COMPOST AS A SUSTAINABLE ALTERNATIVE. ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS IN MONITORING AND OPTIMIZING COMPOST QUALITY

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This research study examines the effects of different additives on compost quality by conducting physico-chemical analyses, emphasising pH, total nitrogen, phosphorus, potassium, organic matter, and humidity content. We observed compost samples enhanced with Bio Kompost (biological accelerator), beer, yeast, and Pleurotus fungi over a period of 45 days. The findings indicated notable differences in nutrient retention and the decomposition of organic matter. Pleurotus fungi and yeast contributed to enhancing nitrogen and organic matter retention, whereas beer facilitated phosphorus mobilisation. Bio Kompost enhances nutrient levels at elevated concentrations. The humidity levels demonstrated the additives' impact on both water retention and microbial activity. The primary objective of this study is to evaluate the impact of specific organic and microbial additives on the nutrient profile and decomposition dynamics of compost, thereby identifying effective strategies to enhance compost quality for agricultural use.

Keywords: compost, nutrients, sustainable, agriculture, soil

1. Introduction

The growing generation of municipal solid waste (MSW) can be directly linked to the rapid increase in population, urbanisation, and economic development, all of which have played a significant role in this rise. Creating sustainable waste management systems, conserving the environment, and recovering resources are all profoundly influenced by the substantial challenges and issues stemming from the increase in waste generation [1]. In relation to other components of municipal solid waste, the organic fraction, primarily comprising food waste, garden waste, and various biodegradable materials, constitutes a substantial portion, ranging from 40% to 70% of the total [2]. The percentage is notably elevated in developing countries. Developing novel waste treatment methods for this organic percentage

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presents both a challenge and a potential opportunity. Conventional garbage disposal methods, such as landfilling and incineration, have faced heightened criticism due to their contributions to greenhouse gas (GHG) emissions, leachate formation, and the depletion of essential organic carbon. In the current context, it is increasingly important to implement waste management practices that minimise environmental risks and promote the recovery of resources [3, 4].

Compost, a soil supplement rich in nutrients, is produced through composting, which entails converting organic waste into compost. Composting offers numerous advantages, such as minimising waste, enhancing soil quality, and mitigating the effects of climate change. Composting can be conducted on a commercial scale or within a household setting. The inputs for composting may vary based on the type of composting system employed. Most composting systems require both carbon and nitrogen sources. Straw, grass clippings, and leaves are examples of materials rich in carbon. Items such as manure, food scraps, and coffee grounds are examples of materials with high nitrogen content.

A diverse range of bacteria, archaea, and fungi contribute to the biodegradation of organic substrates in the composting process, which is characterised as exothermic bio-oxidation. Composting is a biological process that effectively converts organic waste into a uniform material beneficial for plant growth. Organic waste constitutes the portion of refuse that undergoes decomposition fastest. Organic waste can be categorised into kitchen refuse, market waste, and agricultural byproducts. If not managed properly, these forms of waste may result in various environmental problems [5, 6].

Consequently, composting represents the most economical approach to addressing this issue. Composting is a process that breaks down various types of organic waste, such as refuse from gardens, plants, and vegetables [7]. As a part of organic waste, it can be used to manage the environment, supply plant nutrients, and enhance crop fertilisation. Several factors may influence the quality of compost products. This occurs because different types of organic waste have distinct proportions of nutrients such as nitrogen, phosphorus, and potassium (N, P, and K), typically found in fertilisers. The temperature, pH, humidity content, and carbon to nitrogen (C:N) ratio are the key variables influencing the efficiency of compost production. Additionally, numerous factors may impact the composting process and the resulting products [4, 6-8].

Composting is a process that employs microorganisms to facilitate a series of aerobic transformations of organic materials, serving as an important solution. The outcome is a stable product known as compost. Composting offers numerous benefits for the environment. It decreases the volume of waste sent to landfills, mitigates the unpleasant odours associated with the anaerobic decomposition of organic materials, lowers methane emissions, and converts organic waste into high-quality soil amendments that are nutrient-rich. Incorporating compost into soil enhances its structure and its physical, chemical, and biological properties [2, 9].

