

Harnessing Artificial Intelligence (AI) to Mitigate Food Waste: Innovative Strategies for Sustainable Consumption

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ABSTRACT

The capacity of artificial intelligence (AI) to transform food waste management is rooted in its capability to analyse extensive data sets and enhance processes throughout the food supply chain. Despite the potential of AI to transform food waste management, many organisations and consumers remain uninformed about its capabilities and the innovative strategies it can provide to effectively reduce food waste. This study aimed to review innovative strategies for sustainable consumption by harnessing AI to mitigate food waste. This study employed a review analysis as a methodological approach to synthesise existing literature on the intersection of AI and food waste management. The review analysis revealed several innovative strategies for sustainable consumption by harnessing AI to mitigate food waste, including: (a) smart inventory management; (b) recipe suggestions based on available ingredients; (c) automated waste tracking; (d) predictive analytics for meal preparation; and (e) consumer behaviour insights. In conclusion, utilising AI to reduce food waste offers a viable strategy for promoting sustainable consumption practices throughout the food supply chain. Future research should prioritise longitudinal analyses to assess the long-term effectiveness of AI interventions across sectors including agriculture, retail, and hospitality.

Contribution/Originality: This study adds to the existing literature on innovative strategies for sustainable consumption, specifically the use of AI to mitigate food waste. This study made a valuable contribution to the body of knowledge regarding the importance of using AI to reduce food waste as a strategy for sustainable consumption practices.

1. Introduction

The capacity of artificial intelligence (AI) to transform food waste management is rooted in its capability to analyse extensive data sets and enhance processes throughout the food supply chain. Utilising machine learning algorithms enables AI to enhance demand prediction accuracy, consequently minimising overproduction and spoilage (Ozcil, 2024). Furthermore, AI technologies can improve inventory management by facilitating the tracking of food freshness and effectively reducing waste. Innovative applications, including smart bins that detect and measure discarded food, yield significant insights into waste patterns, enabling organisations to adopt targeted reduction strategies. AI enhances operational efficiency and promotes sustainable food consumption, thereby substantially reducing the environmental consequences of food waste (Onyeaka et al., 2023). The increasing adoption of AI-driven solutions necessitates collaboration among stakeholders to share best practices, thereby maximising the benefits of these technologies throughout the food supply chain.

Despite the potential of AI to transform food waste management, many organisations and consumers remain uninformed about its capabilities and the innovative strategies it can provide to effectively reduce food waste. AI improves operational efficiency, optimises resources, and reduces costs in sustainable agriculture and waste management. However, challenges such as infrastructure limitations and societal resistance need to be addressed to realise its full potential (Hernandez et al., 2024). The current landscape indicates a notable disparity between the accessibility of AI technologies and their implementation in practices designed to minimise waste throughout the food supply chain. Factors including a limited understanding of AI applications, resistance to change, and fragmentation within the food industry impede the integration of these technologies into daily operations and consumer behaviours (Cubric, 2020). It is essential to investigate the potential of AI in developing targeted solutions for food waste reduction, promoting sustainable consumption, and establishing a more efficient and responsible food system.

This study presents several advantages, especially in improving resource efficiency and minimising environmental impact (Waltersmann et al., 2021). Integrating AI technologies allows stakeholders to obtain insights into consumption patterns and waste generation, facilitating informed decisions that optimise food production and distribution processes. This approach minimises surplus and spoilage while promoting a circular economy through the effective reuse and repurposing of resources (Tutore et al., 2024). This review can identify best practices and successful case studies, thereby facilitating knowledge sharing between businesses and consumers. This approach fosters a sustainable food system by tackling food waste and addressing the broader issues of resource depletion and climate change.

1.1. Research Objectives

This study aimed to review innovative strategies for sustainable consumption by harnessing AI to mitigate food waste.

2. Literature Review

The integration of AI in food waste management offers a significant opportunity to address a critical global issue: food waste. Approximately one-third of food produced for

human consumption is wasted annually, resulting in significant implications for economic, social, and environmental sustainability. Addressing this issue necessitates integrated solutions, technological advancements, and collaborative efforts (Urugo et al., 2024). AI technologies can improve food waste reduction strategies in agriculture, retail, and hospitality by optimising processes, enhancing decision-making, and promoting sustainable consumption behaviours.

