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FOOD WASTE COMPOSTING MACHINES: A MINI REVIEW ON A PRACTICAL SOLUTION FOR ORGANIC WASTE REDUCTION AT SOURCE

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Abstract:

Food waste composting machines (FWCMs) are increasingly recognized as a practical solution for organic waste reduction at source, contributing to sustainable development and circular economy objectives. A literature search was conducted using Web of Science, Scopus, and Google Scholar, with keywords including “food waste,” “composting,” “machine,” “device,” “system,” and “sustainability.” Peer-reviewed English-language studies explicitly addressing FWCMs were included, while non-English publications, irrelevant studies, and grey literature were excluded. FWCMs support landfill diversion, greenhouse gas mitigation, and nutrient recycling. Key technological advancements, such as microbial inoculants, aeration systems, temperature regulation, and automation, have improved decomposition rates and operational efficiency. Applications range from household devices to large-scale institutional and urban systems, highlighting their adaptability. Nevertheless, challenges remain, including high energy consumption,

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inconsistent compost quality, pathogen survival, bioaerosol emissions, and economic constraints. Uncertainty persists regarding their long-term environmental performance, scalability, and socio-economic integration. FWCMs offer significant potential for advancing sustainable food waste management. However, critical knowledge gaps—particularly in safety standards, compost quality benchmarking, life-cycle assessment, and cost-effectiveness—must be addressed through targeted research, technological innovation, and supportive policy frameworks.

Keywords:

Food Waste; Composting; Composter Machine; Sustainability

Introduction

Food waste has emerged as one of the most pressing sustainability challenges of the 21st century, with profound implications for food security, climate change, and waste management systems. Globally, nearly one-third of all food produced is lost or wasted, contributing to greenhouse gas emissions and placing additional burdens on landfills (Samsudin & Don, 2013; Yin et al., 2024). Figure 1 illustrates circular process of food waste composting, where sorted waste undergoes decomposition, gas capture, and compost creation, reducing landfill emissions and supporting environmental sustainability. Among various mitigation strategies, food waste composting machines—ranging from small-scale household units to large institutional systems—are increasingly recognized as effective technologies for diverting organic waste from disposal pathways while producing valuable compost for agricultural and horticultural applications. The significance of these technologies has expanded in response to stricter waste regulations, urban sustainability initiatives, and growing consumer awareness of circular economy practices.

Figure 1: The Circular Process of Food Waste Composting

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Food waste composting machines provide an effective method to assist in managing and reducing food waste by accelerating the natural decomposition process(Harish et al., 2025; Zhou et al., 2020). These machines integrates mechanical and biological systems to optimize the process of producing valuable compost and reduce the amount of waste sent to landfill (Rudi et al., 2022; Zhou et al., 2020). Food waste is one of the largest contributors to municipal solid waste, poses environmental challenges due to methane emissions and toxic leachate production in landfills (Hashar et al., 2021; Thapa et al., 2022). Composting, especially with the aid of specialized machines, offers a sustainable alternative by transforming this waste into a beneficial resource (Palaniveloo et al., 2020; Selvam et al., 2021; Zhou et al., 2020). Employing food waste composting machines offers several advantages (Mohamed Raimi et al., 2020; Zhou et al., 2020). These machines can substantially reduce the volume of food waste, thus decreasing transportation costs and landfill burden (Zaman et al., 2021; Zhou et al., 2020). The compost produced is a nutrient-rich soil amendment, which can be used in gardening, agriculture, and landscaping, improving soil structure and fertility (Rahman et al., 2022). On-site composting reduces the environmental impact associated with transporting waste to centralized facilities (Zaman et al., 2021) . Furthermore, the use of composting machines aligns with sustainable development goals by promoting waste reduction and resource recovery (Palaniveloo et al., 2020).

The purpose of this mini-review is to synthesize current knowledge on food waste composting machines (FWCMs), emphasizing both the technological opportunities they provide and the barriers limiting their broader adoption. Specifically, this review examines: (i) the key features and technological advancements that underpin FWCM design and operation, (ii) the benefits, limitations, and life-cycle perspectives that shape their environmental and economic viability, and (iii) the future research and policy directions required to enhance their scalability and integration within sustainable waste management frameworks. Building on this foundation, the discussion extends beyond a descriptive account of existing literature to critically analyze the implications of FWCMs across four thematic domains—health risks, sustainable development, food waste management, and composting technology. This dual emphasis on literature synthesis and thematic interpretation offers both a comprehensive overview of the current state of FWCMs and an evaluative framework for identifying opportunities, challenges, and future directions in advancing their role within the transition toward a circular economy.

