

The Potentials and Implementations of Biocompost in Malaysia: A Comprehensive Review

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Abstract

Bio-composting represents an eco-friendly and sustainable approach to recycling organic waste into nutrient-rich compost enriched with beneficial microorganisms. This review elucidates the definition, essential materials, processes, and emerging technologies associated with bio-composting. Moreover, it examines its implementation and the potential benefits within the Malaysian context, where sustainable waste management remains a critical challenge. Defined as a controlled aerobic decomposition of organic matter by microorganisms, bio-composting transforms waste into a stable, humus-like substance that serves as a valuable soil amendment. In particular, Malaysia—being the world's second-largest palm oil producer—generates substantial organic waste, including palm oil mill effluent and agricultural byproducts, which are highly suitable for bio-composting. This method not only mitigates the environmental burden but also supports the agricultural sector by enhancing soil fertility. The process encompasses key steps such as selecting appropriate feedstocks, regulating moisture and aeration, and maintaining optimal temperature and pH levels. Effective control of these parameters is essential for efficient composting. Consequently, bio-composting emerges as a viable and sustainable alternative to conventional waste disposal practices in developing nations.

Key Words: *Biocompost, Organic Waste, Waste Disposals, Biocompost Technologies*

1. Introduction

Given the increasing demand for efficient waste disposal methods and rising environmental concerns, biocomposting has emerged as a globally recognized sustainable waste management solution, as it converts organic waste into nutrient-rich compost through biological processes (Awasthi et al., 2020). Particularly in Malaysia, rapid urbanization and industrialization have led to a substantial increase in organic waste generation, underscoring the critical need to implement effective biocomposting strategies. This study provides a comprehensive examination of biocomposting, including its fundamental principles, the types of organic materials used, the technologies and methodologies employed, and its practical applications within the Malaysian context.

Biocomposting relies on microbial activity to decompose organic waste—such as food scraps, yard waste, and agricultural residues—into a stable, nutrient-dense soil amendment (Azis et al., 2022). Compared to other waste management approaches, composting offers distinct advantages, particularly in developing nations, due to its lower capital and operational costs, reduced technical complexity, and minimal requirement for specialized scientific expertise (Wang et al., 2019a). However, the efficiency of the biocomposting process is influenced by multiple environmental factors, including pH levels, moisture content, aeration, microbial activity, and the carbon-to-nitrogen ratio (Wang et al., 2019a). Beyond reducing the volume and weight of organic waste, composting yields a high-quality end product that enhances soil fertility and structure, thereby contributing to sustainable agricultural practices.

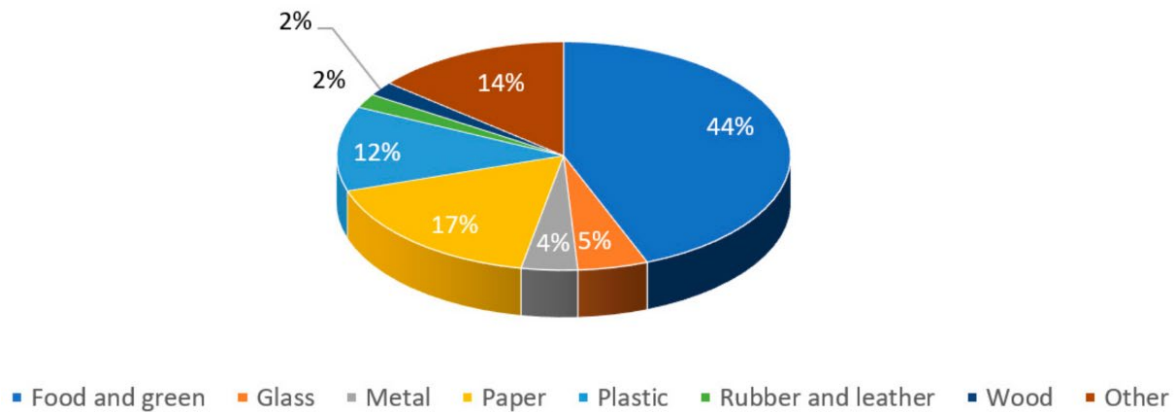


Figure 1: Percentage of global waste composition (Azis et al., 2022)

