Science*, *6*(1), 38. https://doi.org/10.26737/ij-mds.v6i1.3754.

Virginia, R., Wahyunigtyas, R.S., Silalahi, M., & Mamangkey, J. (2023). Pengaruh Limbah Organik Terhadap Pertumbuhan Kangkung Darat (*Ipomoea reptans* Poir) Dan Pemanfaatannya Sebagai Bahan Ajar. *ORYZA Journal of Biology Education*, *12* (2), 252-260. https://doi.org/10.33627/oz.v2i2.1337

Wang, J., Chen, Y., Wang, P., Li, Y. S., Wang, G., Liu, P., & Khan, A. (2018). Leaf gas exchange, phosphorus uptake, growth and yield responses of cotton cultivars to different phosphorus rates. *Photosynthetica*, *56*(X), 1–8.

Yu, H., Xie, B., Khan, R., & Shen, G. (2019). The changes in carbon, nitrogen components and humic substances during organic-inorganic aerobic co-composting. *Bioresource Technology*, *271*, 228–235. https://doi.org/10.1016/j.biortech.2018.09.088

Yu, T., & Chen, Y. (2019). Effects of elevated carbon dioxide on environmental microbes and its mechanisms: A review. *Science of the Total Environment*, *655*, 865–879. https://doi.org/10.1016/j.scitotenv.2018.11.301

Yuan, H., & Zhu, N. (2016). Progress in inhibition mechanisms and process control of intermediates and by-products in sewage sludge anaerobic digestion. *Renewable and Sustainable Energy Reviews*, *58*, 429–438. https://doi.org/10.1016/j.rser.2015.12.261

Yusminan, Walida, H., Harahap, F. S., & Mustamu, N. E. (2022). Comparison of Jakaba growth with the addition of organic matter in rice washing water. *International Journal of Science and Environment (IJSE)*, *2*(2), 74–78. https://doi.org/10.51601/ijse.v2i2.16

Zhu, J., Wang, J., Yuan, H., Ouyang, W., Li, J., Hua, J., & Jiang, Y. (2022). Effects of fermentation temperature and time on the color attributes and tea pigments of Yunnan Congou black tea. *Foods*, *11*(1845), 1–15. https://doi.org/10.3390/foods11131845

Zou, F., Tan, C., Zhang, B., Wu, W., & Shang, N. (2022). The valorization of banana by-products: Nutritional compositon, bioactivities, applications, and future development. *Foods*, *11*(20), 1–25. https://doi.org/10.3390/foods11203170