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Review

Role of technology in food waste: A state of the art science mapping on past and future trends

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Abstract

The present review evaluated the knowledge structure of food waste reduction behaviour through digital technology. As climate change has become a monumental topic in sustainability development, intervention in human consumption, including food wastage, has become crucial. Through a bibliometric analysis, the present review adopted bibliographic coupling and co-word analysis to reveal the current, emerging, and future trends in food waste behaviour. Past themes related to challenges of food waste management, technological approach in food waste management, and determinants of food waste behaviour among consumers. Future trends related to lifecycle management of food waste technologies and food waste in municipal solid waste management. The findings of the present review would be beneficial to researchers and practitioners of food waste management in reducing the impact of food waste among consumers. The present review also corroborated the crucial role of technology in food waste reduction management.

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Introduction

Humans need food to live and survive. Food plays an imperative role in our lives, not only for nutrients, fuel, and sustenance, but also as a social interaction between human beings through social connections (Marwood *et al*., 2023). However, some do not appreciate the value of food, and tend to waste it. An estimated one-third of manufactured foods are wasted or disposed of, costing an estimated $400 billion annually (Srivastava *et al*., 2023). Food waste impacts the environment and economy as it involves high energy consumption. Food waste occurs when edible foods intended for human consumption are discarded due to food service providers' and consumers' purchasing decisions (Aloysius *et al*., 2023).

Food waste can be categorised into three types (Dhir *et al*., 2020): (1) avoidable waste, which refers to food that is edible but has become inedible at a certain time; (2) unavoidable waste, which refers to certain items that are inedible, *i.e*., eggshells; and (3) potentially avoidable food waste, which refers to certain waste that can be consumed at times but not always, such as apple and potato skins. Understanding the types of food waste based on cultural values through consumer behaviour would enable researchers to understand the tacit reason why certain people waste food. The United Nations Food and Agriculture Organization (FAO) estimates that the waste amount is around one-third of the global food produced for human consumption (Bräutigam *et al*., 2014). The European Food Information Council (EUFIC) calculated that in 2019, approximately 931 million tons of food were wasted worldwide, which rose to 1.3 billion tons in 2021 (Ramanathan *et al*., 2023). Developing Asian nations show a steady increase in food waste production from ongoing economic and population growth (Bhatti *et al*., 2023). Conversely, between 720 and 811 million people are facing hunger worldwide in 2020 (FAO, 2021), and the global demand for food (quantified in total calories) is projected to increase by 55% from 2010 to 2050 (Searchinger *et al*., 2019). This worldwide

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issue, if viewed through the lens of food security, conflicts with the Sustainable Development Goal (SDG), and demands immediate attention.

One of the best ways to reduce food waste is through an awareness and intervention approach (Oehman *et al*., 2022). This includes educating consumers on the meaning of food labels that can prevent discarding food due to confusion and misunderstanding of food shelf life (van der Werf *et al*., 2019). Other awareness approaches include educational campaigns and media promotions (Hodgkins *et al*., 2019). Consumers need to be educated on the impact of food waste, not only from economic reasons, but from environmental and social perspectives. Food waste leads to food-related global per capita greenhouse gas emissions by wasting water, land, and energy resources throughout the food chain (Principato *et al*., 2021). Hence, reducing food waste would reduce the impact of climate change (Reisch *et al*., 2021). Apart from awareness, there have been other various approaches to reduce food waste, which include storage to extend food life (van der Werf *et al*., 2019), planning for grocery shopping (Principato *et al*., 2021), and elevating food lifecycle with cosmetic defects (Oehman *et al*., 2022).

The motivation of the present review is two-fold. First, the importance of understanding food waste behaviour is impending. Schanes *et al*. (2018) suggested that food waste is a complex phenomenon attributed to many factors, leading to calls for comprehensive integration from multi-disciplinary perspectives. Understanding the factors and predictors of food waste is monumental in planning a mitigation and intervention plan to reduce food waste among consumers. Although many studies have focused on food waste from the consumer behaviour aspect, based on the authors' knowledge, there are yet to be studies investigating food waste behaviour from a technological point of view. The crucial role of technology in food waste minimisation has yet to be extensively studied (Martin-Rios *et al*., 2020). Technology serves to increase options for food waste valorisation (Lytras *et al*., 2021), evaluate the actual food waste (Wen *et al*., 2016), develop strategies to improve the minimisation and recovery of food (Agarwal *et al*., 2020), and develop awareness among consumers.

Second, there are limited review studies on food waste behaviour, and based on the authors' knowledge, there have been no studies applying the science mapping approach. Despite that, studies have provided a fundamental understanding of the current topic. This includes Schanes *et al*. (2018), who reviewed consumer food waste in the household by looking at social practice theory and psychology-related approaches. Kim *et al*. (2019) studied food waste reduction programs at the household level. Twenty-three programs were analysed based on social marketing domains, but only two food waste programs were social marketing programs, with the main challenge in the source-separation behaviour. In another study, Dhir *et al*. (2020) discovered the themes related to causes of waste generation, waste reduction, and leftover handling. Principato *et al*. (2021) presented a new theoretical framework of household wasteful behaviour to explain food waste behaviour at the household level. Simões *et al*. (2022) reviewed 96 papers on factors contributing to consumer food waste behaviour barriers and drivers. The study evaluated the intervention to change consumer behaviour to reduce food waste through a conceptual map.

