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Original Scientific Article

THE ROLE OF DIGITALIZATION IN THE CIRCULAR ECONOMY: MANAGING FOOD BIO-WASTE IN HOTELS AND RESTAURANTS

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Abstract: Digitalization represents a key driver of the transformation of modern economic systems towards the circular economy model, which is based on the rational use of resources and waste reduction. In the context of managing food bio-waste in the hospitality industry, digital tools enable more efficient planning, monitoring, and optimization of processes. The implementation of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, and digital platforms contributes to precise measurement of waste quantities, identification of causes, and reduction of food surpluses through automated management of procurement and meal preparation. Tools such as Winnow and Leanpath have demonstrated that digitalization can reduce food waste in hospitality facilities by up to 40%, bringing both economic and environmental benefits. In addition to improving sustainability and competitiveness, digitalization fosters greater awareness among employees regarding the responsible use of resources. Therefore, the integration of digital solutions into the circular economy system of hotels and restaurants represents an important step toward reducing the ecological footprint and achieving sustainable development goals.

Keywords: *digitalization, circular economy, bio-waste, food waste management, hotels, restaurants.*

INTRODUCTION

Circular economy is a modern economic concept that aims to reduce the consumption of natural resources, extend the life cycle of products and minimize waste (George et al., 2015). In contrast to the linear "take-make-throw" model, the circular economy is based on the principles of reuse, recycling, regeneration and sustainable resource management. The circular economy aims to preserve the value of materials and energy for as long as possible, while reducing negative impacts on the environment (Geissdoerfer et al., 2017). The basic principles include the concept of Reduce, Reuse, Recycle, i.e. reducing resource use, reusing products and materials and recycling in order to control waste generation and improve resource efficiency. In addition to these, modern approaches also include additional principles such as recover, re-design and other "R" concepts that encourage the restructuring of products for more easily renewable material flows (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

In modern society, this concept is gaining importance due to the increasingly pronounced problems associated with the depletion of resources, climate change and growing amounts of waste. Today, the circular economy is recognized as a key tool for achieving the goals of sustainable development, especially in the context of responsible production and consumption.

The problem of organic biowaste Organic biowaste represents one of the largest and fastest growing categories of waste globally. This group includes food scraps, plant waste, agricultural by-products, as well as waste from gastronomy and the food industry (Parfitt et al., 2010). According to the Food and Agriculture Organization (FAO, 2013), a significant part of the food produced ends up as waste, which leads to economic losses and negative environmental consequences. This type of waste has great potential within the circular economy because it can be transformed into valuable products through various biological and thermochemical processes (Mirabella et al., 2014). The most common applications include:

- Composting – biofermentation converts organic materials into compost that improves soil structure and has a beneficial effect on agroecosystems.
- Biogas – anaerobic digestion of organic waste produces energy-rich methane that is used to generate heat or electricity, reducing greenhouse gas emissions and contributing to energy independence.
- Biochar – pyrolysis of waste produces a stable carbonaceous material that is used as a soil improver or to reduce nitrogen losses in the composting process, which can improve compost quality and reduce greenhouse gas emissions.

Inappropriate management of organic waste contributes to greenhouse gas emissions, soil and water pollution, and the loss of potentially valuable resources (Tepić et al., 2025). However, organic biowaste also represents a significant potential for the circular economy, as it can be used to produce compost, biogas, energy or secondary raw materials, thus closing the material flow and reducing pressure on natural resources. These strategies show how biowaste can be valued as a resource rather

than simply being disposed of, thereby supporting the goals of sustainable and circular resource management.

In the context of the hospitality sector, especially hotels, digitization is recognized as a key factor for improving the management of organic bio-waste. Hotels, as complex systems with a large number of users and diverse services, generate significant amounts of organic waste, primarily through the preparation and consumption of food (Santos-Peñate et al., 2023). The application of digital technologies enables precise monitoring of biowaste flows, identification of critical points in the generation of waste and optimization of the resource management process. Digital tools, such as inventory management systems, smart containers, and analytics platforms, enable hotels to reduce food waste, improve waste collection logistics, and more efficiently incorporate biowaste into circular flows, such as composting and bioenergy production (Ahmadzadeh et al., 2023). In this way, digitalization represents an important mechanism for integrating the principles of circular economy into hotel business and achieving the goals of sustainable development.

