



Composting for Organic Waste Management: A Comprehensive Review on Processes, Applications, and Environmental Integration

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Abstract

Solid waste management remains a critical environmental challenge, particularly in developing nations where urbanization outpaces infrastructure development. The organic fraction of municipal solid waste often exceeds half of the total stream, posing both environmental risks and opportunities for resource recovery. Composting—the controlled aerobic decomposition of organic matter—offers a sustainable, low-cost solution to transform this waste into a stable, nutrient-rich soil amendment. This review highlights the scientific and operational foundations of composting, emphasizing biochemical processes, microbial succession, and key factors such as carbon-to-nitrogen ratio, moisture, aeration, temperature, and feedstock quality. Various composting systems, from simple windrows to advance in-vessel reactors, are compared in terms of efficiency, scalability, and suitability for diverse socioeconomic settings. The agricultural benefits of compost application are explored, including improvements in soil structure, water retention, nutrient availability, and microbial health. Additionally, integrated approaches combining composting with vermicomposting or biochar production are discussed for enhanced waste recycling and soil fertility. Within the broader environmental framework, composting contributes to the circular economy by reducing methane emissions, sequestering carbon, and addressing soil degradation and food security concerns. Overall, this synthesis provides a concise reference for researchers, policymakers, and practitioners pursuing sustainable waste management strategies that align with global sustainability goals and advance multiple United Nations Sustainable Development Objectives.

1. Introduction

The global challenge of solid waste management has reached critical dimensions, with current estimates indicating that cities worldwide generate approximately 2.01 billion tonnes of municipal solid waste annually, a figure projected to increase to 3.40 billion tonnes by 2050 (Kaza et al., 2018; Onwosi et al., 2017; Oreopoulou & Russ, 2007). This escalation is particularly pronounced in developing regions, where urbanization frequently outpaces the development of adequate waste management infrastructure (Marshall & Farahbakhsh, 2013). The environmental consequences of inadequate waste management are severe and multifaceted, encompassing groundwater contamination through landfill leachate, atmospheric pollution from open burning, and the proliferation of disease vectors in uncontrolled dump sites (Marshall & Farahbakhsh, 2013). Within this complex waste management landscape, the organic fraction of solid waste—

comprising food scraps, agricultural residues, yard trimmings, and animal manures—represents both a significant challenge and a substantial opportunity (Thi et al., 2015). When consigned to landfills, organic waste decomposes anaerobically, generating methane, a potent greenhouse gas with a global warming potential 28-36 times greater than carbon dioxide over a century (Bogner et al., 2008). Conversely, when managed through controlled biological processes such as composting, this same organic material can be transformed into a valuable resource that enhances agricultural productivity, improves soil health, and contributes to climate change mitigation (Lim et al., 2016).

Composting represents one of humanity's most ancient waste management strategies, yet it remains remarkably relevant in our modern technological era. Scientifically defined as the controlled aerobic biological decomposition of organic materials under conditions that allow for the

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development of thermophilic temperatures as a result of biologically produced heat, composting transforms unstable organic matter into a stable, humus-like substance through the concerted action of diverse microbial communities (Heribert Insam & Marco de Bertoldi, 2007). The resulting compost constitutes a stable, sanitized, and crumbly material rich in organic carbon, essential plant nutrients, and beneficial microorganisms (Doublet et al., 2011). Its application to soil addresses the critical and widespread problem of soil organic matter depletion, a phenomenon that undermines agricultural sustainability across diverse agroecological zones by impairing water retention capacity, promoting nutrient leaching, and diminishing crop productivity (Lal, 2020).