Furthermore, it could enhance carbon sequestration and bolster soil fertility. Composting contributes to sustainable agricultural practices and enhances long-term food security by promoting nutrient recycling and decreasing reliance on synthetic fertilisers and is an excellent foundation for the circular economy, which is the desired framework. The two main types of composting are aerobic and anaerobic composting. For successful aerobic composting, the most common form of composting, the presence of oxygen is essential. Anaerobic composting is frequently employed to decompose food waste due to its lack of oxygen requirement. Compost enhances crop yields by integrating organic matter and nutrients into the soil, decreasing the necessity for artificial fertilisers [10, 11].

Moreover, it may reduce the necessity for water: compost can retain humidity in the soil, thereby decreasing the requirement for irrigation. Furthermore, compost can manage weeds by creating a dense layer of mulch that obstructs sunlight. Compost attracts beneficial insects such as earthworms and ladybirds, enhancing soil health [10, 12].

In light of the crucial role composting plays in mitigating environmental impacts, enhancing soil health, and supporting sustainable agriculture, improving the quality and efficiency of compost production remains a priority. Various additives, including microbial agents and organic substrates, have been explored to accelerate decomposition and enrich compost nutrient content. However, limited studies have comprehensively compared the effects of biologically active additives on compost quality under controlled conditions. This study aims to evaluate the impact of selected additives—Bio Kompost (a biological accelerator), beer, yeast, and *Pleurotus* fungi—on the physico-chemical properties of compost over a 45-day period. The investigation focuses on key parameters, including pH, total nitrogen, phosphorus, potassium, organic matter, and humidity content. By identifying how these additives affect nutrient dynamics and organic matter decomposition, the study aims to propose practical strategies for improving compost quality and promoting environmentally sound waste management practices.

2. Materials and Methods

2.1. Materials

In this study, particular materials and solutions essentials for the composting process and for characterizing the samples, were used. The materials used was Bio Kompost (produced in Slovakia) and yeast solution, beer and fresh *Pleurotus* fungi. For the composition of compost we used grass, dried leaves, different types of vegetables and small pieces of tree and shrub waste.

2.1.1. Bio Kompost solution

A biological accelerator for composting, Bio Kompost, has been prepared to stimulate the biological process of decomposition of organic materials in compost samples. This solution, was prepared by dissolving 25 g of Bio Kompost in 3000 mL of distilled water. The preparation involves intensive stirring of the mixture until the solid is completely dissolved, ensuring uniform distribution of the active compounds in the solution. The role of this solution is to significantly increase the microbiological activity in the sample composition, leading to a more efficient and faster composting process.

2.1.2. Yeast solution

A yeast solution was used in the experiment to incorporate beneficial microorganisms into the composting process. The preparation involved dissolving 25 g of yeast in 3000 mL of distilled water. The solution was stirred thoroughly until fully dissolved, producing a uniform liquid that facilitated the even distribution of yeast within the composted materials. The yeast facilitated the decomposition of organic matter through fermentation, thereby creating favourable conditions for the proliferation of aerobic and anaerobic microorganisms that play a role in the composting process.

2.1.3. Preparation of compost samples

In this study, 11 compost samples were prepared, each featuring a defined composition and standardised material ratio (Table 1). The samples were prepared using a ratio of 3:1, comprising the following components:

- Grass is a significant nitrogen source, which is crucial for microbiological activity. Dried leaves contribute a significant carbon content, which is essential for balancing the carbon to nitrogen (C/N) ratio in the composting process. Various types of vegetable waste, including plant remnants, vegetable scraps, and other organic materials that are easily biodegradable.
- Tree and shrub waste is processed into smaller fragments to enhance decomposition. The materials create a porous structure within the compost, facilitating aeration.

Table 1.

Samples composition

Sample	Compostion
K1	Ratio 3:1 + 1 mL bio kompost
K2	Ratio 3:1 + 2 mL bio kompost
K3	Ratio 3:1 + 3 mL bio kompost
K4	Ratio 3:1 + 4 mL bio kompost
K5	Ratio 3:1 + 5 mL bio kompost
K6	Ratio 3:1 + 6 mL bio kompost
K7	Ratio 3:1 + 6 mL beer
K8	Ratio 3:1 + 6 g Pleurotus fungi

K9	Ratio 3:1 + 6 mL yeast solution
K10	Ratio 3:1 + 3 g Pleurotus fungi + 3 mL beer
K11	Ratio 3:1 + 3 mL beer + 3 mL yeast solution

The samples were monitored in a controlled environment with regulated light, humidity, and temperature for a duration of 45 days.

