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Composting as an Alternative to Waste Management at State University of Malang

***Eli H. Sanjaya, Abdul K. Syahroni, Much. S. Alwy, Moh. F. Setyawan, Yudhi Utomo, Agung Witjoro, & Mohd F. MD. Din**
Program Studi Kimia/FMIPA – Universitas Negeri Malang, Malang – Indonesia 65145
Center of Science and Engineering/LPPM - Universitas Negeri Malang, Malang – Indonesia 65145
Waste Management Research Center – Universitas Negeri Malang, Malang – Indonesia 65145
Department of Environmental Engineering – Universiti Teknologi Malaysia, Johor – Malaysia 81310

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Abstract

Waste is one factor that becomes an environmental problem. The waste that is often found is inorganic and organic. One of the uses of organic waste is the production of solid organic fertilizer in the form of compost. This research utilizes dried leaves (sono leaves, teak, trembesi, kenitu, breadfruit, and ketepeng) as raw materials for making compost. The compost-making method is carried out by adding an activator called EM4 (Effective Microorganism 4). This research produced pH values, Nitrogen, Phosphorus, Potassium, and Water Content per values under SNI 19-730-2004 regarding the specification of compost from organic waste. And the results of microbial diversity in the compost were obtained, which were dominated by microbes of the type Proteobacteria 40%, Firmicutes 30%, Actinobacteria 13%, Acidobacteria 6%, Bacteroidota 4%, Planctomycetota 3%.

Keywords: Organic compost, NPK, AM4, pH, diversity of microbes

Introduction

Waste is a common problem often faced in various sectors, including the industrial, economic, and educational sectors. Waste is a material or object that is no longer used so it is disposed of by humans (Dehghani et al., 2021). All active sectors must produce waste and what happens on the campus of a well-known State University in East Java, one of which is the State University of Malang. Waste at the State University of Malang comes from canteens, parks, and buildings.

Based on its nature, waste is divided into 2: organic waste and inorganic waste Nurkhasanah et al. (2021) Inorganic waste is a type of waste composed of inorganic compounds (plastic, metal, bottles). This type of waste can usually be reused by recycling methods through the sorting process first. While waste organic compounds. Most organic waste in the form of leaves is overcome by burning it in an open space, but this method causes new problems, namely the occurrence of air pollution and global warming (Habib et al., 2022). While waste organic compounds. Most organic waste in the form of leaves is overcome by burning it in an open space, but this method causes new problems, namely the occurrence of air pollution and global warming (Habib et al., 2022).

Compost is the result of the degradation of organic materials such as leaves, reeds, straw, etc. Hamzah et al. (2020) The manufacture of compost is a method of converting complex organic materials into simpler materials with the help of microbes (Wang et al., 2023). In the natural composting process it generally took much time. Still, with technological advancements, the composting process can be supplemented with bioactivators to speed up the composting process (Mohamad et al., 2021). One of the activators that is often used in the manufacture of compost is EM4. Effective microorganism 4 (EM4) is a microorganism of lactic acid, yeast, actinomycetes, and photosynthetic microbes that can be symbiosis with others so that it is effective in decomposing waste (Mohamad et al., 2021). According to Dewantari et al. (2022) the compost making process using the EM4 actuator has an effect of N, P, and C content conversion in the compost.

The increasing accumulation of organic waste, particularly dry leaves, presents a significant environmental challenge within educational institutions. Based on the description above, the production of organic waste that has not been

*Correspondence:
Eli H. Sanjaya
e-mail: eli.hendrik.fmipa@um.ac.id

appropriately utilized has the potential to be transformed into compost. With greater awareness of dry leaf composting practices, it is expected that this effort can minimize the burning of leaf waste which contributes to greenhouse gas emissions reduce the volume of dry leaf waste at the State University of Malang, and generate economic value for the institution.

However, the current utilization of compost on campus remains limited due to the absence of integrated waste management systems and the lack of awareness regarding its environmental and economic benefits. Moreover, scientific studies investigating microbial diversity in campus-based composting systems are still scarce, resulting in insufficient understanding of the microbial communities responsible for the decomposition and nutrient transformation processes. Therefore, this research aims to explore the potential of dry leaf composting at the State University of Malang while analyzing the diversity of microorganisms involved in the composting process to support sustainable waste management and environmental education efforts.