This comprehensive review aims to provide a holistic examination of composting as a cornerstone technology within sustainable organic waste management systems. We will explore the fundamental scientific principles governing the composting process, including the succession of microbial communities and the biochemical transformations of organic substrates. The review will systematically evaluate the spectrum of composting technologies available, from simple low-cost methods appropriate for rural communities to sophisticated engineered systems suitable for urban centers. We will elucidate the extensive agronomic and environmental benefits associated with compost utilization, with particular attention to its role in building soil health, reclaiming degraded lands, and mitigating climate change. Furthermore, we will position composting within the broader conceptual frameworks of the circular economy and global sustainability agendas, arguing for its strategic implementation as an integrated solution to the interconnected challenges of waste management, soil degradation, and food security. By synthesizing current scientific knowledge and practical experience, this work aims to serve as a definitive reference for researchers, policymakers, and practitioners committed to advancing sustainable waste management practices.

2. The Global Solid Waste Challenge: Characterization and Management Context

The accelerating pace of global urbanization has generated unprecedented challenges in municipal solid waste management, with developing countries facing particularly severe constraints in infrastructure, financing, and technical capacity (Onwosi et al., 2017). Current estimates indicate that approximately 37% of global waste is disposed of in landfills, with 33% ending up in open dumps that pose significant environmental and health risks, particularly in low-income countries where open dumping rates exceed 90% (Lin et al., 2018). The composition of municipal solid waste varies considerably with economic development levels, with organic waste constituting the largest fraction in low and middle-income countries, typically ranging from 50% to 70% of the total waste stream (Wei et al., 2017). This high organic content, coupled with elevated moisture levels, creates

particular management challenges through the generation of leachate and greenhouse gases when improperly disposed of in landfills (Thi et al., 2015).

The environmental impacts of inadequate organic waste management are profound and multifaceted. Decomposition in anaerobic landfill conditions generates methane, accounting for an estimated 11% of global methane emissions, while also producing nutrient-rich leachate that can contaminate surface and groundwater resources (Liu et al., 2008). Additionally, the putrescible nature of organic waste attracts disease vectors and creates public nuisance conditions through odor generation and visual pollution. Beyond these direct environmental impacts, the failure to recover organic waste represents a significant loss of valuable nutrients and organic matter that could otherwise be returned to agricultural soils, thereby exacerbating soil degradation and nutrient mining in agricultural systems (Heidarzadeh et al., 2019).

The management of solid waste in developing countries is further complicated by institutional, financial, and social constraints. Municipal authorities often allocate insufficient budgetary resources to waste management, typically less than 5% of municipal budgets in many Asian cities, compared to 10-15% in developed countries (Henry et al., 2006). Technical capacity limitations, inadequate regulatory frameworks, and low public awareness regarding waste segregation further impede the development of effective waste management systems. Within this challenging context, composting offers a particularly promising approach for managing the organic fraction of municipal solid waste, as it can be implemented at various scales from household to industrial level, requires relatively modest capital investment compared to other waste treatment technologies, and produces a valuable end product with multiple agricultural applications (Füleky & Benedek, 2010).

3. The Science of Composting: Biochemical Processes and Microbial Ecology

Composting represents a complex biochemical process driven by successive communities of microorganisms that progressively decompose organic materials through enzymatic action (Cooperband, 2002). The process typically progresses through four distinct but overlapping phases characterized by specific temperature regimes and microbial populations. The initial mesophilic phase begins at ambient temperatures and is dominated by mesophilic bacteria and fungi that rapidly metabolize readily available sugars, proteins, and lipids, generating metabolic heat that raises the temperature of the composting mass (Onwosi et al., 2017). As temperatures exceed 40°C, the process transitions to the thermophilic phase, during which thermophilic bacteria and actinomycetes become dominant and decompose more complex organic compounds including cellulose, hemicellulose, and proteins [38]. This thermophilic phase is critical for the hygienization of the compost, as sustained

temperatures above 55°C effectively destroy pathogens and weed seeds (Onwosi et al., 2017).