2.2. Methods

2.2.1. Determination of pH in aqueous suspension soil:water ratio (1:10)

The determination of pH in an aqueous soil suspension, with a soil-to-water ratio of 1:10, involves measuring the soil's acidity or alkalinity. This is achieved by creating a suspension that consists of one part soil mixed with ten parts distilled water [13, 16].

2.2.2. Determination of total nitrogen (N)

Determining total nitrogen (N) is a process that involves the quantitative assessment of the overall nitrogen content in soil samples. Therefore, understanding and determining total nitrogen is essential for evaluating soil fertility, understanding plant nutritional status, and conducting environmental monitoring [17, 18].

2.2.3. Determination of total phosphorus (P)

Determining total phosphorus (P) involves quantifying the complete amount of phosphorus found in samples, encompassing its organic and inorganic forms [17].

2.2.4. Determination of total potassium (K)

The assessment of total potassium (K) content entails quantifying the entire amount present, including water-soluble, exchangeable, and mineral-bound forms. This analysis provides a comprehensive overview of potassium levels within samples, ensuring a detailed understanding of their complete potassium composition [17, 18].

2.2.5. Determination of organic matter by calcination

Determination of organic matter by calcination refers to estimating the organic matter content in soil samples by heating them at high temperatures (550-600°C). This process involves the combustion of organic material in the sample, leaving only the inorganic residue behind [8, 15].

2.2.6. Determining humidity at 105°C

For humidity determination the compost samples were introduced and dried at 105°C in an laboratory oven. This method determines the water content in the sample by expressing it as a percentage of its total weight [19, 20-21].

To ensure methodological transparency and reproducibility, Table 1 presents a summary of the physico-chemical parameters analysed in this study, along with the corresponding analytical standards and equipment used during the evaluation process.

Table 1.

Analytical Parameters, Standards, and Equipment Used in Compost Quality Evaluation*

Parameter	Standard Applied	Method Description	Equipment Used
pH (1:10 soil:water suspension)	PS-03 Ed. 3; Rev. 1 (Romania)	pH determined in aqueous suspension (1:10 soil:water) using a calibrated pH meter	Mettler Toledo SevenCompact S220 pH meter
Total Nitrogen (N)	PS-08 Ed. 3; Rev. 1	Kjeldahl digestion followed by distillation and titration	Kjeltec™ 8200 Auto Distillation Unit (Foss)
Total Phosphorus (P)	PS-06 Ed. 3; Rev. 1	Acid digestion followed by colorimetric determination using the molybdenum blue method	UV-Vis Spectrophotometer (Thermo Scientific GENESYS)
Total Potassium (K)	SR 11411-2:1998 PS-02	Acid digestion followed by flame photometric analysis	Jenway PFP7 Flame Photometer
Organic Matter (by calcination)	PL-01 (Romanian National Standard)	Loss on ignition (LOI) method at 550°C in a muffle furnace	Nabertherm B180 Muffle Furnace
Humidity at 105°C	PS-05 Ed. 3; Rev. 2	Gravimetric method: drying sample at 105°C to constant weight	Memmert UF75 Universal Laboratory Oven

*All analyses were conducted at the **"OSPA-USAMVBT" Laboratory**, Timisoara, Romania, which is accredited and follows strict quality assurance protocols. Equipment was calibrated before each set of measurements in accordance with the manufacturer's specifications and internal lab quality control procedures.

3. Results and discussions

Physico-chemical analyses were conducted following established quality standards at Laboratory of Physico-Chemical Analysis "OSPA-USAMVBT" in Timisoara, Romania. pH was determined according to standard PS-03 Ed 3; Rev 1, total nitrogen (N) was assessed based on standard PS-08 Ed 3; Rev 1, total phosphorus (P) was measured using standard PS-06 Ed 3; Rev 1, and total potassium (K) was evaluated following standard SR 11411-2:1998 PS-02. Organic matter was assessed through calcination by standard PL-01, while humidity content was determined at 105°C using standard PS-05 Ed 3; Rev 2. Analyses confirm validity and reproducibility of data obtained.