AI can be utilised in the agricultural sector to improve food processing operations, including sorting, grading, and defect detection in food products (Taneja et al., 2023). Machine learning algorithms enable farmers to predict crop yields with greater accuracy, thereby reducing overproduction and minimising waste (Van Klompenburg et al., 2020). AI and IoT are transforming agriculture through the optimisation of resource utilisation, enhancement of crop yields, and improvement of livestock health monitoring. These advancements ensure that food is harvested at peak freshness, thereby significantly reducing spoilage during transportation and storage (Hussein et al., 2024). This predictive capability reduces waste and enhances resource allocation, thereby fostering a more sustainable food system.

AI technologies in retail enhance inventory management and demand forecasting, which are essential for reducing food waste. Retailers can analyse purchasing patterns and consumer behaviour to optimise stock levels, thereby minimising the risk of overstocking and associated waste (Trevisan & Formentini, 2024). AI-driven demand forecasting, utilising advanced algorithms and machine learning models, enhances inventory optimisation, reduces costs, and improves customer satisfaction, thereby minimising waste (Amosu et al., 2024). Furthermore, AI can facilitate the implementation of a quality-based pricing strategy, resulting in lower prices, increased demand, enhanced profits, and decreased food waste, while information disclosure helps align customers' biased perceptions of food quality (Yang et al., 2022).

The hospitality sector is poised to gain substantial advantages from the integration of AI. AI can be employed to track food waste produced in restaurants and cafeterias, offering insights into waste patterns and pinpointing areas for enhancement (Wu & Tai, 2024). AI systems can monitor food waste during meal preparation and service, allowing managers to modify portion sizes and menu options according to actual consumption data (Gómez-Talal et al., 2024). AI can improve staff communication concerning food waste reduction strategies, thereby promoting a culture of sustainability in the workplace (Luu, 2020). Utilising AI through enhanced learning and training programs can replicate food waste scenarios that effectively instruct employees on optimal practices for waste reduction (Pilarski et al., 2023).

Consumer behaviour significantly influences food waste generation, and AI can be crucial in fostering sustainable consumption practices. AI-driven applications offer personalised recommendations to consumers, facilitating more effective meal planning and creative use of leftovers (Reyes et al., 2024). Mobile applications can notify users of food items approaching expiration and recommend recipes utilising these ingredients, thus minimising waste. AI can analyse consumer feedback and preferences to customise educational campaigns that align with specific demographics, thereby promoting a more environmentally conscious consumer base.

Moreover, the significance of education in reducing food waste is substantial. AI-driven programs that assess the effectiveness of educational interventions can identify the most

impactful strategies for increasing awareness of food waste (Chen & Chen, 2018). Research indicates that targeted messaging campaigns can markedly affect consumer attitudes regarding food waste reduction (Kim et al., 2020). Utilising AI to evaluate the effectiveness of these campaigns allows stakeholders to refine strategies and improve impact. This ensures that messages centred on potential losses—such as increased environmental damage—or gains—such as reduced environmental harm—resonate more effectively and motivate individuals to reduce food waste (Septianto et al., 2020).

Besides consumer education, AI can enhance collaboration among stakeholders within the food supply chain. AI facilitates data sharing and communication, thereby enhancing transparency and accountability. This enables stakeholders to collaborate more effectively in reducing food waste, which can contribute to sustainable and responsible business models (Arowosegbe et al., 2024). Food banks and charities can employ AI to enhance logistics and distribution, ensuring surplus food is redirected to those in need instead of being wasted (Elamin, 2024). This collaborative approach addresses food waste and contributes to food security, especially in underserved communities (Nwokediegwu & Ugwuanyi, 2024).

The capacity of AI to facilitate food waste reduction transcends individual behaviours and organisational practices, incorporating wider policy implications as well. Policymakers can utilise AI analytics to address various solid waste management challenges, such as predicting waste characteristics, detecting bin levels, and forecasting process parameters (Abdallah et al., 2020). AI can assess the effects of regulations designed to minimise food waste across different sectors, offering insights that can guide future policy decisions (Fesenfeld et al., 2022). Integrating AI into food waste governance enables policymakers to formulate more effective strategies that align with sustainability objectives and address the complex nature of food waste.