The role of digitalization in improving waste management processes

Digitalization plays an increasingly important role in improving waste management systems, especially in the context of a circular economy. The application of digital technologies, such as the Internet of Things (IoT), artificial intelligence, big data analytics and digital platforms, enables more efficient monitoring of waste flows, optimization of collection and better exchange of information between actors in the system (Suresh Kumar, 2021). Digital solutions enable accurate recording of quantities and types of organic waste, improvement of logistics, as well as raising user awareness through applications and information systems (Onur et al., 2024). IoT sensors, for example, enable monitoring of waste levels in containers and optimization of garbage collector routes, while AI and big data analytics can predict resource consumption patterns and improve process optimization (Fuqaha and Nursetiawan, 2025). Blockchain technology enables transparency and tracking of material flows throughout the value chain, making waste systems more reliable and resistant to manipulation (Faiz et al., 2024). In this way, digitalization contributes to transparency, efficiency and data-based decision-making, which is crucial for the successful implementation of the principles of the circular economy.

One of the key policy frameworks in the European Union that integrates the principles of the circular economy and waste management is the European Green Deal. This strategy aims to transform the EU economy into a climate-neutral one by 2050, promoting circular practices, renewable energy sources, biodiversity protection and innovation in resource management. Within the Green Deal, there are a number of initiatives that support the goals of circular use of materials and less waste, including mandatory recycling targets and the integration of digital tools into waste management systems.

The goal of this research is to review the role of the circular economy in the management of organic biowaste, with a special focus on the potential of digital solu-

tions in improving these processes. The research aims to identify the key challenges and possibilities of applying circular models in practice, as well as to point out the importance of integrating digital tools into waste management systems. The importance of research is reflected in the contribution to the understanding of sustainable approaches to the management of organic biowaste, as well as in the possibility of applying the obtained results in the creation of policies, strategies and practical solutions in the field of environmental protection and sustainable development.

METHODOLOGY

The research is based on a qualitative methodological approach that includes the analysis of relevant scientific and professional literature, as well as the study of selected examples of good practice in the field of circular economy and organic biowaste management. The literature analysis includes a review of contemporary scientific works, reports of international organizations and strategic documents related to the principles of the circular economy, biowaste management and the application of digital technologies in this sector. In addition to theoretical analysis, the methodology also includes the application of case studies, with the aim of looking at concrete models of the application of digital solutions in practice. Special attention is devoted to the analysis of digital platforms for monitoring and optimizing waste flows in urban areas, the application of smart composters, as well as the development of mobile applications aimed at reducing food waste. The selected examples enable the identification of the key advantages, challenges and potential of digitalization in improving the efficiency of organic biowaste management, as well as the evaluation of their compliance with the principles of the circular economy.

RESULTS AND DISCUSSION

The analysis of available literature and case studies indicates that digitization has a particularly significant role in improving the management of organic biowaste in hotels and restaurants, which represent one of the largest generators of organic waste in the service sector. The application of digital solutions in this segment enables more efficient management of resources, reduction of operating costs and improvement of business sustainability (Table 1).

Table 1. Digital tools in bio-waste management

Technology / Tool	Description	Examples	Application in Bio-Waste
IoT sensors and smart bins	Devices that measure quantity, type of waste, temperature, and humidity	SmartBin, Enevo	Monitoring container fill levels, collection optimization, composting supervision
Mobile and web applications	Software for citizens, restaurants, and hotels to manage waste	Too Good To Go, Winnow, Leanpath	Reducing food waste, user education, analysis of generated waste
Blockchain systems	Decentralized database for transparent waste tracking	Plastic Bank (used for plastic), EU pilot projects	Tracking bio-waste flow from source to processing, process certification
Big Data and AI analytics	Tools for collecting and analyzing large datasets	IBM Environmental Intelligence Suite, municipal systems	Predicting waste quantities, optimizing truck routes, analyzing habits
Computer Vision	Cameras and algorithms for automatic waste recognition	Greyparrot, AMP Robotics	Automated waste sorting, detection of organic material
Digital tools for education and gamification	Learning platforms, apps with rewards	EcoChallenge, AR/VR education	Raising citizen awareness, motivating proper waste separation
Software in agriculture and industry	Specialized tools for monitoring production residues	FarmWaste Tracker, AgroWaste Management	Managing agricultural waste, connecting with bioenergy
IoT sensors and smart bins	Devices that measure quantity, type of waste, temperature, and humidity	SmartBin, Enevo	Monitoring container fill levels, collection optimization, composting supervision
Mobile and web applications	Software for citizens, restaurants, and hotels to manage waste	Too Good To Go, Winnow, Leanpath	Reducing food waste, user education, analysis of generated waste
Blockchain systems	Decentralized database for transparent waste tracking	Plastic Bank (used for plastic), EU pilot projects	Tracking bio-waste flow from source to processing, process certification

