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Physical Characteristics of Organic Fertilizer Based on Banana Corm and Frond Variations

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Abstract. *This study aims to determine the effect of variations in banana corm and banana fronds on the odor and physical properties of solid organic fertilizer made from household waste. In addition, the research also aims to identify the differences in odor and physical characteristics between solid organic fertilizer based on EM4 and that based on banana corm and fronds. The method used is an experimental approach to test the effectiveness of organic fertilizers produced from different raw materials: banana corm, banana frond, rice-washing water, and household waste (predominantly rotten tape). The first treatment used a mixture of banana corm, banana fronds, rice-washing water, and household waste in a 1:1:1:1 ratio. The second treatment consisted of banana fronds, rice-washing water, and household waste in a 1:1:1 ratio. The third treatment included banana corm, rice-washing water, and household waste, also in a 1:1:1 ratio. The fourth treatment used EM4, rice-washing water, and household waste in a ½:1:1 ratio. The results showed that on the first day, all treatments emitted a strong odor of tape and household waste. Over time, an acidic smell began to emerge, eventually turning into a fresh, earthy scent, particularly in treatments with banana corm and EM4. The color of the fertilizer changed from dark brown to blackish brown, indicating successful decomposition. The texture also changed from coarse to more crumbly and homogeneous. The treatment with EM4 showed faster fermentation and a more stable odor compared to the other treatments.*

Keywords: *Banana corm, banana fronds, solid organic fertilizer, physical properties*

1. Introduction

Organic waste is the residue or waste material that can be recycled and originates from living organisms, such as food scraps, animal or human excrement, and plant waste. In other words, organic waste refers to materials derived from humans, animals, or plants (1). This type of waste can decompose naturally in the environment or through specific processes. Generally, organic waste breaks down into smaller particles and does not emit odors. However, if not managed properly, it can produce unpleasant smells and even become a source of disease (2).

Based on its type, organic waste is classified into two categories: wet and dry organic waste. Examples of wet organic waste include food leftovers and animal waste. On the other hand, examples of dry organic waste include wood stems, eggshells, and coconut shells (3). One effective method of utilizing organic waste is by processing it into fertilizer that is useful in the agricultural sector (2).

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Banana plants (*Musa paradisiaca L.*) are tropical plants that thrive in warm climates and require full sunlight. These plants grow well in moist soils at altitudes of up to 2,000 meters above sea level. In Indonesia, banana plants are found in nearly all regions. While almost all parts of the banana plant can be used, the fruit is the most commonly utilized (4). Banana plants are monocarpic, meaning they die after bearing fruit (5). The dead stems then become waste that must be managed properly. The disposal of large and heavy waste materials, such as banana stems, can be costly, thus requiring economical and environmentally friendly solutions (6).

Banana corm is a type of organic waste from banana plants that is often abundant but underutilized. However, it has great potential as a primary component in compost production due to its rich macro- and micronutrient content (5). The corm, or stem part, of the banana plant contains important nutrients, including nitrogen (N), phosphorus (P), and potassium (K). Additionally, banana corm contains carbohydrates that can stimulate microbial growth in the soil. The corm contains 3087 ppm NO_3, 1120 ppm NH_4, 439 ppm P_2O_5, and 574 ppm K_2O. With its relatively high macronutrient content, the banana corm has the potential to serve as a source of potassium (K) in the form of organic material to enrich soil media for plant cultivation (7,8).

Another part of the banana plant is the banana frond. Banana fronds are commonly found in rural areas, especially during the post-harvest period. Typically, banana fronds are discarded after the plant bears fruit. The potential of banana frond waste is substantial in agrarian regions, especially in Indonesia (9). Banana is a common crop across many districts, with an estimated 800,000 banana trees planted in 2005 and a production assumption of 80%, which suggests approximately 640,000 fronds become waste. Banana fronds also contain a considerable amount of cellulose, yet their utilization has been suboptimal (10).

Rice is the staple food of the Indonesian population, consumed daily. Before cooking, rice is washed, and the resulting rice-washing water is often discarded as household waste without optimal use. In fact, rice-washing water benefits plants either as irrigation water or as organic fertilizer, reducing reliance on chemical fertilizers and offering a more economical alternative. This water contains important nutrients such as nitrogen (0.03%), phosphorus (0.42% P_2O_5), potassium (0.06% K_2O), organic carbon (0.46%), and minerals like calcium (14.25%), sulfur (0.03%), and iron (0.04%), which support plant growth. Moreover, its vitamin B1 content plays a role in plant metabolism, converting carbohydrates into energy and stimulating root growth during the seedling phase (11,12).