Methods

Materials and tools

Material in the research others dry leaves (sukun, sono, manecu, jati, trembesi, dan ketapang), EM4, and water. Oven (Memmert UN30), sieve, leaf cutting machine, paint bucket, and Next Generation Squencing. Data processing was conducted using statistical and bioinformatic analysis software to evaluate microbial diversity and nutrient composition. Nutrient analysis was performed using instruments compliant with the Indonesian National Standard (SNI), including a UV-Vis spectrophotometer for phosphate and potassium determination and Kjeldahl apparatus for total nitrogen analysis.

Experimental design

Composting was initiated by separating the collected dry leaf waste from any plastic contaminants. The dried leaves were then ground using a milling machine until a fine consistency was obtained. The ground material was subsequently placed into a composting tank for fermentation. Fermentor was added until the mixture reached a moisture content of approximately ±5%, followed by thorough mixing to ensure homogeneity. The composting process was maintained for approximately four weeks under closed conditions, with manual stirring performed once per week to support aerobic decomposition. After the composting period, the material was transferred to a drying area, leveled, and air-dried. The dried compost was then milled and sieved using a sifting machine to obtain a uniform particle size. The experiment was conducted by making 6 types compost fertilizers using 6 different types of dry leaves.

Results and Discussion

Compost fbrication

The manufacture of compost is carried out by looking for samples in the form of dried leaves from kenitu, breadfruit, teak, trembesi, sono, and ketepeng trees obtained from the campus area of the State University of Malang. Then, the leaves obtained using a machine are enumerated to obtain leaf pulp. Then, fermentation is carried out by adding a fermentor in the form of EM4, which is expected to speed up the fermentation process. The results obtained during 3 weeks of watering show that the leaves change color to blackish-brown, indicating that the leaves have been perfectly fermented. Fermented leaves were tested for compost quality, and microbial distribution content was tested using the NGS (Next Generation Sequencing) method. The results of the organic compost fertilizer specifications can be seen in Table 1.

Fertilizer characteristics test

Texture and color

Texture and color are indicators that determine the maturity of compost. From the results of the analysis that have been carried out, each type of compost has a different color. Where changes in the physical properties of the compost are caused by the process of decomposition and mineralization by microorganisms. Good compost is weathered by having a different color from the color of the material from which it originated, having a low moisture content, and a temperature that corresponds to room temperature (Worotitjan et al., 2022).

The results of color analysis on each type of leaf compost show that the compost from the trembesi and keta pang leaf types is brown, different from other types of leaf compost that are blackish-brown.

The difference in color in the compost of the leaf type is caused by the rapid and slow decomposition and mineralization processes by microorganisms. All compost of all kinds of leaves has a crumbly texture, which indicates the compost is of good quality. The results of the research from Hermawansyah et al. (2021) which was carried out for 2 months, namely on the 56th day, had the results of the compost having matured with a blackish color.

Odor

The purpose of the compost odor test is to determine whether the compost is ripe or not. Mature compost will smell like soil. The research lasted for 60 days. All composts of all types had an earthy odor (neutral), which indicated that the compost had undergone decomposition.

pH

pH is one of the physical parameters of compost that needs to be considered and controlled. pH is a measurement of the concentration of hydrogen ions in a solution that indicates the degree of acidity of a solution. Based on the pH analysis in Table 2, the highest pH value is found in teak leaf compost with a pH value of 7.94, while the lowest is in the sono foliar fertilizer with a pH value of 6.82. The high pH value in teak leaves is caused by the content of natural substances from teak leaves, such as anthocyanins, flavonoids, tannins, and saponins, that are completely decomposed by microorganisms, so that the organic acids in the teak leaves become ripe.

The pH value in composting is between 5.5 and 8. During the composting process, organic acids are completely decomposed by microorganisms, increasing pH values between 6 and 8. The pH value of all fertilizers obtained is in accordance with SNI 19-730-2004 regarding compost specification from organic waste, which requires a minimum value of 6.8.