Literature Review

Composting has emerged as one of the most effective methods for diverting organic waste from disposal pathways, transforming it into a valuable soil amendment that supports nutrient recycling and soil health. In recent years, technological innovations have facilitated the development of FWCM, which accelerate the composting process while addressing limitations associated with traditional methods. These machines are increasingly applied across diverse settings, from households and institutions to urban-scale waste management systems, and their growing adoption reflects the global shift toward circular economy practices and sustainable waste management.

Key Features and Technological Advancements

Food waste composting machines typically incorporate several key features to expedite the composting process. Shredding mechanisms reduce the size of food waste particles, increasing the surface area available for microbial (Harish et al., 2025; Zhou et al., 2020). Temperature control systems maintain optimal conditions for thermophilic microorganisms, accelerating decomposition (Sailesh & Shinde, 2016; Zaman et al., 2021; Zhou et al., 2020). Aeration

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systems ensure sufficient oxygen supply, promoting aerobic decomposition and minimizing odor production (Dinesh Kumar. et al., 2024). Many machines also include moisture management features to maintain ideal moisture levels for microbial activity (Dinesh Kumar. et al., 2024). The integration of these features significantly reduces composting time compared to traditional methods (Zaman et al., 2021).

Various types of food waste composting machines are available, each suited to different scales of operation (Dinesh Kumar. et al., 2024; Harish et al., 2025; Rudi et al., 2022; Zhou et al., 2020). Home composting devices are designed for household use, rapidly crushing food waste and producing mature compost that meets quality standards for planting soil (Zhou et al., 2020). In-vessel composting systems are used for larger-scale operations, providing controlled environments that optimize the composting process (Hashar et al., 2021; Lu et al., 2020) . Thermal composters accelerate composting through the use of heat, reducing the time required for decomposition (Zaman et al., 2021). Portable shredding machines combine shredding and composting functionalities, efficiently processing organic waste (Resmi & Vinod, 2022). Smart Food Waste Recycling Bins (S-FRB) utilize wooden biochips with naturally occurring fermentative microorganisms to convert food waste into an energy resource (Yeo et al., 2019).

Benefits, Limitations, and Evaluating systems

Composting plays a crucial role in promoting a circular economy by closing the loop on organic waste (de Sadeleer et al., 2020; Di Fraia et al., 2024). By diverting food waste from landfills and transforming it into valuable compost, composting supports resource recovery and reduces reliance on finite resources (Di Fraia et al., 2024). This aligns with the principles of a circular economy, which aims to minimize waste and maximize the use of resources. Composting contributes to a more sustainable and resilient food system by enhancing soil health and reducing the environmental impact of waste disposal (Sagar et al., 2024).

Despite the benefits, food waste composting also presents challenges. The low pH during the early composting phase can inhibit microbial activity (Selvam et al., 2021). Inconsistent waste composition requires robust and adaptable composting systems (Thapa et al., 2022). Bioaerosols generated during composting can affect human airway epithelial cells, necessitating proper ventilation and safety measures (Chang. et al., 2014). Economic viability can be a concern, requiring efficient operation and potential incentives (Daskal et al., 2022; Saravia-Matus et al., 2021).

Life cycle assessment (LCA) is used to evaluate the environmental impacts associated with composting techniques (Al-Rumaihi et al., 2020; Lundie & Peters, 2005) . LCA considers all stages of the composting process, from waste collection to compost application, assessing factors such as greenhouse gas emissions, energy consumption, and resource use (Batool et al., 2024). Studies have compared different composting techniques, such as windrow composting and anaerobic digestion, to determine their environmental performance (Al-Rumaihi et al., 2020). LCA helps in identifying the most sustainable options for food waste management, considering both environmental and economic factors (Lu et al., 2020).

Opportunities and Future Prospects

Future research and development in food waste composting should focus on optimizing composting processes, improving machine efficiency, and addressing the challenges associated with food waste composition and emissions (Di Fraia et al., 2024; Sagar et al., 2024). Innovations in pretreatment methods, such as mechanical, thermal, and biological treatments, can enhance the efficiency of composting (Sagar et al., 2024). The integration of composting with other waste management strategies, such as anaerobic digestion, can further improve resource recovery (Siaw et al., 2022). Additionally, policies and incentives that promote composting can play a key role in expanding the adoption of this sustainable waste management practice (Rotthong et al., 2022). In conclusion, food waste composting machines offer a promising solution for managing food waste and promoting sustainable waste management. By accelerating the composting process and producing valuable compost, these machines contribute to waste reduction, resource recovery, and environmental protection (Dinesh Kumar. et al., 2024; Palaniveloo et al., 2020; Selvam et al., 2021; Zhou et al., 2020). Although challenges remain, ongoing research and development are enabling more efficient and sustainable composting practices, thereby supporting the transition towards a circular economy.