As illustrated in Figure 1, plastic and microplastics dominate global waste composition in terms of reuse and recycling rates. However, organic waste remains a critical concern, particularly in Malaysia, where it constitutes a significant portion of municipal solid waste (Moh & Abd Manaf, 2017). The efficiency of biocomposting—a sustainable organic waste management solution—is influenced by key environmental parameters, including pH, moisture content, aeration, microbial activity, and the carbon-to-nitrogen ratio (Singh et al., 2020). Unlike conventional waste management approaches that prioritize collection over treatment, biocomposting offers a dual benefit: it not only reduces the volume and weight of organic waste but also converts it into a stable, nutrient-rich amendment that enhances soil fertility and structure. Given Malaysia's pressing waste management challenges, adopting biocomposting could mitigate landfill dependency, transform organic waste into a valuable resource, and reduce the environmental impact of improper waste disposal.

2. Biocompost

Biocompost, produced through the controlled aerobic decomposition of organic waste materials, has gained recognition as a sustainable approach to addressing escalating waste management challenges (Pandit et al., 2020). This process involves the transformation of diverse organic substrates—including agricultural residues, animal manure, and municipal solid waste—into a stabilized, humus-like material (Wang et al., 2019a). Microbial activity plays a pivotal role in this conversion, as microorganisms facilitate the breakdown and mineralization of organic compounds (Ahmad et al., 2007). During composting, metabolic heat generated by diverse microbial communities elevates temperatures, thereby accelerating the decomposition of complex organic matter into simpler, nutrient-dense constituents (Pandit et al., 2020). The resulting biocompost serves as a valuable soil amendment, enriched with essential macronutrients such as nitrogen, phosphorus, and potassium, which are critical for agricultural and horticultural applications (Fawole et al., 2021). Beyond nutrient provision, biocompost enhances soil health by improving its physicochemical properties and fostering beneficial microbial populations, thereby promoting long-term soil fertility and productivity (Gaspar & Doria, 2020).

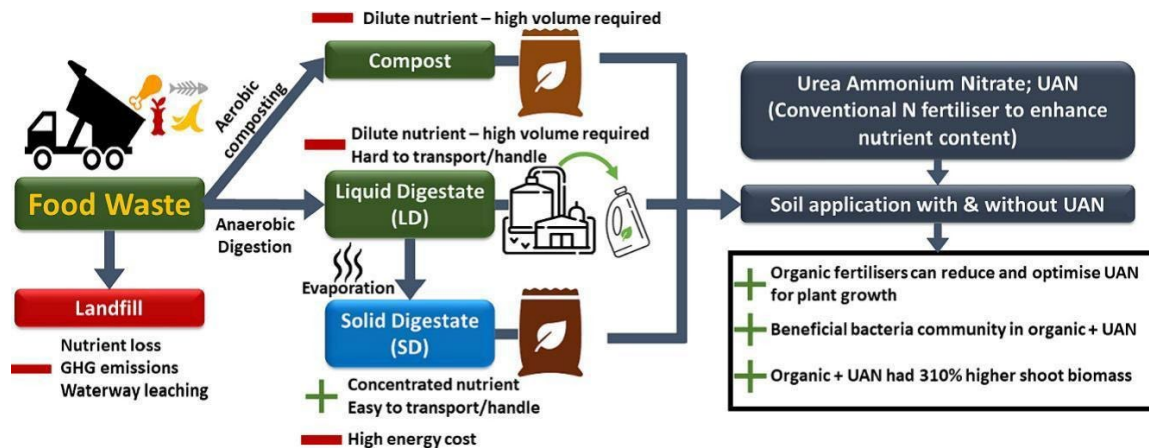


Figure 2: A graphical image of food waste-derived fertilisers (O'Connor et al., 2024)