3.1. Determination of pH in aqueous suspension soil:water ratio (1:10)

As it can be observed in Fig. 1, the values of samples (K1–K6) stayed in a slight range (9.05–9.17), which suggests that the Bio Kompost additive does not have a significant effect on the pH of the compost. By adding 6 mL of beer resulted in the K7 sample achieving a pH value of 9.15, significantly higher than most other samples.

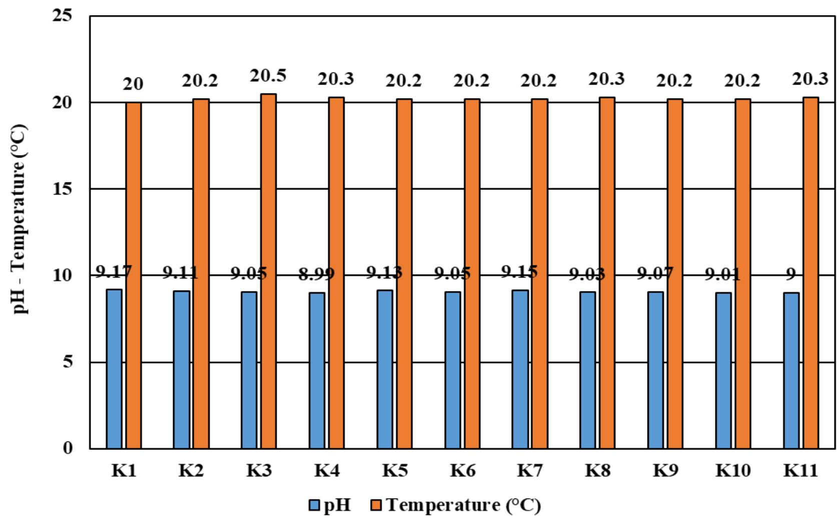

Fig. 1. Determination of pH in aqueous suspension soil:water ration (1:10)

It may be because beer fermentation byproducts or other compounds affect compost pH. Adding Pleurotus fungi to sample K8 caused a slight pH decrease to 9.03, suggesting that fungal metabolic activity influences the composting environment. pH for yeast sample K9 was measured at 9.07, a higher value than K8, possibly reflecting differences in metabolic contributions between yeast and fungi. A pH of 9.07 for K10 suggests that the interaction between fungi and beer stabilized pH, similar to samples with each additive separately. Sample K11 showed one of the lowest pH values at 9.00, potentially indicating interactions among additives that reduce alkalinity.

3.2. Determination of total nitrogen (N)

In Fig. 2 are presented the results regarding the total nitrogen content of the samples. Reduced nitrogen levels in K2 (1.74%) and K5 (1.88%) suggest that stabilization is influenced by additional factors such as microbial activity, material composition, or storage conditions. Sample K6 contains the highest nitrogen level at 2.62%, indicating that increased Bio Kompost concentration may enhance nitrogen retention or minimize losses during composting. Sample K7, with a nitrogen content of 2.11%, suggests that beer addition could introduce nitrogen compounds or stimulate microbial activity, contributing to nitrogen preservation.

Sample K8 showed the highest nitrogen content at 2.74%, suggesting that Pleurotus fungi enhance retention by more effectively decomposing organic matter.

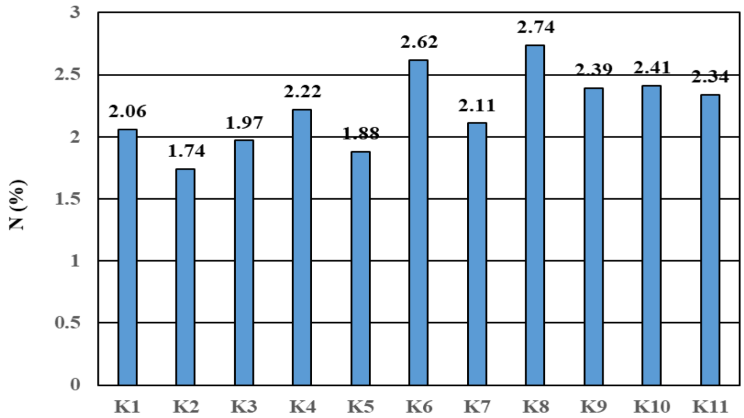

Fig. 2. Total nitrogen content of the samples

Sample K9 has a nitrogen content of 2.39%, higher than most samples, indicating that yeast may contribute to microbial processes enhancing nitrogen stabilization in compost. Sample K10, with a nitrogen content of 2.41%, suggests a potential interaction between fungi and beer in nitrogen preservation. Sample K11 contains 2.34% nitrogen, a value lower than K10 but still above the median range, demonstrating effective nitrogen retention.