Following the thermophilic phase, as the availability of readily decomposable substrates declines, microbial activity decreases and the composting mass enters the cooling phase, during which temperatures gradually decline and mesophilic microorganisms, particularly fungi and actinomycetes, recolonize the material and decompose more resistant compounds such as lignin (Shilev et al., 2007). The final maturation phase involves complex biochemical reactions leading to the formation of stable humic substances through polymerization and condensation reactions, resulting in a biologically stable product that is phytotoxin-free and beneficial for plant growth (Tweib et al., 2014). The successful progression through these phases depends on the maintenance of appropriate environmental conditions, particularly with regard to oxygen availability, moisture content, and the carbon-to-nitrogen ratio of the feedstock (Wickramatilake et al., 2011).

The microbial ecology of composting is remarkably diverse, encompassing bacteria, actinomycetes, and fungi that successively dominate different phases of the process. Bacterial populations typically dominate the initial mesophilic and thermophilic phases, with Proteobacteria, Firmicutes, and Actinobacteria representing the most abundant phyla (H Insam & M De Bertoldi, 2007). Fungal populations, particularly Ascomycota and Basidiomycota, become more prominent during the cooling and maturation phases, where their enzymatic capabilities enable the decomposition of complex lignocellulosic materials (H Insam & M De Bertoldi, 2007). The diversity and succession of these microbial communities are influenced by multiple factors, including feedstock composition, aeration regime, temperature, and pH, with different microbial taxa contributing specific enzymatic capabilities that collectively enable the complete decomposition of heterogeneous organic materials (Franke-Whittle et al., 2014).

4. Critical Parameters in Composting Process Control

The efficiency and quality of the composting process are governed by several critical parameters that must be carefully managed to ensure optimal microbial activity and process outcomes (Figure 1). The carbon-to-nitrogen (C/N) ratio represents one of the most important factors influencing composting efficiency, with an initial ratio of 25-30:1 generally considered optimal for most composting operations (Senzige et al., 2014). Excessively high C/N ratios result in slow decomposition rates due to nitrogen limitation for microbial growth, while excessively low C/N ratios lead to nitrogen losses through ammonia volatilization and the generation of odor nuisances (Mahmood et al., 2017; Mahmood et al., 2015). The adjustment of C/N ratio through the blending of different feedstocks, such as the combination of nitrogen-rich food wastes with carbon-rich agricultural residues, represents a fundamental practice in composting operations (Sánchez et al., 2017).

Moisture content constitutes another critical parameter, as water serves as a medium for nutrient transport and



Figure 1: Art of composting and parameters impacting it.

microbial metabolism while also influencing the physical structure and porosity of the composting matrix (Zayed & Abdel-Motaal, 2005). Optimal moisture content typically falls within the range of 50-60%, with levels below 40% limiting microbial activity and levels above 65% creating anaerobic conditions that impede aerobic decomposition and generate odor problems. The maintenance of appropriate moisture levels requires careful monitoring and management, particularly in open composting systems exposed to precipitation or evaporation, and may require the addition of water or the use of bulking agents to adjust moisture conditions (J. Zhang et al., 2011; L. Zhang & Sun, 2016).

Oxygen availability represents a fundamental requirement for aerobic composting, as oxygen serves as the terminal electron acceptor in microbial respiration. Oxygen concentrations below 5-10% typically lead to the development of anaerobic conditions characterized by reduced decomposition rates, odor generation, and the production of methane and other greenhouse gases (Füleky & Benedek, 2010). Aeration management strategies include passive aeration through natural convection, active aeration through forced air injection or extraction, and mechanical turning of the compost mass to reintroduce oxygen and disrupt anaerobic zones. The frequency and intensity of aeration must be balanced against the potential for excessive heat and moisture loss, particularly in colder climates (Wang & Li, 2009).

Temperature serves as both an indicator and a driver of microbial activity during composting, with different temperature ranges selecting for distinct microbial communities (Wang & Li, 2009). The achievement of thermophilic temperatures (55-65°C) is essential for pathogen destruction and rapid decomposition, but excessively high temperatures (above 70°C) can be detrimental to microbial diversity and process efficiency. Temperature monitoring and control through aeration management therefore represent critical aspects of

composting process control, particularly in systems designed to produce hygienically safe compost products (Mohee & Mudhoo, 2005).