As illustrated in Figure 2, food waste can be effectively repurposed for fertilizer production through biocomposting. The advantages of biocompost extend well beyond its nutritional contributions to soil. Significantly, this method offers an environmentally preferable alternative to conventional waste disposal by diverting organic matter from landfills and incinerators, thereby reducing greenhouse gas emissions and other negative environmental impacts (Ambasta & Kumari, 2013). Moreover, when combined with vermicomposting techniques - which employ earthworms to enhance the decomposition process - the resulting product demonstrates superior quality, containing elevated levels of nutrients and beneficial microorganisms (Pandit et al., 2020). The scientific principles underlying biocomposting highlight two critical aspects: the importance of sustainable waste management practices and the potential to transform organic waste into valuable soil amendments (Pandit et al., 2020). By harnessing natural decomposition processes and microbial activity, biocompost serves as a key component in both circular economic models and sustainable agricultural systems. This dual functionality simultaneously addresses pressing environmental concerns related to waste accumulation while improving soil health and fertility through ecological means.

2.1 Materials used in Biocomposting

Biocomposting represents an effective biological process that transforms diverse organic substrates into nutrient-dense soil amendments through controlled decomposition. The process strategically utilizes complementary waste streams to optimize the carbon-to-nitrogen ratio essential for microbial activity. Nitrogen-rich green waste components, including grass clippings, fresh leaves, and garden trimmings, are balanced against carbon-dense brown materials such as wood chips, straw, and dried leaves. Furthermore, the system effectively incorporates food waste streams, particularly fruit and vegetable scraps, coffee grounds, and crushed eggshells, which contribute valuable micronutrients and organic matter. Beyond household and garden waste, the methodology demonstrates significant potential for valorizing agricultural byproducts (including crop residues) and industrial organic waste from food processing operations, thereby expanding its applications within circular economy frameworks.



Figure 3: Step-wise small-scale composting with agro-waste (Pratap Singh & Prabha, 2018)

As depicted in Figure 3, the systematic composting of agricultural byproducts involves multiple stages to produce quality organic amendments. The process efficiency fundamentally depends on maintaining an optimal blend of diverse organic materials, as this balance directly affects microbial activity and decomposition rates (O'Connor et al., 2024; Singh et al., 2020). When properly proportioned, these complementary waste streams provide microorganisms with the necessary carbon and nitrogen substrates, along with adequate oxygen and moisture levels, facilitating their metabolic processes. This controlled biological conversion yields a stabilized end-product characterized by neutral odor and minimal pathogen content. Notably, the physicochemical properties of input materials significantly determine the quality parameters of the final compost. Therefore, a thorough comprehension of biocomposting mechanisms - including microbial ecology, biochemical transformations, and process optimization - is imperative for designing effective waste management systems. Such knowledge enables the establishment of composting facilities capable of sustainably processing organic waste streams while adhering to environmental quality standards.

2.2 Process involved in Biocomposting

Biocomposting represents a sustainable organic waste management strategy that systematically transforms biodegradable materials into agriculturally valuable compost through three distinct phases: (1) collection and sorting of feedstock, (2) active decomposition, and (3) maturation (Pandit et al., 2020). This microbially-mediated process harnesses diverse microbial communities, including bacteria and fungi, to facilitate the biological, physical, and chemical conversion of organic substrates into stable, nutrient-dense soil amendments (Wang et al., 2019a). During decomposition, these microorganisms enzymatically break down complex organic compounds through biochemical processes such as mineralization and humification (Ahmad et al., 2007). The resultant high-quality compost not only enhances soil fertility but also addresses critical environmental challenges by diverting organic waste from landfills, thereby reducing methane emissions and promoting circular resource utilization (Gaspar & Doria, 2020). As such, biocomposting serves as a multifaceted solution that simultaneously advances waste valorization, soil health improvement, and sustainable land management practices.