Moisture

Moisture content is the amount of water in a sample expressed in percent, where moisture content can affect appearance and texture. From the analysis of the moisture content that has been carried out, the results of each type of fertilizer are obtained in the 50 – 71% range. The results have met the minimum standard determined by SNI19-7030-2004, which is 50%. However, it is above the range specified by SNI19-7030-2004 because, in the composting process, the container is too closed, which causes water to accumulate in the composting results. The moisture content obtained varies because the activity of each microorganism in each composting container differs.

According to Muliani et al. (2022), humidity must be maintained in the range of 40-60% to keep microbes active. Excess water in the composting process will reduce air volume; however, the decomposition process will be inhibited if it is too dry. In a study conducted by Hermawansyah et al. (2021) The moisture content was 32.5%, which was below the range needed by microbes to carry out activities because the raw materials were too dry and not covered with compost piles, which caused evaporation.

Table 1. Results of the Specification of Compost Fertilizer from Dried Leaves

Sampel Kompos	Nitrogen (%)	Phosphorus (ppm)	Kalium (ppm)	pH	Kadar Air (%)	Tekstru/Warna	Smell
Jati	1,12	2045	854	7.94	52,16	Remah/Dark brown	Tanah (Netral)
Ketapang	1,12	1592	997	7,47	51,16	Remah/Brown	Tanah (Netral)
Manecu	1.175	2261	593	7.04	66.8	Remah/Dark brown	Tanh (Netral)
Sono	1.82	1560	1309	6.82	71.8	Remah/Dark brown	Tanah (Netral)
Sukun	1.33	2149	10124	7.65	62.3	Remah/Coklat kehitaman	Tanah (Netral)
Trembesi	2.45	2321	1647	7.28	50.4	Remah/Brown	Tanah (Netral)
Kompos Campuran	1.19	1067	690	7.53	50	Remah/Coklat Kehitaman	Tanah (Netral)

Total N content

Nitrogen is a macroelement absorbed by plants in the form of nitrate or ammonium ions, which are both soluble in water (Wang et al., 2024). The nitrogen content from trembesi is 2.45%. Meanwhile, the lowest nitrogen concentration is found in teak and ketapang leaf compost, with a content of 1.12%. The low nitrogen content in teak and ketapang leaves can be affected by the decrease in the activity of microorganisms in the compost. The nitrogen content in all fertilizers obtained is by SNI 19-730-2004 regarding the specification of compost from organic waste, which is at a minimum value of 0.40%.

The nitrogen content in the compost affects the level of phosphorus produced. High nitrogen levels increase the number of microbes present, thus also increasing phosphorus levels (Kaswinarni & Nugraha, 2020). The highest nitrogen concentration in compost is found in trembesi leaf compost with a content of 2.45%. Meanwhile, the lowest nitrogen concentration is found in teak and ketapang leaf compost, with a content of 1.12%. The low nitrogen content in teak and ketapang leaves can be affected by the decrease in the activity of microorganisms in the compost. The nitrogen content in all fertilizers obtained is by SNI 19-730-2004 regarding the specification of compost from organic waste, which is at a minimum value of 0.40%.

Nitrogen and phosphorus have a closely related role in plant nutrition and microbial activity during composting. Nitrogen supports the synthesis of amino acids and proteins, which are essential for microbial growth, while phosphorus is vital for energy transfer through ATP and nucleic acid formation. A balanced ratio of nitrogen to phosphorus enhances microbial metabolism, accelerates the decomposition of organic matter, and improves the overall nutrient quality of the resulting compost. Conversely, an imbalance—such as low nitrogen or phosphorus levels—can slow microbial activity and reduce the compost's maturity and nutrient availability for plants.