3.3. Determination of total phosphorus (P)

The P content in these samples exhibits minor variation, ranging from (3.49%) K3 to (4.44%) K6 (Fig. 3).

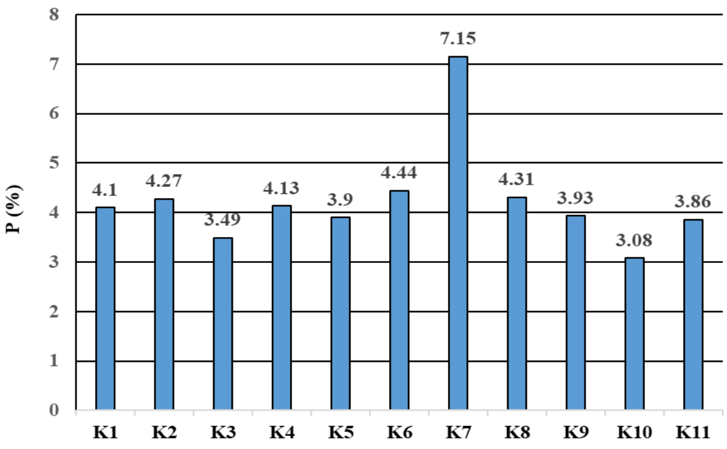

Fig. 3. Total phosphorus content of the samples

Sample K7 contains the highest phosphorus content at 7.15%, exceeding all other samples. This substantial increase suggests that beer may enhance phosphorus absorption in organic matter, potentially due to fermentation accelerating the decomposition process. K8 has a phosphorus content of 4.31%, indicating a moderately high level of this nutrient. This finding suggests that fungi contribute to phosphorus mobilization, improving its bioavailability. K9 contains 3.93% phosphorus, a lower value than K8, implying that while yeast plays a role in microbial activity, its effect on phosphorus mobilization appears weaker than that of beer or fungi. The phosphorus content in K10 is 3.08%, the lowest among all analyzed samples, suggesting that the interaction between fungi and beer did not enhance phosphorus availability. K11 contains 3.86% phosphorus, a higher value than K10 but lower than in other samples, indicating that this combination may not significantly impact phosphorus levels.

3.4. Determination of total potassium (K)

As it can be seen in Fig. 4, lower concentrations of Bio Kompost (K5 with 2.69%) lead to decreased potassium levels compared to K6 (3.91%). The potassium concentration in K7 is the lowest of all samples, measured at 1.35%.

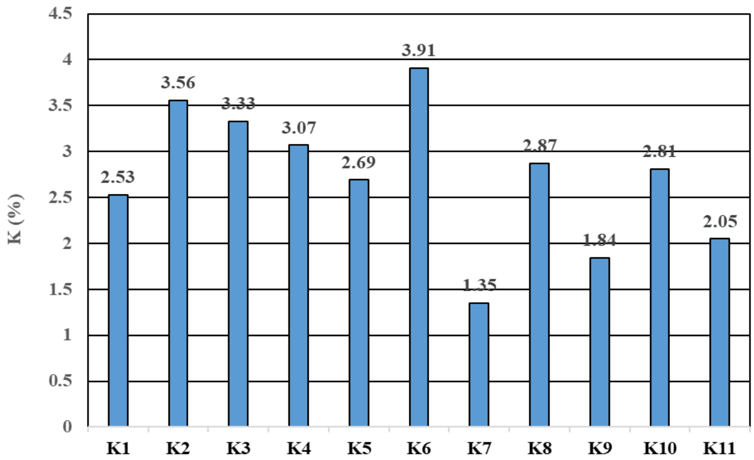

Fig. 4. Determination of total potassium (K)

Findings suggest that beer alone may not effectively mobilize potassium in compost due to its specific composition or a lack of potassium-rich components. K8 contains 2.87% potassium, a moderately higher value than K7, indicating that Pleurotus fungi contributes to organic matter decomposition, promoting potassium release. K9 holds 1.84% potassium, exceeding K7 yet remaining lower than most other samples. K10, with 2.81% potassium, shows a slight increase compared to K8 and K9, suggesting an interaction between fungi and beer that aids potassium release. K11 contains 2.05% potassium, a higher value than K7 and K9 but still significantly lower than samples with Bio Kompost.