While AI holds significant promise for reducing food waste, various challenges need to be addressed to fully harness its advantages. Data privacy and security concerns are critical, as the effective implementation of AI technology can extract sensitive personal information from extensive overlapping granular data sets, raising privacy issues and questions regarding the sufficiency of current privacy legislation (Carmody et al., 2021). Collecting and utilising data ethically is crucial for sustaining consumer trust and promoting the widespread adoption of AI-driven solutions. The digital divide is a critical factor, as stakeholders may not possess equal access to the technology and resources required for the effective implementation of AI solutions.

Furthermore, the effective integration of AI in food waste management necessitates collaboration among government, industry, and academia. Interactions among stakeholder networks are essential for effective food waste management strategies. Diverse coalitions demonstrate greater efficacy than single-stakeholder partnerships (Ghinoi et al., 2020), particularly when utilising AI solutions designed for specific contexts. Fostering a collaborative ecosystem enables stakeholders to utilise their combined expertise to tackle the intricate issues related to food waste and effect significant change.

In summary, utilising AI to reduce food waste offers a complex opportunity to improve sustainability within food systems. Optimising agricultural practices, enhancing retail inventory management, and encouraging responsible consumer behaviours can lead to a significant reduction in food waste throughout the supply chain. Realising this potential

necessitates addressing challenges associated with data privacy, equity, and collaboration among stakeholders. The global community is addressing the implications of food waste, and the integration of AI technologies presents a viable approach to achieving a sustainable and equitable food future.

3. Research Methods

This study employed a review analysis as a methodological approach to synthesise existing literature on the intersection of AI and food waste management. The review concentrated on topics including “artificial intelligence,” “food waste,” “sustainable consumption,” “machine learning,” and the “food supply chain.” Databases pertinent for literature sourcing comprised academic platforms including Google Scholar, ResearchGate, and ScienceDirect. The inclusion criteria consisted of peer-reviewed articles published in the past decade that focused on the use of AI in food waste reduction, innovative approaches to sustainable consumption, and empirical studies showcasing the effectiveness of AI technologies across sectors such as agriculture, retail, and hospitality. This study consolidates findings from various studies to offer actionable insights for policymakers and industry stakeholders dedicated to advancing sustainable practices in food management.

The review analysis process comprised several systematic steps. A comprehensive search was conducted using the identified keywords across selected databases, followed by screening titles and abstracts to filter relevant studies. Full-text articles were subsequently evaluated for eligibility according to the established inclusion and exclusion criteria. Data extraction emphasised essential themes, methodologies, findings, and implications concerning AI's contribution to reducing food waste. The analysis utilised qualitative synthesis methods to discern patterns and gaps in the literature, enhancing the understanding of how AI can be utilised to advance sustainable consumption practices. The review also emphasised innovative strategies and case studies that demonstrated successful AI applications in food waste management, establishing a basis for future research and practical applications. This review systematically analyses the existing body of knowledge to provide insights into the potential of AI technologies for promoting a sustainable food system.

4. Results and Discussion

The review analysis revealed several innovative strategies for sustainable consumption by harnessing AI to mitigate food waste, including: (a) smart inventory management; (b) recipe suggestions based on available ingredients; (c) automated waste tracking; (d) predictive analytics for meal preparation; and (e) consumer behaviour insights.

4.1. Smart Inventory Management

AI can enhance inventory management in restaurants and grocery stores through improved demand forecasting. Through the analysis of historical sales data and trends, AI systems can aid businesses in optimising food inventory, thus minimising surplus that could result in waste. Effective inventory management utilising AI and IoT technologies is essential for reducing food waste and encouraging sustainable consumption. AI improves the precision of demand forecasting, facilitating optimised inventory levels that decrease surplus stock and minimise waste (Adegbola et al., 2024; Kim et al., 2022). IoT-enabled systems, including smart shelves with RFID and weight sensors, enable

real-time inventory tracking, which aids in timely restocking and minimises stockouts (Rejeb et al., 2019). The integration of technologies streamlines operations and enhances transparency and efficiency within the supply chain (Zhao et al., 2023; Jarašūnienė et al., 2023).