Total P content

In the phosphorus analysis that was carried out, the highest yield was obtained, which is 0.23%, contained in trembesi leaf fertilizer. With moderate levels in sukun and manecu, and the lowest phosphorus content is 0.156% in the sono leaf fertilizer. The results obtained met the minimum standard that was determined by SNI 19-7030-2004, which is 0.10%. The high phosphorus level in trembesi leaves is influenced by the high nitrogen levels found in trembesi leaves. The existence of this phosphorus nutrient is caused by the weathering of organic matter from leaves that are used as compost. According to Novizan in 2004, phosphorus mainly came from the weathering of natural mineral rocks, and the rest came from the weathering of organic matter (Andjani, 2022). Although there are many sources of phosphorus in the soil, plants can still experience phosphorus deficiency. Most phosphorus is chemically bonded by other elements, becoming a compound that is difficult to dissolve in water. Phosphorus in plants serves as a nutrient for cell division and plant growth point tissue development.

Phosphorus also plays a synergistic role with other macronutrients, particularly nitrogen and potassium. Together, these nutrients regulate key physiological processes such as energy transfer, protein synthesis, and root development. Adequate phosphorus availability enhances nitrogen uptake efficiency and promotes balanced plant growth, while its interaction with potassium improves enzyme activation, water regulation, and stress resistance. Therefore, maintaining an optimal balance among phosphorus, nitrogen, and potassium is crucial for achieving healthy plant development and maximizing nutrient efficiency in compost-based fertilizers.

Total K content

Analysis of potassium levels that have been carried out, the results of each type of compost fertilizer are 0.0845%, 0.0997%, 0.0593%, 0.13%, 0.10%, 0.16%, 0.069%. The results obtained have not met the minimum standard set by SNI 19-7030-2004, which is 0.20%. In a study conducted by Shim et al. (2022) the average potassium content of commercial organic compost sit around 2,79% which was caused by a different types of material that has a high potassium content. Potassium elemental binders come from organic matter that microorganisms have decomposed in a pile of compost material. This fresh organic matter contains potassium in the form of complex compounds that plants cannot use for growth. However, microorganisms can decompose it into simple compounds that produce absorbable potassium elements.

Diversity of microbes

The microbial diversity in dry foliar fertilizer was obtained by the diversity of activating microbes in the form of an EM4 solution dominated by 2 phyla, namely the phylum proteobacteria and firmicutes, as seen in Figure 1. Meanwhile, the results of microbial diversity in dry leaf compost can be seen in Figure 2