Information regarding the utilization of household waste as organic fertilizer remains limited. Proper household waste management includes converting it into value-added solid organic fertilizer (13). Furthermore, optimized waste processing contributes to environmental cleanliness. Household waste has the potential to be processed into liquid fertilizer, solid fertilizer, or even biogas (14). Various types of household waste, such as spinach stems, banana peels, water spinach stems, tea dregs, mangoes, leftover rice, papaya peels, eggshells, banana leaves, carrots, mustard greens, and onion skins, can be used as raw materials for compost production (15).

Effective Microorganism-4 (EM4) contains various beneficial microorganisms that accelerate the composting process and improve fertilizer quality by eliminating foul odors. These microorganisms include photosynthetic bacteria (*Rhodopseudomonas spp.*), which produce compounds essential for plant growth, and lactic acid bacteria (*Lactobacillus spp.*), which suppress harmful microbes and speed up the fermentation of organic matter. Yeasts

(*Saccharomyces spp.*) produce hormones and enzymes that support root growth, while Actinomycetes work synergistically with photosynthetic bacteria to enhance soil fertility. In addition, fermentation fungi help eliminate odors, prevent pests, and decompose complex compounds into beneficial substances for soil and plants (16). While EM4 is known to accelerate composting, there is scant research comparing its effectiveness with natural composting agents such as banana corms and fronds.

The quality of organic fertilizer is determined by its color, texture, and odor. Color is a key indicator in assessing the quality and maturity of solid organic fertilizer. During fermentation, color typically changes from brown to dark brown or blackish due to microbial activity—such as that of bacteria and fungi—that breaks down complex compounds like cellulose and lignin into simpler substances, resulting in a darker hue (17). Odor changes during the fermentation of solid organic fertilizer follow a distinct pattern: beginning with the fresh scent of raw materials, followed by an acidic or fermented smell, and ultimately transitioning to a fresh earthy aroma. The acidic or fermented odor is due to the activity of *Lactobacillus spp*., which converts carbohydrates from molasses, rice-washing water, and EM4 into lactic acid. In contrast, the fresh earthy smell can be attributed to geosmin, a compound produced by soil bacteria such as *Actinomycetes* present in EM4. This earthy odor also indicates that the organic materials have been properly decomposed by the microbes (18).

Changes in texture during composting are marked by the transformation of tough and fibrous materials into smaller, crumbly particles. Mature compost feels loose and no longer sticks when held. This change in texture signifies microbial activity that has successfully decomposed organic matter into well-matured compost (19).

Despite the known nutrient content in banana corms and fronds, their comparative effectiveness in organic fertilizer production, particularly in enhancing physical properties such as odor and texture, remains underexplored. The influence of different organic waste materials on the odor and physical characteristics of compost, particularly in the context of household waste composting, is not well-documented. This represents a crucial knowledge gap, given the potential of odor and physical properties to affect compost usability and acceptance. This study aims to investigate the impact of variations in banana corm and banana fronds on the odor and physical properties of solid organic fertilizer produced from household waste. Furthermore, it seeks to identify the differences in odor and physical properties between solid organic fertilizers made using EM4 and those using banana corm and frond as base materials. This research is closely aligned with SDG 13: Climate Action, as it focuses on utilizing household waste that could otherwise contribute to greenhouse gas emissions and transforming it into solid organic fertilizer that can benefit agricultural practices.

2. Methods

This study employed an experimental method to examine the effectiveness of solid organic fertilizer produced from a combination of banana corm, banana frond, rice-washing water, and household waste dominated by rotten tape. The research was conducted on Tuesday, February 11, 2025, at the courtyard of Building B23, Department of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang. The fermentation process lasted for approximately 10 days, from February 11 to February 21, 2025. The research methodology applied in this study was adapted from the work of Jiang et al.

(2023)(20), with several modifications introduced to suit the specific objectives and experimental conditions.

The materials used in this study included banana corm, banana frond, rice-washing water, household waste (consisting mainly of rotten tape, mixed with leftover vegetables and fruit peels), and EM4 (Effective Microorganisms 4) as an organic decomposition activator. The tools and equipment used consisted of four plastic bottles (as decomposition containers), a knife (for chopping raw materials), a weighing scale (for precise measurement), a stirrer (for mixing), a 500 mL beaker, a 50 mL measuring cylinder, and plastic gloves.