5. Composting Technologies and System Design

Composting technologies encompass a wide spectrum of approaches ranging from simple, low-cost methods suitable for small-scale application to sophisticated engineered systems designed for large-scale municipal operations. Windrow composting represents one of the most widely implemented technologies, particularly for agricultural and municipal applications, involving the formation of organic waste into elongated piles that are periodically turned to introduce oxygen and redistribute materials (Al-Jarallah & Aleisa, 2014). This approach offers relatively low capital and operating costs and operational simplicity but requires significant land area and careful management to control environmental impacts such as odors, leachate, and vectors. The effectiveness of windrow systems depends considerably on the frequency and method of turning, with optimal turning regimes balancing aeration requirements against the potential for excessive heat and moisture loss (Wang & Li, 2009).

Aerated static pile (ASP) systems represent an alternative approach that uses forced aeration to provide oxygen and remove excess heat and moisture, typically through a network of perforated pipes embedded in a base material beneath the compost pile. This technology offers improved process control compared to windrow systems, with reduced odor emissions and lower labor requirements, but involves higher capital costs for aeration equipment and requires more sophisticated monitoring and control systems. ASP systems can be configured with positive (blowing) or negative (suction) aeration, with each approach offering distinct advantages in terms of moisture and temperature distribution and odor management (De Guardia et al., 2012). In-vessel composting systems represent the most technologically advanced approach, confining the composting process within enclosed containers, tunnels, or chambers that allow for precise control of environmental conditions including aeration, temperature, and moisture. These systems offer the highest level of process control and environmental protection, with minimal odor emissions, reduced processing times, and smaller footprint requirements, but involve substantially higher capital and operating costs compared to open systems. Various in-vessel configurations have been developed including agitated bays, rotating drums, and enclosed tunnels, each with distinct advantages for specific feedstock characteristics and processing objectives (Mohee & Mudhoo, 2005).

The selection of appropriate composting technology depends on multiple factors including the quantity and characteristics of available feedstocks, available financial resources, land availability, regulatory requirements, and intended compost markets [68]. Small-scale and decentralized composting approaches have gained increasing attention as strategies for managing organic wastes in

developing country contexts, offering potential advantages in terms of reduced transportation costs, community engagement, and recovery of local resources. Regardless of the technological approach adopted, successful composting operations require careful attention to site design, materials handling, process monitoring, and product quality assurance to ensure environmental protection and market acceptance (Mahmood et al., 2015; Sánchez et al., 2017; Wang & Li, 2009).

6. Compost Quality and Application in Agricultural Systems

The agronomic value of compost derives from its multiple contributions to soil physical, chemical, and biological properties, making it a valuable soil amendment in diverse agricultural systems (Farrell & Jones, 2009). From a physical perspective, compost application improves soil structure by promoting aggregation, increasing porosity, and enhancing water retention capacity, thereby improving root penetration, water infiltration, and erosion resistance (Ramos & López-Acevedo, 2004). These physical improvements are particularly valuable in degraded or compacted soils, where compost application can facilitate the restoration of favorable soil physical conditions for plant growth (Bellamy et al., 2005). The organic matter in compost also contributes to soil buffering capacity, helping to stabilize soil pH and mitigate the impacts of soil acidification or alkalization.

From a chemical perspective, compost serves as a slow-release source of essential plant nutrients including nitrogen, phosphorus, potassium, and micronutrients, reducing the requirement for synthetic fertilizers and minimizing nutrient leaching losses. The nutrient content and availability in compost vary considerably depending on feedstock composition and composting process, with typical nitrogen contents ranging from 1-3% on a dry weight basis, of which only 10-20% is typically available in the first growing season. Beyond its direct nutrient contributions, compost enhances soil chemical fertility through its influence on cation exchange capacity, with compost application typically increasing CEC through the addition of negatively charged organic functional groups that retain nutrient cations such as calcium, magnesium, and potassium (Mkhabela & Warman, 2005).