Furthermore, the implementation of blockchain technology enhances traceability and accountability within food supply chains, consequently improving food safety and minimising waste (Wang et al., 2022; Chelh, 2023). These innovative strategies significantly enhance sustainable consumption practices by ensuring effective management of food products throughout their lifecycle, thereby reducing environmental impact (Mondol, 2021; Azevedo et al., 2021). The integration of AI with blockchain technology facilitates real-time monitoring of food products, allowing stakeholders to respond swiftly to potential issues like spoilage or contamination. This proactive strategy enhances food safety and reduces the probability of surplus inventory, a common factor in food waste. The integration of AI and blockchain enhances supply chain transparency and efficiency, enabling consumers and businesses to make informed decisions that support sustainability and minimise environmental impact.

4.2. Recipe Suggestions Based on Available Ingredients

AI-driven applications can aid consumers by recommending recipes based on the ingredients available in their households. This reduces the likelihood of food being overlooked and wasted, as users are prompted to use existing supplies before acquiring additional items. The incorporation of AI in advancing sustainable consumption and reducing food waste is increasingly acknowledged as an effective approach. AI technologies can promote mindful consumption patterns, enabling consumers to make informed choices that minimise waste (Del Prete, 2022). Educational initiatives that include discussions on food systems, particularly in university settings, have demonstrated the potential to promote sustainable consumption behaviours among students (Herrera Burstein & Goñi Avila, 2024). The implementation of AI-driven platforms can improve consumer engagement through personalised recommendations derived from available ingredients, thereby reducing food waste (Somlai, 2023).

Moreover, the concept of a circular economy highlights the significance of reusing and recycling food products, a process that is effectively enhanced by AI systems that monitor inventory and propose recipes for surplus ingredients (Santos-Corrada et al., 2024). Utilising AI to enhance sustainable practices addresses overconsumption and food waste, thereby contributing to a more sustainable food system (Frehner et al., 2022). The incorporation of AI within the circular economy improves food management and promotes innovation across multiple sectors. AI facilitates the optimisation of supply chains by analysing consumption patterns and predicting demand, thereby minimising excess production and waste. The collaboration between AI and the circular economy can enhance the resilience of the food system, enabling adaptation to changing environmental conditions and ensuring food security for future generations.

4.3. Automated Waste Tracking

AI technologies can be utilised for the real-time monitoring and analysis of food waste. Systems utilising image recognition can accurately identify and record the types and quantities of food waste, yielding data that can enhance purchasing and consumption

strategies. AI-driven solutions in agriculture enhance efficiency, minimise waste, and foster environmental responsibility within the food supply chain (Anwar et al., 2023). Additionally, they improve sustainability and cost savings by facilitating real-time tracking and analysis of environmental impact (Ameah, 2024). The integration of AI in waste management systems offers innovative strategies for reducing food waste and promoting sustainable consumption. AI-driven waste management systems can optimise resource allocation and enhance operational efficiencies in restaurants and food services, resulting in cost reductions and improved brand reputation (Gao et al., 2024).

Moreover, the integration of AI with the Internet of Things (IoT) enables real-time monitoring and data analysis, which assists stakeholders in identifying waste patterns and executing targeted interventions (Nwokediegwu et al., 2024). This approach addresses immediate food waste challenges and contributes to sustainability and the circular economy by maximising resource efficiency (Ouro Salim et al., 2021). The system employs IoT and AI technologies, incorporating embedded sensors and machine learning, to classify and quantify food waste in real-time. This approach effectively minimises food wastage and operational costs, thereby enhancing financial performance (Mehta, 2024). Leveraging AI for waste tracking is essential for achieving sustainable consumption practices. The integration of AI and IoT technologies enhances collaboration among stakeholders, including consumers, businesses, and policymakers, thereby fostering a collective effort towards waste reduction. These technologies facilitate actionable insights and enhance transparency in waste management processes, enabling individuals and organisations to adopt more sustainable behaviours and practices.

4.4. Predictive Analytics for Meal Preparation

In contexts such as airlines or catering services, AI can forecast meal requirements by analysing passenger bookings and historical data. This facilitates accurate meal preparation, thereby substantially decreasing food waste production. Predictive analytics in meal preparation can effectively reduce food waste by utilising AI to enhance food consumption patterns. The Theory of Planned Behaviour (TPB) has been utilised to analyse the psychological factors affecting intentions to reduce food waste. It identifies attitudes, subjective norms, and perceived behavioural control as significant predictors of waste-reducing behaviours (La Barbera et al., 2022; Blešić et al., 2021; Tsai et al., 2020). Predictive models have demonstrated effectiveness in forecasting household food waste, especially among families with children, through the analysis of socio-economic and food-related behaviours (Tonini et al., 2023).