The objective of this study was to observe and describe the odor and physical characteristics—specifically color and texture—of solid organic fertilizer resulting from different treatment combinations. The research aimed to compare decomposition outcomes based on varying organic materials, particularly by contrasting fertilizers using banana corm, banana frond, and EM4. Odor observations were conducted by cautiously smelling the fermented fertilizer and recording the scent, such as earthy, acidic, or ammonia-like smells. Color observations involved visually identifying any changes, such as from dark brown to blackish hues, while texture was assessed by examining the consistency—whether it was coarse, smooth, or crumbly—to determine the level of material breakdown.

The fermentation was conducted for 10 days, during which daily gas release was performed to maintain optimal conditions. Before treatment, the banana corm and frond were chopped using a knife and then crushed using a stone to create coarse pieces suitable for decomposition. The experiment included four different treatments, each involving different compositions of materials. The treatments are detailed in the table 1.

Table 1. Composition and ratio of materials used in each treatment for solid organic fertilizer fermentation.

Treatment	Composition	Ratio	Weight (grams)
1	Banana corm, banana frond, rice-washing water, household waste	1:1:1:1	100g each
2	Banana frond, rice-washing water, household waste	1:1:1	100g each
3	Banana corm, rice-washing water, household waste	1:1:1	100g each
4	EM4, rice-washing water, household waste	½:1:1	10g EM4, 100g rice water & waste

3. Results and Discussion

This study aims to evaluate the effect of varying combinations of banana corm and banana frond on the odor and physical properties of solid organic fertilizer. The fertilizer was produced by mixing key ingredients such as banana corm, banana frond, household waste, and rice-washing water in specific proportions. Additionally, a treatment involving EM4 as a bioactivator was applied to assess the effectiveness of the fermentation process. Observations were carried out over a period of six days, focusing on three parameters: odor, color, and texture.

3.1. Treatment 1 consisted of a mixture of banana corm, banana fronds, household waste, and rice washing water in a 1:1:1:1 ratio.

Treatment 1 consisted of a mixture of banana corm, banana fronds, household waste, and rice washing water in a 1:1:1:1 ratio is shown in Table 2.

Table 2. Physical properties of Treatment 1

Observation Period	Parameters	
	Odor	Physical Properties
Day 1 (February 11th, 2025)	At the beginning of the observation, a strong odor resembling fermented cassava (tape) and decomposing household waste, particularly leftover vegetables and fruits was clearly noticeable.	The initial appearance showed the natural color of the banana corm and frond, with a rough, chopped texture and clearly distinguishable pieces of the raw materials.
Day 2 (February 13th, 2025)	The unpleasant odor of household waste and spoiled cassava began to subside, giving way to an increasingly dominant earthy aroma, accompanied by a subtle hint of acidity.	The color progressively darkened into deep brown, the texture became noticeably crumblier, and initial signs of decay were observed, including the appearance of maggots.
Day 4 (February 15th, 2025)	The smell of soil became dominant, the acidic odor was no longer detectable, and the tape-like smell had almost disappeared.	The color turned dark brown to almost black, with a very crumbly and homogeneous texture. A small number of maggots began to appear, moving slightly on the surface of the sediment.
Day 6 (February 17th, 2025)	A strong earthy smell was dominant, with a slight hint of ammonia. The number of maggots began to decrease, and some were observed entering the pupal stage.	The compost showed a dark brown to black coloration with a highly crumbly and uniform texture. The temperature was stable at ambient conditions, and several maggot pupae were present.

3.2. Treatment 2 consisted of a mixture of banana fronds, household waste, and rice washing water in a 1:1:1 ratio.

Treatment 2 consisted of a mixture of banana fronds, household waste, and rice washing water in a 1:1:1:1 ratio is shown in Table 3.

Table 3. Physical Properties of Treatment 2

Observation Period	Parameters	
	Odor	Physical Properties
Day 1 (February 11th, 2025)	The initial odor detected was a strong smell of fermented cassava (tape) combined with other household waste, such as leftover vegetables and fruit peels.	The original color of the banana frond was visible, with a coarse chopped texture and noticeable pieces of raw materials.
Day 2 (February 13th, 2025)	The sweet smell of fermented cassava (tape) began to slightly diminish, while a fairly strong sour odor started to emerge.	The color turned dark brown, and the texture began to soften.
Day 4 (February 15th, 2025)	The acidic odor became dominant, while the smell of household waste and fermented cassava (tape) had almost disappeared. A slight earthy scent began to emerge.	The color turned dark brown with visible banana sheath fibers; the texture became crumbly, though some coarse fibers remained. A small number of maggots began to appear, moving on the surface of the compost.
Day 6 (February 17th, 2025)	A strong earthy smell was dominant, with a slight hint of ammonia. The number of maggots decreased, and some were observed entering the pupae stage.	The color turned dark brown to almost black, with a very crumbly and homogeneous texture. The temperature remained stable at room temperature. Several maggot pupae were observed.