3.5. Determination of organic matter by calcination

The findings show that the different levels of Bio Kompost (K1-K6) help keep organic matter in the soil longer and may speed up decomposition (Fig. 5). The organic matter content in K7 is 60.7%.

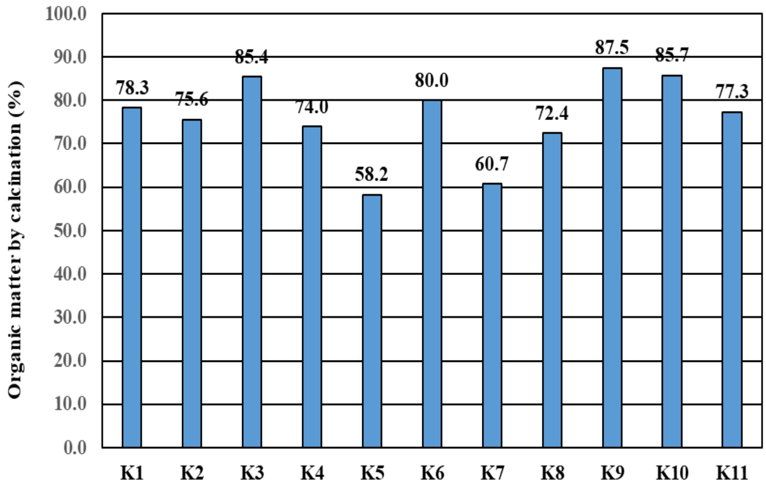

Fig. 5. Organic matter by calcination

Findings suggest that beer accelerates organic matter decomposition, advancing the composting process. K8 contains 72.41% organic matter, demonstrating the fungi's ability to break down material efficiently. K9 holds the highest organic matter content at 87.45%, indicating that yeast enhances microbial activity while maintaining material integrity in compost. K10, with 85.72% organic matter, shows a notably high level, suggesting an interaction between additives that aids in preservation. K11 contains 77.31% organic matter, a moderately high value but lower than K10, implying that the combination of beer and yeast is less effective at preserving organic matter than the pairing of Pleurotus fungi and beer.

3.6. Determining humidity at 105°C

The humidity levels observed in these samples vary from 9.41% for sample K4 to 11.05% for sample K6 (Fig. 6).

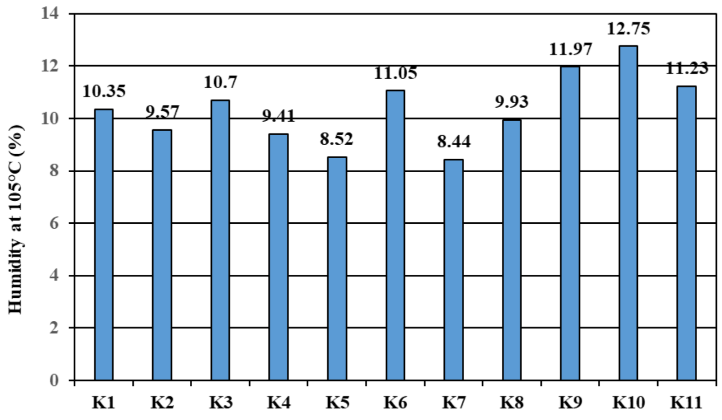

Fig. 6. Humidity at 105°C

An increase in humidity content alongside higher Bio Kompost concentrations suggests that the additive may retain water or stimulate microbial activity, leading to water production as a byproduct. K7 contains the lowest humidity at 8.44%, implying that beer accelerates decomposition and reduces water retention, resulting in drier compost. K8 holds 9.93% humidity, a higher value than K7, indicating that fungi contribute to moisture retention during organic matter breakdown. K9 exhibits a significant humidity level of 11.97%, suggesting that yeast enhances microbial activity, potentially increasing water production as decomposition progresses. K10 shows the highest humidity content at 12.75%, pointing to a combined effect of fungi and beer in promoting microbial activity and moisture retention. K11 contains 11.23% humidity, slightly lower than K10 yet still elevated, highlighting the influence of both additives on water retention.