The biological benefits of compost application derive from its introduction of diverse microbial communities and its provision of organic substrates that support soil biological activity (Agnolucci et al., 2013). Compost application typically enhances the abundance and diversity of soil microorganisms including bacteria, fungi, and actinomycetes, with consequent improvements in nutrient cycling, organic matter decomposition, and soil structure formation (Franke-Whittle et al., 2014). Certain types of compost can also suppress soil-borne plant pathogens through multiple mechanisms including competition, antibiosis, and induced systemic resistance in plants, providing an alternative to chemical pesticides in integrated

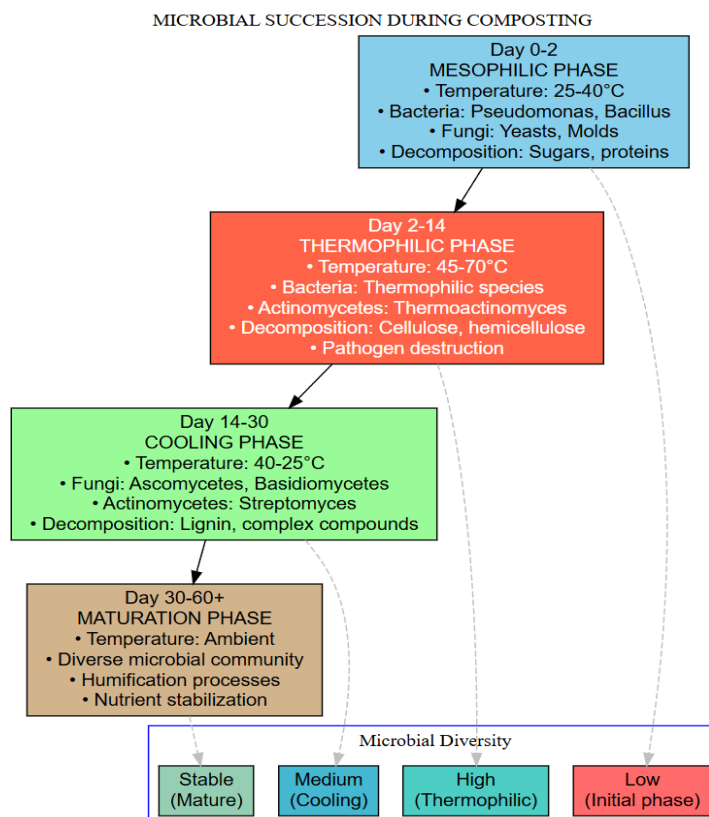


Figure 2: Simplified Composting Process Flow Diagram: This linear workflow diagram outlines the sequential stages of compost production from raw organic materials to end-use applications. The process begins with heterogeneous organic waste inputs, progresses through essential pre-processing operations (sorting, shredding, mixing), enters the active composting phase under various technology options, undergoes quality control monitoring, proceeds through maturation and stabilization, completes final quality testing, and culminates in diverse agricultural and environmental applications. Environmental benefits including greenhouse gas reduction, waste diversion from landfills, and soil carbon sequestration are shown as cross-cutting outcomes throughout the value chain. The diagram emphasizes the transformation of waste streams into valuable resources while highlighting key operational stages and quality checkpoints.

pest management systems (Karnchanawong & Nissaikla, 2014) as shown in Figure 2.

The effective utilization of compost in agricultural systems requires attention to application timing, placement, and rates based on crop nutrient requirements, soil characteristics, and compost quality parameters (Hossain et al., 2010). Excessive application rates can lead to nutrient imbalances, salinity problems, or environmental contamination, while inadequate rates may fail to provide significant agronomic benefits (Broitman et al., 2018). Compost quality standards and testing protocols have been established in many countries to guide appropriate compost utilization and ensure product safety with regard to contaminants such as heavy metals and persistent organic pollutants (Lokeshwari & Swamy, 2010).