AI-driven solutions, including meal booking systems, improve demand planning in food services, leading to a reduction in overproduction and waste (Chen, 2023). Moreover, incorporating environmental awareness into predictive models can enhance intentions to minimise food waste, as individuals with greater environmental consciousness typically demonstrate more sustainable consumption behaviours (Faezirad et al., 2021; Purwanto et al., 2023). Utilising these innovative strategies enables stakeholders to promote sustainable consumption patterns and substantially reduce food waste across multiple sectors. The integration of AI technologies with consumer behaviour insights can enhance intervention effectiveness, thereby fostering a culture of sustainability in the food industry. With the rising awareness of food waste issues, the implementation of AI-driven solutions is expected to play a crucial role in fostering responsible consumption practices. This transition enhances environmental sustainability while

promoting economic resilience through optimised resource utilisation and decreased waste management costs.

4.5. Consumer Behaviour Insights

AI can analyse consumer behaviour patterns to identify trends in food purchasing and waste. Understanding these patterns enables businesses to customise their marketing strategies and product offerings to better align with consumer needs, thereby reducing food waste at the consumer level. The incorporation of AI in food waste management offers novel approaches to promote sustainable consumption. AI technologies can enhance food production and distribution processes, thus reducing waste at multiple stages of the food supply chain (Liu et al., 2023). AI can improve inventory management in restaurants by minimising overproduction and facilitating more accurate forecasting of consumer demand (Trabelsi et al., 2023). AI-driven analytics can provide consumers with insights into their purchasing habits and food expiration dates, thereby encouraging more responsible consumption behaviours (Jones-Garcia et al., 2022; Fadji et al., 2023).

Research demonstrates that consumer engagement is essential for the effective mitigation of food waste. Analysing the psychological and behavioural factors that affect food waste can inform targeted interventions, including educational campaigns and smart technologies designed to prompt consumers to use leftovers (Vittuari et al., 2020). Moreover, cultivating a sense of community and shared responsibility among consumers can improve collective action against food waste (Pong, 2021; Shaw et al., 2018). Leveraging AI enhances operational efficiency and enables consumers to make informed choices, thereby contributing to a more sustainable food system. The integration of social media platforms can enhance these efforts by establishing networks that promote the sharing of tips and resources for food waste reduction. Increased consumer engagement and awareness are likely to result in the adoption of more sustainable practices, thereby significantly reducing food waste at both individual and community levels.

5. Conclusion

In conclusion, utilising AI to reduce food waste offers a viable strategy for promoting sustainable consumption practices throughout the food supply chain. The integration of AI technologies has shown considerable potential in optimising agricultural processes, improving inventory management in retail, and encouraging responsible consumer behaviours. Utilising machine learning algorithms and data analytics enables stakeholders to make informed decisions that reduce waste and enhance resource allocation and food security. This research paper highlights that innovative strategies, including predictive analytics, dynamic pricing, and tailored consumer applications, can effectively address the complex challenges associated with food waste. To fully realise these benefits, it is essential to address the challenges related to data privacy, equity in technology access, and the necessity for collaboration among diverse stakeholders. The effective implementation of AI-driven solutions can facilitate a more sustainable and equitable food system, supporting broader environmental objectives and improving societal resilience in response to the escalating global food waste crisis.

Future research should prioritise longitudinal analyses to assess the long-term effectiveness of AI interventions across sectors including agriculture, retail, and

hospitality. Interdisciplinary approaches that integrate insights from behavioural science may improve the understanding of consumer attitudes towards AI-driven solutions and their willingness to participate in sustainable consumption practices. Research should examine the implications of data privacy and security concerns, analysing how these factors affect the adoption of AI technologies across various demographics and regions. Additionally, conducting comparative studies to evaluate the effects of AI applications across various cultural contexts would enhance the understanding of global food waste challenges. Further exploration of collaborative frameworks among stakeholders, including food banks, policymakers, and technology developers, may produce innovative strategies to enhance the effectiveness of AI in food waste reduction initiatives, thereby contributing to a more sustainable food system.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest concerning the research, authorship, or publication of this article.

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