Among the tested formulations, Sample K8—which contains *Pleurotus* fungi as the primary additive—emerged as the most suitable mixture for producing high-quality compost under real-world conditions. K8 demonstrated the highest nitrogen content (2.74%), moderate to high phosphorus (4.31%) and potassium (2.87%) levels, substantial organic matter content (72.41%), and balanced moisture (9.93%), indicating its strong potential to retain essential nutrients, support microbial activity, and facilitate organic matter decomposition. Furthermore, its slightly lower pH (9.03) compared to other samples may contribute to better nutrient stability and bioavailability, enhancing its agronomic value.

Comparatively, yeast-based Sample K9 achieved the highest organic matter content (87.45%) and significant humidity retention (11.97%), reflecting its effectiveness in promoting microbial growth and maintaining compost structure. However, it showed lower phosphorus (3.93%) and potassium (1.84%) levels, which may limit its standalone use for nutrient-demanding applications. Bio Kompost at higher concentrations (e.g., K6) also performed well, especially in enhancing nitrogen (2.62%) and phosphorus (4.44%) levels; however, it fell short in preserving organic matter compared to fungal or yeast additives.

Interestingly, the combination of *Pleurotus* fungi and beer in Sample K10 yielded synergistic benefits, including high organic matter content (85.72%) and the highest humidity (12.75%), suggesting a robust microbial environment. However, it showed reduced phosphorus (3.08%) and moderate potassium (2.81%) values, positioning it as effective for compost structure improvement but less optimal for phosphorus enrichment.

Additionally, the study monitored heavy metal concentrations in all compost samples to ensure environmental safety. All values were found to be within the permissible limits set by applicable ecological and agricultural standards, confirming that none of the additives—whether microbial, fungal, or fermentation-derived—introduced hazardous contaminants into the final product. This confirms the environmental viability of the proposed mixtures for land application, particularly in agricultural or horticultural settings.

In conclusion, while each additive offers distinct advantages, Sample K8 with *Pleurotus* fungi represents the most balanced and effective option for enhancing compost quality across key parameters. These findings provide actionable guidance for practitioners and policymakers seeking to implement sustainable composting strategies that improve soil fertility, reduce reliance on chemical fertilisers, and safely recycle organic waste.

4. Conclusions

This study demonstrates that the choice of additive has a significant influence on compost quality, nutrient retention, and overall decomposition dynamics. Among the tested additives, Bio Kompost, when applied at higher concentrations, substantially improved the retention of essential nutrients—namely nitrogen, phosphorus, and potassium—highlighting its potential as a reliable enhancer for nutrient-rich compost. Beer contributed notably to phosphorus mobilisation but was less effective in preserving nitrogen and organic matter, suggesting its utility may lie in targeted nutrient adjustments rather than holistic compost improvement.

Pleurotus fungi demonstrated strong performance in decomposing organic matter while maintaining high levels of nitrogen and potassium, making them a suitable additive for accelerating degradation and improving nutrient availability. Yeast-enhanced microbial activity yielded the highest organic matter content and optimal moisture retention, supporting a well-balanced composting environment conducive to microbial stability.

Notably, the combination of *Pleurotus* fungi and beer produced synergistic effects, enhancing both organic matter preservation and water retention, two crucial factors for sustaining microbial activity and maintaining long-term compost quality. These findings highlight the importance of selecting and integrating suitable additives based on the desired composting outcomes.

Ultimately, this study provides valuable insights for optimising composting strategies, promoting sustainable waste management, and improving soil fertility through safe and effective organic amendments.

In addition to nutrient analysis, future studies will also consider the presence of heavy metals, which should also be monitored to assess potential environmental risks. The heavy metal concentrations should be compared to relevant ecological standards to determine whether the proposed composting approaches are not only effective in enhancing nutrient profiles but also safe for agricultural application and long-term soil health.

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