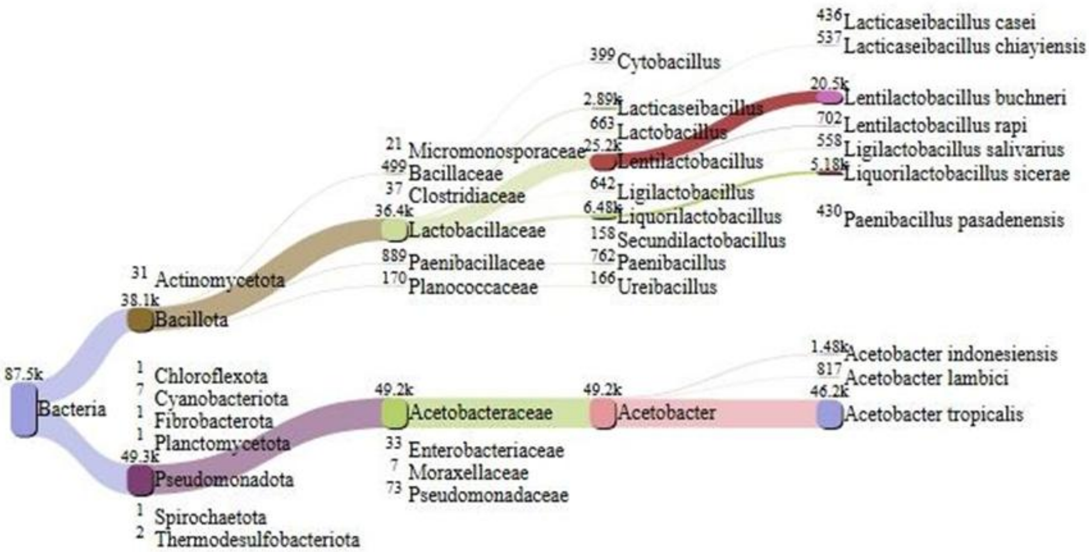

Figure 1. Activator microbes diversity

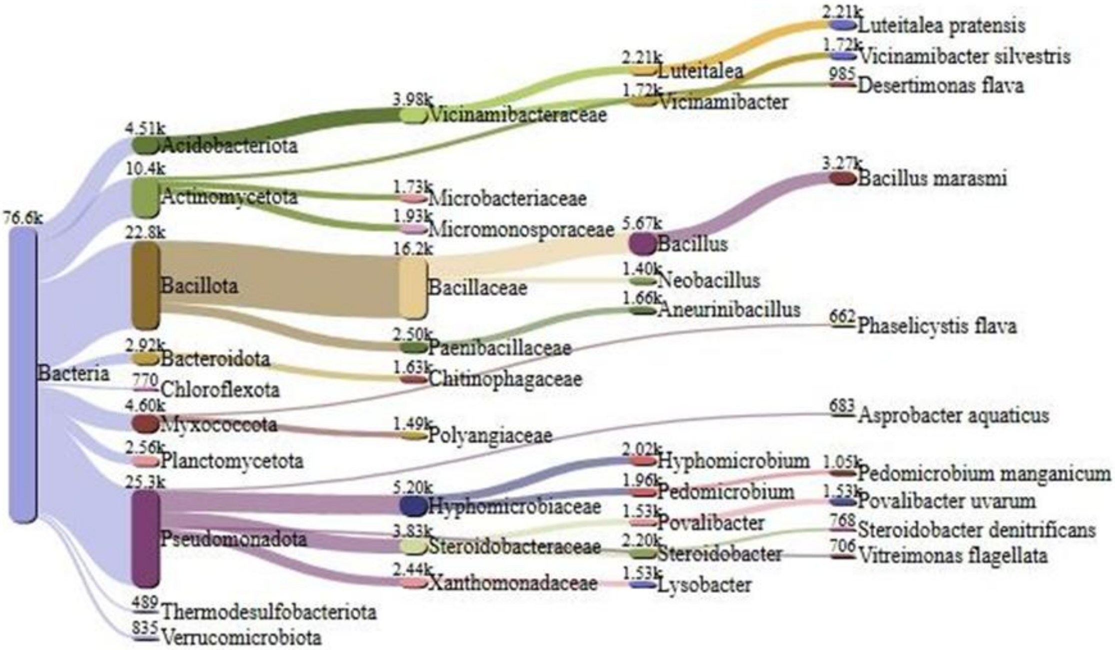

Figure 2. Microbes Diversity of Dry Leaves Compost

In the NGS results, Dry Leaf Compost shows a varied microbial diversity compared to the microbial diversity in the activator. This is due to natural microbes in dry leaves during the composting process. Thus, the dry compost sample confirms the formation of compost assisted by microbes. In the aerobic composting process, the main determinants of the microbial community are temperature, pH, moisture, and the raw materials of the compost.

In the research conducted by [A. B. Henry 2020], microbial diversity in compost was found to include the phylum Firmicutes (Bacillus, Clostridium, Paenibacillus, Kurthia, Ureibacillus, Lysinibacillus, and Fictibacillus), Actinobacteria (Flavobacterium spp., Chryseobacterium spp., and Sphingobacterium spp.), and Bacteroidetes (Streptomyces).

Conclusion

The composting process is the decomposition of organic material by microorganisms into humus. The compost with the highest N, P, and K content is compost made from trembesi leaves, which yields 2.45%, 2321 ppm, and 1647 ppm, respectively, with a moisture content of 50.4%, a neutral odor, as well as a brown color and crumbly texture. The high phosphorus content in trembesi leaves is influenced by the high nitrogen content present in the leaves. The composting process is dominated by the bacterial phyla Firmicutes, Actinobacteria, Proteobacteria, Bacteroidetes, and Chloroflexi (Chukwuma et al., 2021). The production of dry leaf compost is expected to minimize the behavior of burning leaf waste, which can produce greenhouse gas emissions, and to reduce the amount of dry leaf waste at Universitas Negeri Malang. Additionally, it can provide economic value to the institution.

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