Method

A literature search was conducted using Web of Science, Scopus and Google Scholar. Keywords such as

("food waste" OR "organic waste" OR "kitchen waste" OR "biodegradable waste") AND ("composting" OR "compost" OR "decomposition" OR "organic recycling") AND ("machine" OR "device" OR "system" OR "equipment") AND ("sustainability" OR "environment" OR "waste management" OR "resource recovery")

Keywords including food waste; composting; composter machine; sustainability were employed to retrieve relevant articles. Eligible sources encompassed peer-reviewed publications such as original research, systematic reviews, meta-analyses, case studies. To ensure rigor and consistency, clearly defined inclusion and exclusion criteria were applied, as detailed below.

Inclusion Criteria

- Studies discussing various types of food waste composting machines highlight their role in reducing landfill burdens, lowering greenhouse gas emissions, and generating nutrient-rich compost, though outcomes vary depending on scale and operating conditions.
- Studies focusing on the application of composting technologies in food waste management emphasize microbial optimization, automated controls, and decentralized systems as promising innovations, while noting concerns over energy intensity, cost, and compost quality.
- Studies analyzing opportunities, barriers, and future directions collectively identify FWCMs as valuable tools for sustainable waste management but underline persistent challenges, including affordability, regulatory gaps, and inconsistent performance across settings.
- Studies published in English converge on the view that further research should standardize compost quality, assess health and environmental risks, and integrate FWCMs into broader policy and circular economy frameworks to enhance adoption and scalability.

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Exclusion Criteria

- Studies published in languages other than English were excluded.
- Studies that discuss food waste management without reference to food waste composting machines were excluded.
- Grey literature (e.g., conference abstracts, unpublished reports) was excluded.

Discussions

The foregoing literature review has outlined the technological features, benefits, limitations, and future prospects of food waste composting machines, emphasizing their role in advancing sustainable waste management. Building upon these insights, the ensuing analysis contextualizes the current status of food waste composting machines within four thematic domains—health risks, sustainable development, food waste management, and composting technology (figure 2). This thematic framing not only bridges theoretical and empirical perspectives but also enables a critical assessment of the opportunities and challenges shaping the broader adoption and optimization of these technologies.