Source: Author's research

Reducing the amount of organic waste in hotels and restaurants: Digital tools for inventory management and meal planning allow hotels and restaurants to more accurately track the procurement, storage and consumption of food. Software solutions and mobile applications that record amounts of wasted food, expiration dates and consumption patterns contribute to the identification of critical points in the generation of waste. The results of the case studies show that facilities that use digital waste monitoring systems achieve a significant reduction in food waste, especially in the preparation and serving stages, which directly affects the reduction of the amount of organic waste.

Optimizing the logistics of collecting bio-waste from catering establishments: The application of IoT sensors and smart containers in hotels and restaurants enables monitoring the occupancy of bio-waste containers in real time. This approach allows utilities and operators to optimize the schedule and frequency of waste collection, thereby reducing unnecessary vehicle departures and logistics costs. Digitization of logistics also contributes to better hygiene in catering facilities, as it prevents overfilling of containers and reduces the risk of unpleasant odors and contamination.

Table 2. Reduction of bio-waste by type of object using digital technologies; Case of selected objects

Type of object	Digital technology	Percentage of waste reduction	Source
Hotels / HORECA (Germany, Switzerland, Greece)	AI waste tracking system	23–51 %	Sigala et al., 2025
IHG хотели (EMEA регион)	Winnow Vision AI	~30 %	https://hospitalitytech.com/ai-technology-helps-ihg-hotels-track-measure-and-reduce-food-waste?utm_source=chatgpt.com
Marriott Hotels (UK, Ireland, Nordics)	Winnow AI	~25 %	Adams, 2024 https://fooddigital.com/restaurants/marriott-hotels-ai-technology-leads-to-food-waste-reduction?utm_source=chatgpt.com
Mandarin Oriental (4 пилот хотела)	AI technology	~36 %	Mandarin Oriental Embraces Artificial Intelligence for Food Waste Reduction for Luxury Hospitality https://www.hotelnewsresource.com/article131819.html
Novotel London Excel	AI waste measurement	~39 %	Food Waste: AI Supporting Accor Hotels https://www.hotelnewsresource.com/article128394.html

Fairmont Jakarta	AI waste measurement	~16 %	Food Waste: AI Supporting Accor Hotels https://www.hotelnewsresource.com/article128394.html
Hilton Tokyo Bay	AI & Waste Analytics	~30 %	Tackling Food Waste In Hospitality With AI https://www.businesstoday.com.my/2024/08/22/savoring-sustainability-hotels-in-asia-pacific-tackling-food-waste/?utm_source=chatgpt.com
IHG хотели (EMEA регион)	Winnow Vision AI	~30 %	AI Technology Helps IHG Hotels Track, Measure and Reduce Food Waste https://hospitalitytech.com/ai-technology-helps-ihg-hotels-track-measure-and-reduce-food-waste?utm_source=chatgpt.com

Source: Author's research

Raising awareness and changing the behavior of employees and guests: Digital platforms and applications intended for hotels and restaurants have an important educational role. Through digital interfaces, employees can be trained for proper waste separation, rational food preparation and application of circular economy principles (Radović et al., 2025). At the same time, hotels increasingly use digital tools to inform guests about sustainable practices, such as reducing food waste in buffet systems or the possibility of donating surplus food (Simões et al., 2023; Green, 2025). Such approaches contribute to strengthening environmental awareness and improving the image of facilities as socially responsible.

Development of bioenergy solutions in the hospitality sector: Organic biowaste from hotels and restaurants represents a stable and predictable source of raw material for bioenergy plants, especially for biogas production. Digital systems enable precise monitoring of the amount and composition of biowaste originating from catering facilities, which contributes to better planning and more efficient plant operation (Simões et al., 2023). In some cases, larger hotel complexes apply decentralized solutions, such as smaller digesters or smart composters, whose operation relies on digital monitoring and process automation (da Costa et al., 2023).