7. Environmental Benefits and Climate Change Mitigation

Composting contributes to climate change mitigation through multiple mechanisms, most notably by diverting organic waste from landfills where it would decompose anaerobically and generate methane, a potent greenhouse gas (Liu et al., 2008). The global warming potential of methane is 28-36 times greater than carbon dioxide over a 100-year timeframe, making methane reduction from waste management a high priority for climate change mitigation (Lim et al., 2016). Additionally, the application of compost to soil enhances carbon sequestration through the formation of stable soil organic matter, effectively transferring carbon from the atmosphere to agricultural soils where it can be stored for decades to centuries (Rushton, 2003). The carbon sequestration potential of compost application varies with soil type, climate, and management practices, but typically ranges from 0.5 to 2.0 tonnes of CO₂ equivalent per hectare annually (Lim et al., 2016).

Beyond its direct contributions to greenhouse gas reduction, compost application supports climate change adaptation by enhancing soil water retention capacity, thereby improving drought resilience in agricultural systems (Cea et al., 2012; Yosef et al., 2015). The improved soil structure resulting from compost application also enhances water infiltration and reduces surface runoff, mitigating flood risks and soil erosion during extreme precipitation events (Onwosi et al., 2017). These adaptive benefits are particularly valuable in the context of climate change, which is projected to increase the frequency and intensity of both drought and heavy precipitation events in many agricultural regions (Neklyudov et al., 2008).

Composting also contributes to broader environmental protection by reducing nutrient pollution of water resources. When applied to soil, compost releases nutrients gradually in synchrony with plant uptake, minimizing leaching losses to groundwater and runoff to surface waters compared to readily soluble synthetic fertilizers. This reduced nutrient mobility helps to mitigate eutrophication of freshwater and marine ecosystems, which represents one of the most significant water quality challenges globally. Additionally, by providing a valuable use for organic wastes, composting reduces the environmental impacts associated with alternative disposal methods including landfilling and incineration, such as leachate generation, air emissions, and land resource consumption (Füleky & Benedek, 2010).

8. Integration with Other Waste Valorization Approaches

Composting can be effectively integrated with other organic waste management approaches to enhance overall system efficiency and resource recovery. Vermicomposting represents a complementary approach that uses earthworms to fragment and stabilize organic matter, producing a fine-textured amendment with particularly favorable chemical and biological properties (Lim et al., 2016). The combination of conventional composting and vermicomposting in two-stage systems can leverage the advantages of both approaches, with initial thermophilic composting providing pathogen reduction and rapid decomposition followed by vermicomposting to enhance nutrient availability and produce a more uniform final product (Hanc & Pliva, 2013; Sami-ur-Rehman et al., 2020).

The integration of composting with biochar production represents another promising approach that creates synergistic benefits for soil amendment quality and carbon sequestration. Biochar, produced through the pyrolysis of biomass, provides a stable carbon matrix with high porosity and surface area that can be co-composted with organic materials or mixed with finished compost (Cea et al., 2012). During co-composting, biochar enhances the composting process by reducing nitrogen losses through ammonia volatilization, improving aeration, and providing habitat for microbial communities. The resulting biochar-compost mixtures combine the long-term carbon sequestration benefits of biochar with the nutrient provision and immediate

soil improvement benefits of compost, creating a soil amendment with superior properties for both agricultural productivity and climate change mitigation (Ahmad et al., 2014; Bashir et al., 2018; Cayuela et al., 2014).

Anaerobic digestion represents another complementary technology that can be integrated with composting in comprehensive organic waste management systems (Lin et al., 2018). In such integrated systems, organic wastes first undergo anaerobic digestion to produce biogas for energy recovery, followed by composting of the digestate to stabilize the remaining organic matter and produce a valuable soil amendment. This integrated approach maximizes resource recovery from organic wastes, simultaneously generating renewable energy and producing a soil amendment while minimizing environmental impacts. The specific configuration of integrated systems depends on local priorities regarding energy production, soil amendment quality, and economic considerations, with different technological combinations offering distinct advantages for specific contexts (M. K. Awasthi et al., 2015; M. K. Awasthi et al., 2014; S. K. Awasthi et al., 2020).