3.3. Treatment 3 consisted of a mixture of banana corm, household waste, and rice washing water in a 1:1:1 ratio

Treatment 3 consisted of a mixture of banana corm, household waste, and rice washing water in a 1:1:1 ratio is shown in Table 4.

Table 4. Physical Properties of Treatment 3

Observation Period	Parameters	
	Odor	Physical Properties
Day 1 (February 11th, 2025)	The initial odor detected was a strong smell of fermented cassava (tape) combined with other household waste, such as leftover vegetables and fruit peels.	The original color of the banana corm was visible, with a coarse chopped texture and noticeable pieces of raw materials.

Observation Period	Parameters	
	Odor	**Physical Properties**
Day 2 (February 13th, 2025)	The sweet smell of fermented cassava (tape) began to slightly diminish, while a fairly strong sour odor started to emerge.	The color turned dark brown, and the texture began to soften.
Day 4 (February 15th, 2025)	The acidic odor became dominant, while the smell of household waste and fermented cassava (tape) had almost disappeared. A slight earthy scent began to emerge.	The color is dark brown with the tuber fibers still visible, the texture is crumbly but there are still coarse fibers. Maggots began to be seen in small numbers moving on the surface of the sediment.
Day 6 (February 17th, 2025)	The sour smell dominates, the sweet smell of the tape is almost gone. A slight earthy smell began to smell. Maggots are increasing.	The color is dark brown with the tuber fibers still visible, the texture is crumbly but there are still coarse fibers, the temperature is stable at room temperature. Maggots can be seen all over the fertilizer, but some have entered the pupal phase.

3.4. Treatment 4 consisted of a EM4 variation, household waste, and rice washing water in a ½ :1:1 ratio.

Treatment 4 consisted of a EM4 variation, household waste, and rice washing water in a ½ :1:1 ratio is shown in Table 5.

Table 5. Physical Properties of Treatment 4

Observation Period	Parameters	
	Odor	**Physical Properties**
Day 1 (February 11th, 2025)	The initial odor detected was a strong smell of fermented cassava (tape) combined with other household waste, such as leftover vegetables and fruit peels.	The original color of the remaining household waste, rough texture with pieces of raw material still visible, slightly cloudy due to the EM4 mixture.
Day 2 (February 13th, 2025)	The smell of the tape began to decrease, the sour smell and characteristic smell of EM4 began to smell.	The color turned dark brown, and the texture began to soften.

Observation Period	Parameters	
	Odor	**Physical Properties**
Day 4 (February 15th, 2025)	The characteristic smell of EM4 dominates, the smell of household waste and acid is almost gone.	The color turned dark brown with visible banana sheath fibers; the texture became crumbly, though some coarse fibers remained. A small number of maggots began to appear, moving on the surface of the compost.
Day 6 (February 17th, 2025)	The typical EM4 smell dominates, the tape and acid smell is almost gone, but there is a slight smell of ammonia. Maggots are increasing.	The color turned dark brown to almost black, with a very crumbly and homogeneous texture. The temperature remained stable at room temperature. Several maggot pupae were observed.

The fermentation process of organic fertilizer in this study showed significant development from day to day based on the four treatments used in the study. However, after 6 days of observation, none of the treatments had produced solid organic fertilizer that was completely mature and ready to use. On the first day, the first treatment (banana stump, banana stem, household waste, and rice washing water) showed a strong odor of tape and waste, a rough texture, and the ingredients were still clearly visible. The second treatment (banana stem, household waste, and rice washing water) had similar characteristics but with a slightly more fibrous texture. The third treatment (banana stump, household waste, and rice washing water) showed slightly more crude fiber than the other treatments. The fourth treatment (EM4, household waste, and rice washing water) began to show a distinctive fermentation odor from the beginning.