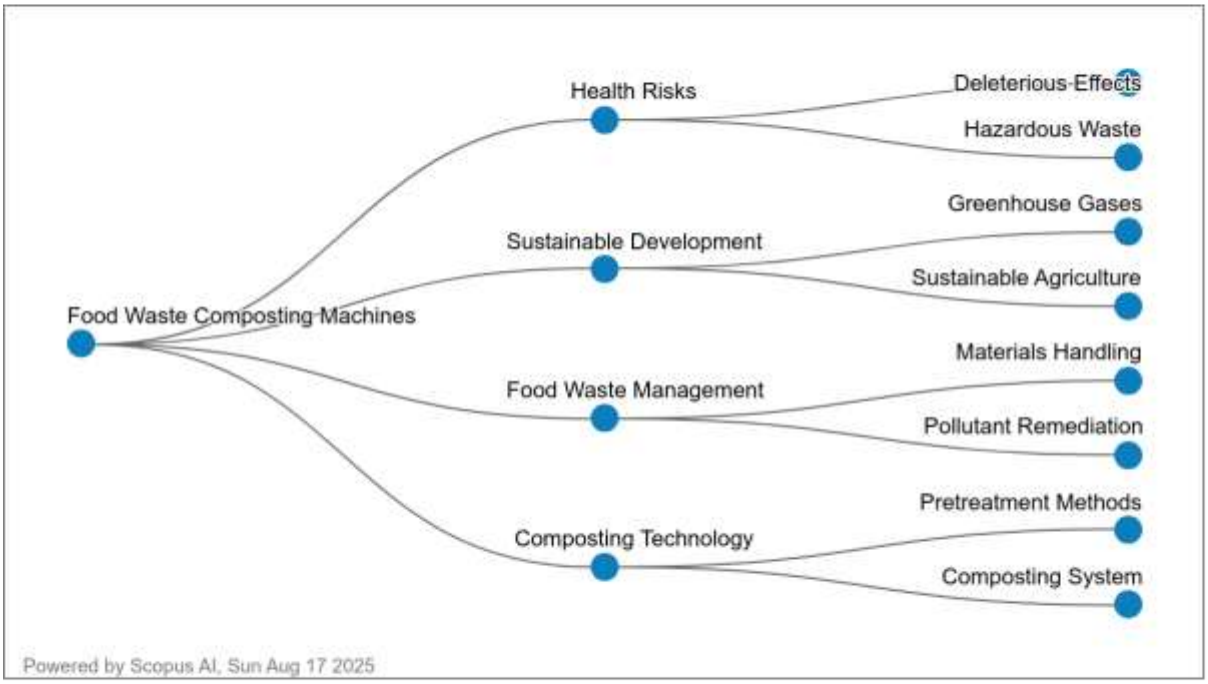

Figure 2: Food Waste Composting Machines generated by Scopus AI

Source: (retrieved from Scopus AI on Sun Aug 17 2025)

Health Risks

Food waste composting machines (FWCMs) are increasingly promoted as sustainable technologies to divert organic waste from landfills and generate compost. However, their use raises important health risks requiring critical assessment. Future directions emphasize improving hygienization standards and pathogen monitoring to ensure compost safety. Benefits include waste reduction and nutrient recycling, while challenges involve bioaerosol exposure, odor emissions, and potential pathogen survival during incomplete composting. Key technologies—such as controlled aeration, thermophilic microbial inoculants, and automated temperature regulation—help mitigate risks but debates persist over their reliability across diverse waste streams. Practical applications span households, schools, and urban farms,

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though regulatory oversight is uneven. Addressing gaps in health risk assessments and establishing safety benchmarks remain priorities for broader FWCM adoption

Sustainable Development
Food waste composting machines (FWCMs) are emerging as innovative tools to manage organic waste sustainably, aligning with global efforts to reduce landfill reliance and promote circular economies. In the context of sustainable development, FWCMs support waste valorization and local resource recovery but face concerns regarding scalability and affordability. Benefits include greenhouse gas reduction, nutrient recycling, and decentralized waste solutions, while challenges involve high energy demands, inconsistent compost quality, and regulatory gaps. Key technologies focus on microbial inoculants, temperature regulation, and automation to accelerate decomposition. Practical applications span households, institutions, and smart cities. Future research should standardize compost quality, enhance energy efficiency, and integrate FWCMs within policy frameworks to advance sustainable urban waste management.

Food Waste Management
Food waste composting machines (FWCMs) are emerging as vital tools in food waste management, addressing rising concerns over landfill dependence and greenhouse gas emissions. Future directions include integrating renewable energy, digital monitoring, and policy incentives to improve scalability. Benefits involve nutrient recovery, reduced disposal costs, and localized waste valorization, while challenges include high energy demands, inconsistent compost quality, and limited public awareness. Key technologies such as microbial inoculants, controlled aeration, and automated temperature regulation accelerate decomposition but raise debates over affordability and environmental trade-offs. Practical applications span households, institutions, and urban agriculture. Bridging gaps in standardization, economic viability, and social acceptance offers opportunities for FWCMs to become central to sustainable food waste management systems.

Composting Technology
Food waste composting machines (FWCMs) represent a growing innovation in composting technology, designed to transform organic waste into valuable compost while supporting sustainability goals. Future directions point toward energy-efficient designs, smart monitoring systems, and integration with renewable energy sources. Benefits include reduced landfill use, greenhouse gas mitigation, and localized nutrient cycling, while challenges involve high operating costs, odor management, and inconsistent compost quality. Key technologies such as microbial inoculants, aeration control, and automated temperature regulation enhance decomposition but face debates on long-term scalability and environmental trade-offs. Practical applications extend across households, institutions, and urban agriculture. Further research should standardize quality metrics, reduce costs, and explore policy integration to expand FWCM adoption globally.

Conclusion
This mini review underscores the potential of food waste composting machines (FWCMs) as a practical solution for organic waste reduction at source, with insights spanning health risks, sustainable development, food waste management, and composting technology. Collectively, the literature affirms their capacity to divert waste from landfills, mitigate greenhouse gas emissions, and generate nutrient-rich compost. Yet, significant limitations persist, including inconsistent compost quality, high energy demands, affordability constraints, and inadequate

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regulatory oversight. Controversies remain over health risks linked to pathogen survival and bioaerosol exposure, as well as uncertainties about their long-term scalability. Knowledge gaps in socio-economic integration, compost standardization, and lifecycle assessments highlight areas for further inquiry. Future research should prioritize energy-efficient designs, safety benchmarks, and supportive policies to maximize FWCM adoption, ensuring their effective role in advancing circular and sustainable waste systems.

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