9. Challenges and Future Perspectives

Despite the well-established benefits of composting, multiple challenges impede its wider adoption, particularly in developing country contexts. Technical challenges include the heterogeneous nature of municipal solid waste, which often contains contaminants such as plastics, glass, and heavy metals that can compromise compost quality and market acceptance. The separation of organic fractions at source represents a critical prerequisite for producing high-quality compost, but requires effective public education, appropriate collection systems, and consistent participation from households and businesses. Financial challenges include the relatively high costs of collection and processing compared to conventional disposal methods, coupled with limited market development for compost products that often fails to reflect their full environmental value.

Institutional and regulatory challenges also present significant barriers, including inadequate policy support, fragmented institutional responsibilities, and insufficient enforcement of waste management regulations. In many developing countries, the informal sector plays a significant role in waste management, particularly in waste collection and segregation, but rarely participates in formal composting initiatives [108]. The integration of informal waste workers into formal composting operations represents both a challenge and an opportunity for improving waste management while providing livelihood opportunities for vulnerable populations.

Future developments in composting technology and management are likely to focus on improving process efficiency, enhancing product quality, and reducing environmental impacts. Technological innovations may include more sophisticated aeration control systems, real-time monitoring of process parameters, and the development

of specialized microbial inoculants to enhance decomposition rates and product quality. There is also growing interest in decentralized and community-based composting approaches that reduce transportation costs, enhance community engagement, and support local circular economies. From a policy perspective, greater emphasis on extended producer responsibility, landfill diversion mandates, and carbon credit mechanisms could provide stronger economic incentives for composting and other organic waste valorization approaches. The integration of composting within broader circular economy and bioeconomy frameworks represents a promising direction for future development, positioning organic waste as a valuable resource rather than a disposal problem. Such integrated approaches recognize the multiple values embedded in organic waste as sources of energy, nutrients, and organic matter—and seek to optimize resource recovery through appropriate technological combinations. The future development of composting will also need to address emerging challenges such as contaminants of emerging concern, including microplastics and pharmaceutical residues, which may require additional pretreatment or polishing steps to ensure product safety.

10. Conclusion

Composting represents a proven, sustainable, and versatile technology for managing the organic fraction of municipal solid waste while simultaneously producing a valuable soil amendment with multiple agricultural and environmental benefits. The scientific understanding of composting has advanced significantly in recent decades, providing a solid foundation for process optimization and quality control across diverse technological approaches and feedstock characteristics. The environmental benefits of composting are substantial and multifaceted, including greenhouse gas mitigation through landfill diversion and carbon sequestration, nutrient recycling that reduces dependence on energy-intensive synthetic fertilizers, and soil quality improvement that enhances agricultural productivity and resilience.

Despite these clear benefits, the wider adoption of composting faces significant challenges related to waste characterization, source separation, market development, and policy support. Addressing these challenges will require coordinated efforts across multiple sectors, including technological innovation, institutional strengthening, economic incentive design, and public education. The integration of composting with complementary approaches such as anaerobic digestion, vermicomposting, and biochar production offers promising pathways for enhancing overall system efficiency and resource recovery.

Within the broader context of sustainable development, composting represents a practical manifestation of circular economy principles, transforming waste streams into valuable resources while supporting multiple Sustainable Development Goals related to sustainable cities, responsible consumption, climate action, and life on land. As global

challenges related to waste management, soil degradation, and climate change continue to intensify, composting is likely to play an increasingly important role in sustainable resource management strategies worldwide. Future efforts should focus on adapting composting technologies to local contexts, developing innovative business models, strengthening policy frameworks, and building capacity at all levels to realize the full potential of composting as a cornerstone of sustainable waste management and agricultural systems.

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14. Conflict of Interest:

Authors declare no conflict of interest.

15. SDGS Addressed:

SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production) by promoting sustainable waste management and resource recovery within a circular economy. Other strongly connected goals include SDG 13 (Climate Action) through methane emission reduction and SDG 15 (Life on Land) by combating soil degradation.

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