On the second day, the smell of tape began to decrease and a sour smell began to appear in all treatments. The color of the treatment with EM4 darkened faster than the other treatments. The first and third treatments experienced an earlier change in smell compared to the second treatment, while the combination of banana stems and stems still showed a more pungent smell before gradually decreasing. The texture slowly became crumblier, but was still rough and the material had not fully decomposed. On the fourth day, the sour smell became stronger in all treatments. The smell of tape and waste residue began to decrease, especially in the treatment with EM4 which stabilized the fermentation smell faster (16). The texture slowly became smoother, but coarse fibers were still visible in the first and third treatments. Maggots began to appear in small numbers on the surface of the sediment, especially in the treatment without EM4.

On the sixth day, the fermentation odor was more stable with the sour odor starting to disappear. This is in accordance with the findings which stated that decomposed organic waste will experience a change in odor along with the activity of decomposing microbes (2). In addition, Actinomycetes bacteria and other microbes that play a role in the final stage of decomposition begin to dominate, causing the odor to change to be more neutral (3,18). The texture of the fertilizer is increasingly crumbly and more homogeneous, especially in the EM4 treatment which showed the fastest change (16). However, all treatments still showed the presence of coarse fibers and materials that were not fully decomposed. Maggots began to appear in greater numbers throughout the fertilizer, with some starting to enter the pupal phase. The treatment without EM4 still showed coarse fibers that were not fully decomposed, especially in the second treatment.

During the initial two days of fermentation, odor intensity increases due to the metabolic activity of microorganisms that utilize the available nutrients in domestic wastewater for their survival and growth. However, between days 4 and 6, the odor decreases as the nutrient content in the household waste becomes depleted. The addition of rice water can intensify odor generation, as it promotes bacterial growth. The proliferating bacteria subsequently produce malodorous gases such as hydrogen sulfide, ammonia, mercaptans, alcohol ester, aldehydes ketones and other volatile compounds (20,21).

At the end of the observation, no treatment had truly produced solid fertilizer that was ready for use. All treatments were still in the active fermentation stage with remaining crude fiber that had not been completely decomposed. The treatment with EM4 showed the fastest development in texture homogenization and odor stabilization, but still required a longer time to be ready for use as solid organic fertilizer. Other treatments still showed significant crude fiber and the presence of maggots in quite large numbers, indicating that the decomposition process was not yet complete. These results indicate that the treatment with EM4 accelerated fermentation, but was not enough to produce solid organic fertilizer that was mature within 6 days. Further observation is needed to determine the optimal fermentation time until the fertilizer is truly ready for use.

The results of this study indicate that fermentation involving banana stems and EM4 results in a change in odor from the smell of tape and garbage to the typical smell of fermentation, as well as a darker color. This is in accordance with the theory that the fermentation process of organic fertilizer is characterized by a change in odor due to microbial activity that decomposes complex organic compounds into simpler substances (18). In addition, the color change from dark brown to blackish brown indicates that the decomposition process is running optimally. The activity of microorganisms in organic fertilizer causes the degradation of lignin and cellulose, which results in a color change (17). The change in color of composting material serves as an indicator of stability during the composting process. A bright brown color at the initial stage suggests that the composting process is actively occurring. During this phase, insects are often observed around the compost, as the lighter color tends to attract them. Once stability is achieved, the compost gradually turns dark or black, accompanied by a noticeable reduction in odor (22,23)

Changes in the texture of the fertilizer that are increasingly crumbly and homogeneous also indicate that the decomposition of organic materials is going well. However, based on observations, the fertilizer produced is not fully mature and requires further fermentation before it is ready for use. Good fermentation produces fertilizer with a loose and non-clumping texture, which is a sign of fertilizer maturity (24). Thus, this study supports previous findings which state that the use of organic waste as a fertilizer material can improve the quality of the fertilizer produced, but the fermentation time must be extended so that the results are truly optimal and ready for use (2).

Conclusion

Based on the results of the research that has been conducted, it can be concluded that the variation of the use of banana corms, banana fronds, organic household waste, rice washing water, and the addition of EM4 have a significant effect on changes in the odor and physical properties of solid organic fertilizer during the fermentation process. Treatment with the addition of EM4 showed a faster fermentation process, marked by a more stable odor change, darker color, and a more crumbly and homogeneous texture compared to other treatments. However, all treatments were still in the active fermentation stage until the sixth day, and had not produced fertilizer that was fully mature and ready to use. Therefore, additional fermentation time is needed so that the decomposition process of organic materials can take place perfectly and produce solid organic fertilizer with optimal quality.

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Conflicts of Interest

The authors declare no conflict of interest

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