Transactions on Environment, Energy and Earth Sciences
ISSN: 2960-1924, eISSN: 2960-2300 | Volume 7
GTREE 2026

Microbiological Mechanisms of Bokashi Composting from Fermentation to Soil Ecological Effects

Tiange Hao *

Dalian Royal School, Dalian, China

* Corresponding Author Email: tiago.hao.tg@student.dalianroyalschool.com

Abstract. Bokashi composting is a small-scale anaerobic fermentation technology that uses Effective Microorganisms (EM) to treat organic waste. This paper will systematically study the microbial mechanisms of Bokashi from fermentation to soil application. Lactic acid bacteria are the most numerous organisms in the community during fermentation, and they produce organic acids. Therefore, a self-limiting acidic environment is generated to inhibit pathogens and putrefactive organisms. A low Substrate Carbon-to-Nitrogen Ratio is also a reason for low-efficiency or poor-quality fermentation. Bokashi is aerobically aged a second time after soil incorporation to improve soil structure and water-holding capacity, reduce compaction, and supply nutrients for plants. In addition, the bioactive substances and organic acids produced in fermentation are generally antimicrobial and therefore meet the conditions for biosafety and crop growth. However, the functional advantages of EM inoculation over indigenous microbiota and the mechanistic connections between community structure and ecological function have not been fully revealed. Provide a theoretical basis for standardising household Bokashi protocols and promoting urban organic waste utilisation in this review.

Keywords: Bokashi; Effective Microorganisms; Lactic acid fermentation; Soil amendment; Organic waste.

1. Introduction

An increase in the amount of organic waste from urban areas has become a problem for municipal management systems around the world; landfills produce considerable amounts of methane and pollute groundwater, thereby disrupting the urban biogeochemical cycle of nutrients permanently [1]. With the development of cities and changes in people's lives, the amount of food waste has been rising steadily; therefore, small-scale, decentralized treatment facilities that can operate in homes are urgently needed.

Aerobic composting is the traditional type of recycling; it needs a large area, regular aeration and a long-term maturation period, so it is not convenient for many households [2]. Continuous rotation and fine control of the carbon-to-nitrogen ratio are also needed; thus, it is not suitable for densely populated urban apartments due to odour control problems and space limitations.

Bokashi composting is a small-scale way that uses Effective Microorganisms (EM), a group of lactic acid bacteria, yeasts, photosynthetic bacteria and actinomycetes, to ferment organic matter in a sealed, mesophilic environment [3]. Glycolysis and lactic acid fermentation are used to quickly lower the pH of the substrate to 3.0-4.0, inhibiting pathogens and putrefactive organisms, and preserving nutrients in a partially decomposed solid residue and acidic leachate [3]. Fermentation is not used to reduce mineralisation in this way; after soil application, native aerobic microorganisms break down recalcitrant substances to produce humic substances that improve soil structure, water-holding capacity and nutrient supply by raising the pH [1].

Although Bokashi adoption is growing, the metabolic interactions within EM consortia, temporal dynamics of community succession, and mechanistic pathways of soil ecological effects remain poorly synthesized. Integrate current knowledge of the core metabolic pathway, physicochemical regulation during fermentation and post-incorporation soil modification to build a unified mechanistic

Content from this work may be used under the terms of CC BY-NC 4.0 licence (https://creativecommons.org/licenses/by-nc/4.0/).
Published by Warwick Evans Publishing.

framework, and point out unresolved controversies such as inoculation efficacy [4] and environmental impact [1] to guide future research and standardised household practice.

2. Microbial Inoculant and Core Metabolic Pathways

2.1. EM Consortium Composition and Synergistic Interactions

EM is a functional cooperative group of lactic acid bacteria (LAB), yeasts, photosynthetic bacteria and actinomycetes [5]. Higa and Parr (1994) proposed that this taxonomic diversity provides support for systematic niche complementarity: photosynthetic bacteria produce amino acids and sugars from organic substrates, which LAB and yeasts then metabolize into lactic acid and ethanol, thus acidifying the environment and inhibiting pathogens [5]. Field validation in a temperate climate shows that these cross-feeding interactions increase substrate stabilisation compared with indigenous microbiota alone [6]. In agricultural-waste Bokashi systems, this synergy is further realised by actinomycetes-mediated decomposition of fibrous residues and LAB-driven acidification to achieve complete pre-digestion before soil incorporation [7].

2.2. Central Metabolic Pathways and Carrier-Mediated Delivery

The two main paths for the biochemical transformation of organic matter in Bokashi are the Embden-Meyerhof-Parnas (EMP) glycolytic pathway and the phosphoketolase (PK) pathway [8]. Homofermentative LAB mainly channel hexoses to pyruvate via EMP and produce almost exclusively lactic acid; heterofermentative species generate a mixed-acid profile of lactate, ethanol and acetate through PK, thus diversifying the inhibitory organic-acid spectrum [8]. Efficiently transport these metabolic products to the substrate via carrier formulation; wheat bran is a porous, carbon-rich matrix that protects living cells during storage and can be rapidly restored upon contact with moist food waste [7]. Carrier-mediated inoculum preparation connects the laboratory-scale metabolic potential with actual household fermentation results under the EM framework [5].