(a)



(b)

Figure 4: (a) A worker doing the biocompost process, (b) A collected food waste

The biocomposting process initiates with the systematic collection and sorting of organic waste to remove contaminants as shown in Figure 4 (a) and Figure 4 (b), followed by mechanical shredding to increase surface area for microbial action. This pretreatment phase is crucial for optimizing subsequent biodegradation, as the shredded waste is then mixed to achieve an optimal carbon-to-nitrogen ratio (25:1 to 30:1), which sustains microbial metabolism. Concurrently, aeration and moisture control (50-60%) are maintained to support aerobic microbial activity, ensuring efficient decomposition through enzymatic hydrolysis and oxidative breakdown. During this active phase, diverse microbial consortia—including bacteria, fungi, and actinomycetes—sequentially degrade organic matter, generating heat, CO₂, and water while mineralizing nutrients into plant-available forms.

The process culminates in the maturation phase, where compost stabilizes through biochemical humification and pathogen suppression, resulting in a phytotoxin-free, nutrient-dense product. Temperature dynamics play a critical regulatory role, progressing from mesophilic to thermophilic (50–70°C) stages, which enhance decomposition efficiency while sanitizing the substrate. Ultimately, this hierarchically structured process—governed by physicochemical and microbiological interactions—transforms organic waste into a valuable soil amendment, offering an economically viable and environmentally sustainable waste management solution, particularly in developing nations due to its low technical complexity and operational costs.

3. Technologies in Biocomposting

Biocomposting has emerged as a cornerstone of sustainable waste management, facilitating the conversion of organic waste into nutrient-rich soil amendments through controlled biological decomposition (Pandit et al., 2020). Recent technological advancements have significantly enhanced the efficiency of this process, optimizing parameters such as aeration, moisture control, and microbial activity to accelerate organic matter breakdown (Wang et al., 2019a). The process relies on the synergistic action of diverse microbial communities to mineralize complex organic compounds into bioavailable nutrients, including nitrogen, phosphorus, and micronutrients (Ahmad et al., 2007). As a result, biocomposting not only diverts organic waste from landfills but also produces a stabilized, agriculturally valuable end product (Ambasta & Kumari, 2013). Given its dual benefits—waste reduction and soil enrichment—this method represents a critical strategy in circular bioeconomy frameworks (Gaspar & Doria, 2020).

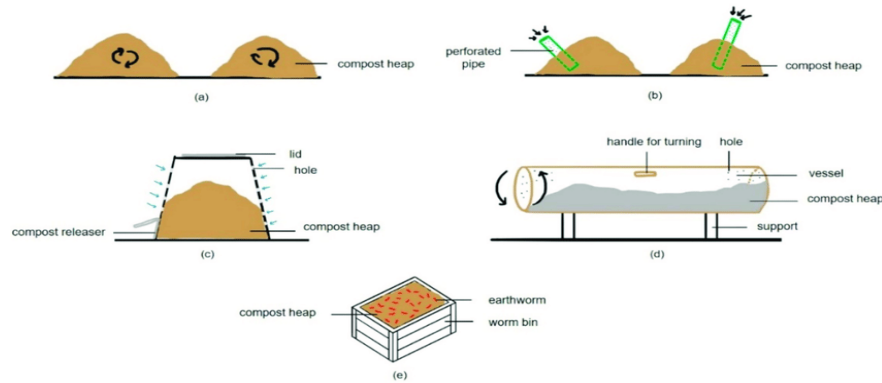


Figure 5: Windrow composting (Azis et al., 2022)

Modern composting technologies employ diverse methodologies to optimize organic waste valorization, with windrow composting emerging as a cost-effective solution for large-scale applications due to its simple infrastructure and periodic mechanical aeration. In contrast, aerated static pile (ASP) systems utilize forced aeration to maintain optimal oxidative conditions, enhancing microbial activity while minimizing operational complexity. For urban environments, in-vessel composting offers superior process control through enclosed bioreactors that regulate temperature, moisture, and aeration, thereby accelerating decomposition while mitigating odor and leachate concerns. Meanwhile, vermicomposting leverages epigeic earthworms as biological accelerants, producing nutrient-rich vermicast through synergistic interactions between detritivores and microbial consortia, which collectively enhance organic matter degradation and soil fertility.