Barriers in the application of digital solutions in hotels and restaurants

Despite numerous advantages, the application of digital technologies in hotels and restaurants faces certain limitations. The most commonly identified barriers include high initial costs of acquiring and implementing digital systems, insufficiently developed infrastructure for separate collection of biowaste, as well as low digital literacy of employees (Mohd Rahman et al., 2024). An additional challenge is resistance to changes in established work processes, especially in smaller catering establishments with limited financial and personnel resources. The results indicate that digitization

can play a key role in the transformation of hotels and restaurants towards more sustainable and circular business models. The analysis of available literature and case studies shows that digital solutions, including IoT sensors, smart containers, mobile and web applications, blockchain systems, big data and AI analytics, enable accurate monitoring of quantities and types of organic waste, optimization of collection logistics, reduction of operational costs and improvement of business sustainability. These tools especially contribute to the reduction of food waste in the stages of preparation and serving, which directly affects the reduction of total organic waste in the catering sector (Stoica et al., 2023). The application of digital technologies in hotels and restaurants enables the optimization of biowaste collection logistics. IoT sensors and smart containers enable real-time occupancy monitoring, which allows utilities and operators to plan the route and frequency of pickup more efficiently, reducing unnecessary vehicle departures and logistics costs. At the same time, digital solutions improve hygiene in facilities, prevent overfilling of containers and reduce the risk of unpleasant odors and contamination.

Digital tools also play an important educational role, raising awareness and changing the behavior of employees and guests. Platforms and applications enable training of employees for proper waste separation, rational food preparation and application of circular economy principles. Hotels and restaurants increasingly use digital channels to inform guests about sustainable practices, such as reducing food waste in buffet systems or donating surplus food (Simões et al., 2023; Radović et al., 2025). These approaches strengthen environmental awareness and contribute to a positive image of the facilities as socially responsible. The application of digitization enables the development of bioenergy solutions in the hospitality sector. Organic biowaste from hotels and restaurants is a stable and predictable source of raw material for biogas production or composting. Digital systems allow monitoring the amount and composition of waste, which contributes to better planning and more efficient operation of bioenergy plants (Papargyropoulou et al., 2014). Some larger hotel complexes apply decentralized solutions, such as smaller digesters or smart composters, whose operation is integrated with digital monitoring and automation.

Despite the obvious advantages, the implementation of digital technologies in hotels and restaurants faces certain barriers. The most significant include high initial acquisition and implementation costs, insufficiently developed infrastructure for separate collection of biowaste, low digital literacy of employees and resistance to changes in established work processes, especially in smaller facilities with limited financial and personnel resources (Filimonau and De Coteau, 2019;). These barriers indicate the need for additional education, support through financial incentives and the development of appropriate infrastructure in order to enable a wider and more effective application of digital solutions in hospitality. The integration of digital technologies with the principles of the circular economy enables the hospitality sector to reduce the negative impact on the environment, improve business efficiency and respond to the growing expectations of environmentally conscious consumers. The

results of the case studies clearly show that digitization not only contributes to operational and economic efficiency, but also strengthens the environmental and social responsibility of hotels and restaurants, making them key actors in the development of sustainable and circular business models in the service sector.

CONCLUSION

Literature analysis and case studies show that digitalization is a key factor in improving the management of organic biowaste in hotels and restaurants, which are one of the largest generators of this type of waste in the service sector. The application of IoT sensors, smart containers, mobile and web applications, blockchain systems, big data analytics and AI tools enables precise monitoring of quantities and types of biowaste, optimization of collection logistics, reduction of food waste and better education of employees and guests. The integration of digital technologies with the principles of the circular economy enables the hospitality sector to reduce the negative impact on the environment, increase operational efficiency and improve social responsibility. At the same time, there are significant barriers in the implementation of digital solutions, including high initial costs, insufficiently developed infrastructure and low digital literacy, which indicates the need for additional education, financial support and the development of adequate infrastructure.

In the future, the wider application of digital tools can enable hotels and restaurants not only to operate more sustainably, but also to play an active role in circular flows of resources, creating a model that combines economic efficiency, environmental responsibility and guest satisfaction. The research results confirm that digitization represents a necessary step towards the transformation of the hospitality sector into a sustainable and environmentally conscious system.

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