3. Physicochemical Regulation and Microbial Community Succession during Fermentation

3.1. Physicochemical Parameters and Microbial Community Composition

Bokashi composting fermentation is, in fact, a type of facultative anaerobic fermentation promoted by EM, and changes in physicochemical parameters are closely linked to alterations in the microbial community. At the level of physicochemical properties, the three main characteristics are a continuous decrease in pH, a drop in oxidation-reduction potential (ORP), and the maintenance of a mesophilic (ambient) temperature. Systematic research on microbial diversity and functional potential at different times during household-scale Bokashi composting was conducted using 16S rRNA amplicon sequencing and shotgun metagenomic sequencing [9]. The study found the main physicochemical and biological features of the fermentation process: all Bokashi leachates were acidic, with pH values between 3.7 and 4.9, and contained a large number of organic acids, among which lactate was the main acid (14-19 mM), followed by acetate (9-14 mM), propionate (1.5-2.5 mM), and butyrate (>5 mM) [9]. Accumulation of multiple organic acids causes a continuous decrease in pH, resulting in a highly acidic environment; at a certain concentration of organic acids, the metabolic activity of most microorganisms is inhibited, and thus the fermentation process self-limits and stabilizes. At the same time, the acidic environment will not promote the growth of pathogens; metagenomic analysis showed very low levels of potential pathogens in Bokashi [9].

At the level of microbial communities, actively fermenting Bokashi communities were shown to be dominated by the phylum Firmicutes, with relative abundances ranging from 50% to 99%, and among these, Lentilactobacillus accounted for 20% to 60% of the relative abundance in most household samples [9]. The community succession showed a clear temporal pattern: at the initial stage, facultative anaerobes rapidly proliferated from the EM inoculum; in the mid-phase, lactic acid

bacteria became the dominant group and produced organic acids; and in the late stage, due to a drop in pH to an extremely low level, the microbial community simplified, and only acid-tolerant taxa survived [9]. Some metabolic pathways for the production of organic acids have also been identified in the study, and lactic acid fermentation has been confirmed as a required link in the metabolic network of Bokashi [9].

3.2. Influence of Substrate Composition on Fermentation Efficiency

The chemical composition of the substrate can also affect the formation of microbial communities and fermentation efficiency to some extent; for example, a high carbon-to-nitrogen (C/N) ratio and a large proportion of protein or carbohydrate may occur. A completely randomised design was used to study the effects of different C/N ratios (30, 70 and 110) of organic raw materials at various fermentation times (10, 17 and 24 days) on Bokashi quality [10]. Key results show that the highest total colony count (TCC) (1.44×10^{11} CFU/g) was obtained from raw materials with a C/N ratio of 70; thus, this C/N level is most favourable for microbial proliferation. Raw materials with C/N ratios between 30 and 70 produced high-quality Bokashi after 10 days of fermentation, and their final C/N ratios fell within the desired range for soil, 10-20; however, materials with a C/N ratio of 110 took 24 days to decompose sufficiently [10]. In addition, during the 10-day fermentation, the pH continuously increased; at the same time, the temperature first rose and then started to fall after day 8.

Notably, although the final C/N ratio of Bokashi was lower than that of the initial raw materials, a fermentation period of 10 days was still not long enough to fully decompose the organic matter in the raw materials with an initial C/N of 150 [10]. Microbial communities also change naturally during composting, and the rise and fall of TCC are closely associated with alterations in nutrient availability and the suitability of different microbial groups [10]. As shown in the above results, alterations in the substrate C/N ratio directly affect the structure and function of microbial communities, thus changing fermentation efficiency and the quality of the final product.

4. Soil Ecological Effects of Bokashi Products

4.1. Characteristics of Bokashi Outputs and Their Effects on Soil Physicochemical Properties

The end products of Bokashi fermentation are a solid residue (fermented organic matter) and a liquid leachate that is collected during the process. Both outputs have a low pH (around 3.0-4.0) and a high concentration of organic acids, such as lactic and acetic acid; only a small fraction of the solids have been decomposed [9]. When these materials are added to the soil, a secondary aerobic maturation process occurs: soil actinomycetes and fungi further decompose the recalcitrant organic matter, and as a result, accumulated organic acids are gradually mineralised, causing the soil pH to return to a near-neutral state.

Many studies have shown that Bokashi additions can improve the physical properties of the soil to some extent. For example, organic amendments such as bokashi have reduced the bulk density of sandy agricultural soils by as much as 9.8%, increased aggregate stability by as much as 60.0%, and improved water-holding capacity by as much as 77.8% [11]. Similar improvements in porosity and aggregation have been reported; thus, bokashi application can help alleviate soil compaction and increase the water-holding capacity of the soil. Bokashi can also provide some essential nutrients (N, P, K, Ca and Mg) and increase the amount of available phosphorus and exchangeable cations; however, the exact amount depends on the composition of the feedstock and the application rate [11].