Technological advancements have further refined these systems, with microbial inoculants improving lignocellulose breakdown in ASP and in-vessel systems, while vermicomposting demonstrates dual agronomic and ecological benefits, including soil structure enhancement and microbial population stimulation. These methods—windrow (as illustrated in Figure 5), ASP, in-vessel, and vermicomposting—collectively address varying operational scales and environmental constraints, offering scalable solutions for sustainable waste management. By balancing economic viability with process efficiency, they facilitate organic waste conversion into high-quality soil amendments, supporting circular economy principles in both developed and developing regions.

4. Biocomposting Policies Implementation in Malaysia

Malaysia has strategically positioned biocomposting as a key component of its sustainable waste management framework, implementing targeted initiatives to harness its potential in addressing mounting organic waste challenges (Ministry of Housing and Local Government, 2021). This commitment is operationalized through comprehensive policy instruments, most notably the National Solid Waste Management Policy, which establishes institutional mechanisms for organic waste valorization (Malleshham et al., 2016). Concurrently, the Zero Waste Malaysia initiative provides a multi-stakeholder platform that synergizes governmental, private sector, and community efforts to mainstream biocomposting practices across urban and rural contexts. These coordinated interventions reflect Malaysia's progressive approach to circular economy implementation, where organic waste streams are systematically diverted from landfills and transformed into valuable soil amendments (O'Connor et al., 2024; Singh et al., 2020). The policy framework is further reinforced by capacity-building programs that enhance technical competencies among local authorities and composting entrepreneurs,

ensuring the scalability and long-term viability of biocomposting solutions (Oviedo-Ocaña et al., 2015a, 2015b).



Figure 6: A waste collection and segregation center at a TVET institution

The Malaysian government has implemented strategic policies such as the National Solid Waste Management Policy (Jabatan Pengurusan Sisa Pepejal Negara, 2016) and National Clean Policy (Kementerian Perumahan dan Kerajaan Tempatan, 2019) initiative to promote biocomposting with the establishment of waste collection and segregation centers in the institution (Figure 5), addressing the country's pressing waste management challenges where organic waste constitutes 65-67% of municipal solid waste. Despite these efforts, systemic barriers persist, including low public participation in waste segregation, inadequate infrastructure, and insufficient data for evidence-based policymaking. To overcome these challenges, a multi-stakeholder approach has emerged, combining government-led programs with community-based composting projects and commercial ventures that transform organic waste into agricultural and landscaping products. Educational institutions and NGOs further bolster these initiatives through workshops and training, emphasizing the environmental and economic benefits of composting while building technical capacity among stakeholders. Community-driven composting projects have gained traction in both urban and rural areas, supported by Malaysia's robust food processing sector, which provides significant feedstock potential for large-scale organic waste valorization. However, the success of these initiatives hinges on integrated strategies that include public awareness campaigns, policy reinforcement, and economic incentives to shift perceptions of waste management responsibility. Commercial composting enterprises are increasingly filling a critical niche by processing industrial food waste, while municipal programs expand curbside collection and composting services. Collectively, these efforts—spanning government policy, community action, private sector engagement, and education—aim to reduce landfill dependence, mitigate methane emissions, and create circular economy opportunities, positioning biocomposting as a cornerstone of Malaysia's sustainable waste management future.