4.2. Effects on Soil Microbiome, Enzyme Activities, and Plant Growth

The changes in the soil microbial community after bokashi application are not uniform. Metagenomic analysis has revealed that although bokashi leachate or fermented solids supply nutrients and organic acids that can promote plant growth, they do not necessarily lead to a prolonged alteration in the

general structure of the soil microbial community [9]. However, the same study also found a very low level of potential human pathogens in properly fermented bokashi and verified that the acidic environment produced by lactic acid fermentation is effective against harmful microorganisms [9]. Organic acids in the leachate of bokashi are also known to have broad-spectrum antibacterial properties and thus promote the biosafety of the final product.

Plant growth promotion has been confirmed by both field and pot experiments. For example, a full-field study in a temperate climate examined the effect of EM-based bokashi on crop growth and found that the yield of several vegetable crops, such as tomatoes and onions, was significantly higher than that of unamended controls [6]. Many species have shown an increase in germination rate, stronger seedlings, and a larger quantity of shoots and roots. The reasons for the above effects include improving the physical environment of the soil, increasing nutrient availability and promoting root growth through the production of bioactive substances during fermentation [6]. Additionally, the transient enrichment of plant-growth-promoting rhizobacteria (PGPR) in the rhizosphere has been proposed as another mechanism, but the evidence is still limited and requires further research [9].

In short, bokashi products are good for the soil-plant system because they improve the structure and water-holding capacity of the soil, provide necessary nutrients, inhibit pathogens by releasing organic acids, and promote plant growth. The above attributes are suitable for Bokashi to serve as a method of long-term, small-scale organic waste recycling under favourable fermentation conditions.

5. Conclusion

Bokashi composting is a good microbial strategy for decentralised organic waste treatment that uses lactic-acid-dominant fermentation to rapidly acidify the substrate, inhibit pathogens, and retain nutrients. Community succession leads to a dominance of Firmicutes and changes the C/N ratio of fermentation. Soil application can improve the physical qualities and nutrient availability of plants, and an acidic environment is bio-safe. However, the comparative advantage of EM inoculation over native microbes has not been identified, and the way in which community structure affects function is unknown. Standardise household protocols and conduct extended ecological assessments to fully realise the potential of Bokashi in urban waste utilisation.

References

[1] Hillberg, K. (2020). Bokashi – kitchen waste treatment without greenhouse gas emissions? (Master's thesis). Swedish University of Agricultural Sciences, Department of Soil and Environment, Uppsala.

[2] Fan, Y. V., Lee, C. T., Klemeš, J. J., Chua, L. S., Sarmidi, M. R., & Leow, C. W. (2018). Evaluation of Effective Microorganisms on home scale organic waste composting. Journal of Environmental Management, 216, 41-48.

[3] Higa, T., & Wididana, G. N. (1991). The concept and theories of effective microorganisms. In J. F. Parr, S. B. Hornick, & C. E. Whitman (Eds.), Proceedings of the First International Conference on Kyusei Nature Farming (pp. 118-124). Washington, DC: USDA.

[4] Formowitz, B., Elango, F., Okumoto, S., Müller, T.,&Buerkert, A.(2007) The role of "effective microorganisms" in the composting of banana (Musa ssp) residues. Journal of Plant Nutrition and Soil Science, 170(5), 649-656.

[5] Higa, T., & Parr, J. F. (1994). Beneficial and Effective Microorganisms for a Sustainable Agriculture and Environment. International Nature Farming Research Center, Atami.

[6] Mayer, J., Scheid, S., Widmer, F., Fliessbach, A., & Oberholzer, H.-R. (2010). How effective are 'Effective microorganisms(EM) Results from a field study in temperate climate. Applied Soil Ecology, 46(2), 230–239.

[7] Fall, M., Gueye, N., Mbaye, A., Sene, A. D., & Ndiaye, P. A. (2026). Valorization of agricultural waste through Bokashi production: A review. Journal of Applied Life Sciences International, 29(1), 1-16.

[8] Abedi, E., & Hashemi, S. M. B. (2020). Lactic acid production-producing microorganisms and substrates sources-state of art. Heliyon, 6(10), e04974.

[9] Kujala, K., & Kinnunen, V. (2025). Lactic acid bacteria dominate urban Bokashi: A culture-independent study of microbial diversity and functional potential in household-scale food waste fermentation. bioRxiv, 2025.10.16.682835.

[10] Irfan, I., Yunita, D., & Fauzan, F. (2023). Effect of raw materials C/N ratio on the quality of Bokashi. International Journal of Recycling of Organic Waste in Agriculture, 13(1).

[11] Kok, D.-J. D., Scherer, L., de Vries, W., & van Bodegom, P. M. (2023). Temporal variability in organic amendment impacts on hydro-physical properties of sandy agricultural soils. Soil Science Society of America Journal, 87(4), 963-984.