5. Biocomposting Challenges and Future Directions in Malaysia

The implementation of biocomposting practices in Malaysia encounters significant barriers, primarily stemming from insufficient public awareness regarding its environmental benefits and limited community engagement (Tan et al., 2022). This challenge emerges within a broader context of escalating solid waste management pressures, characterized by rising waste generation rates and critically constrained landfill capacity (Grima-olmedo et al., 2014). While

community-based composting initiatives demonstrate operational efficacy, their long-term viability necessitates a tripartite collaboration framework encompassing: (1) active community participation, (2) supportive government policies, and (3) private sector investment (Delucchi, 2011). From a technological perspective, composting offers a viable biological solution for organic waste stabilization and environmental impact mitigation (Wang et al., 2019b). However, widespread adoption faces persistent sociocultural obstacles including: (1) the prevailing perception of waste management as solely a municipal responsibility, (2) inadequate civic environmental stewardship, and (3) insufficient environmental education effectiveness (Pratap Singh & Prabha, 2018). Strategic interventions focusing on comprehensive public awareness campaigns and systematic technology integration are essential to overcome these barriers and establish sustainable waste management paradigms (Jabatan Pengurusan Sisa Pepejal Negara, 2016).



(a)



(b)

Figure 7: (a) Waste collection activity, (b) Waste cooking oil is collected for recycling

The widespread adoption of biocomposting faces several critical challenges that require a multi-faceted approach to address. Foremost among these is the need for enhanced public awareness campaigns to educate communities about the environmental benefits of organic waste diversion and proper participation techniques as shown in Figure 7. Concurrently, developing adequate infrastructure for waste collection, sorting, and processing remains fundamental, as optimal composting conditions depend on maintaining precise parameters including carbon-to-nitrogen ratios (25-30:1), moisture content (50-60%), and oxygen levels. Furthermore, the establishment of clear regulatory frameworks is imperative to ensure compost quality and safety, necessitating collaboration between government bodies, research institutions, and industry stakeholders to develop standardized protocols and quality control measures. These interconnected elements—public engagement, infrastructure development, and regulatory standardization—collectively form the foundation for successful biocomposting implementation.

Continued research and development plays a pivotal role in advancing biocomposting technologies, with current studies focusing on optimizing reactor designs, microbial inoculants, and process efficiency to enhance both economic viability and product quality. The physicochemical properties of input materials significantly influence process dynamics, underscoring the need for comprehensive databases documenting material specifications and best practices. As developing nations grapple with rapid urbanization and increasing waste volumes, biocomposting offers a sustainable solution that aligns with circular economy principles by reducing landfill dependence, mitigating greenhouse gas emissions, and producing valuable soil amendments. However, realizing this potential requires coordinated efforts across public education, infrastructure investment, regulatory development, and

technological innovation to overcome existing barriers and maximize the environmental and agricultural benefits of large-scale biocomposting systems.

6. Conclusion

Biocomposting presents a promising solution to organic waste management in Malaysia, offering a range of environmental, economic, and social benefits that can contribute to the country's transition towards a more sustainable and circular economy. Malaysia, like many developing nations, has witnessed a significant increase in municipal solid waste generation in recent years, driven by rapid economic growth and urbanization. The waste stream is characterized by a high proportion of organic matter, moisture content, and bulk density.

- i. Composting organic waste, a process known as biocomposting, can effectively transform these materials into valuable soil amendments, reducing the burden on landfills and mitigating environmental impacts.
- ii. Compost is highly valued for its ability to enhance the chemical, physical, and biological properties of soil, making it a valuable resource for various agricultural and landscaping applications.
- iii. The success and replication potential of community-based composting projects in neighboring countries, such as Bangladesh, demonstrate the viability of this approach.
- iv. To fully harness the benefits of biocomposting, it is crucial to address the existing challenges and promote the adoption of these practices. This requires an integrated approach involving collaboration among the government, industry, and local communities.

By investing in the infrastructure and policies to support biocomposting, Malaysia can reduce the environmental impact of organic waste, create new economic opportunities, and foster social engagement in sustainable waste management practices. Ultimately, the widespread adoption of biocomposting can contribute to Malaysia's transition towards a more circular economy, where organic waste is viewed as a valuable resource rather than a burden.

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