Furthermore, Jia and Qiao (2022) presented a performance analysis of global food waste research using CiteSpace to uncover the scholarly impact based on countries, authors, and keywords. Based on a systematic review of 12 studies in Southeast Asia, Diana *et al*. (2023) discovered that household food waste behaviour was associated with food quality and safety, psychological factors, and consumer behaviour pertaining to purchasing, storage, and eating patterns. Srivastava *et al*. (2023) studied household food waste, and the theory of planned behaviour through a systematic review and meta-analysis. The finding discovered that the relationship between attitude and intention was the strongest, with subjective norm and intention coming in second and third, respectively. Aloysius *et al*. (2023) studied household leftover food waste generation behaviour and discovered themes related to socio-demographic, psycho-social, and lifestyle factors. Based on the authors' knowledge, there has yet to be a study on food waste reduction behaviour from the technology perspective through bibliometric analysis. Small- and large-scale technology management must be designed, developed, and implemented to treat food waste issues. Understanding the fundamental knowledge of food waste technology implementation allows researchers, practitioners, and stakeholders to develop policies and regulations to enhance procession technology integrating with economic, technical, and environmental impact considerations

(Farahdiba *et al*., 2023). Hence, to fill in the gap, the present review performed a science mapping approach to uncover the knowledge structure of the phenomenon through bibliometric analysis. The objectives of the present review were (i) to reveal the emerging and current themes on food waste reduction behaviour based on digital technologies and bibliographic coupling analysis, and (ii) to determine and predict future trends in food waste reduction behaviour through co-word analysis.

Methodology

Bibliometric approach

Bibliometric approach is a quantitative method that analyses bibliographic databases by a science mapping technique (Donthu *et al*., 2021). Bibliometric analysis applies objectivity to scientific evaluation by aggregating multiple opinions of scholars in a field (Zupic and Čater, 2015). There are two main approaches to bibliometric analysis: performance analysis and science mapping (Noyons *et al*., 1999). Performance analysis evaluates the impact, productivity, and temporal distribution of publications and citations based on the impact of journals, authors, institutions, and countries (Tiberius *et al*., 2020). Science mapping, on the other hand, depicts the visualisation of the linkage between published work to show the content-related outcome (Fauzi, 2023). Science mapping is the analysis of scientific knowledge reflected by the aggregated collection of past studies and intellectual contributions from the community of a specific field (Chen, 2017). To fulfil the research objectives, the following bibliometric approaches were applied:

i. Co-citation analysis: A technique of science mapping that assumes the publication being cited (co-cited) has similar themes (Donthu *et al*., 2021). The basis of co-citation analysis is that when the higher frequency of co-cited documents appears, the more likely the content of the papers is similar (Zupic and Cater, 2015). This analysis is useful for evaluating past influential publications throughout the field's history (Hota *et al*., 2020; Fauzi *et al*., 2023a).
ii. Co-word analysis: This analysis relies on the words within the publications' actual content (Donthu *et al*., 2021). The words can be derived from the title, abstract, and author keywords (Fauzi, 2023). Co-word analysis can forecast future research progress by evaluating notable words from the publication's implications and future research directions.

Research design and data collection procedure

We employed the following search string (Table 1) to identify publications based on relevant keywords. The keywords were searched based on three domains: food waste, reduction, and technology. The Web of Science (WoS) was applied as the bibliographic database, the most prominent and robust bibliographic database. WoS performed in terms of quality as it is more selective than other databases such as Scopus and Dimensions (Singh *et al*., 2021). The topic search (TS) option was applied in WoS to retrieve articles captured by the search string within the document title, abstract, and keywords. To ensure that top-quality works are included in the present review, only journal publications were included, limiting other publications such as conference proceedings, editorials, white papers, books, and book chapters. Such limitation is crucial so that the present review would only include empirical findings from quality publications to ensure robustness (Khaldi and Prado-Gascó, 2021; Fauzi, 2023). VOSviewer Version 1.6.19 was applied to perform the science map network visualisation. Compared to other bibliometric software such as Biblioshiny and CiteSpace, VOSviewer is the best at constructing and visualising bibliometric networks (Moral-Muñoz *et al.,* 2020). Biblioshiny and Citespace work best when performance analysis is performed rather than science mapping (Fauzi *et al.,* 2024; Zulkepeli *et al.,* 2024).

Results and discussion

The search in WoS was performed on 7 August 2023. The total number of publications related to the search string employed was 947. The number of citations was 21,909 and 21,265 (without self-citations). The average citation per item was 23.14, with a *h*-index of 69. Figure 1 depicts the number of publications and citations. The first publication emerged in 1993 but did not appear until 2007. The graph shows that the number of publications and citations increased steadily until the preparation/publication of the present review, and is expected to increase in the coming future.

Table 1. Search string in WoS database.

No.	Keyword	Justification
1	"food waste" OR "wasted food" OR "food to waste" OR "food loss"	To identify literature related to food waste and associated terminologies
2	"reduce" OR "decline" OR "minimise"	To identify literature related to the reduction behaviour of food waste
3	"digital" OR "technology"	To identify literature related to digital and technology

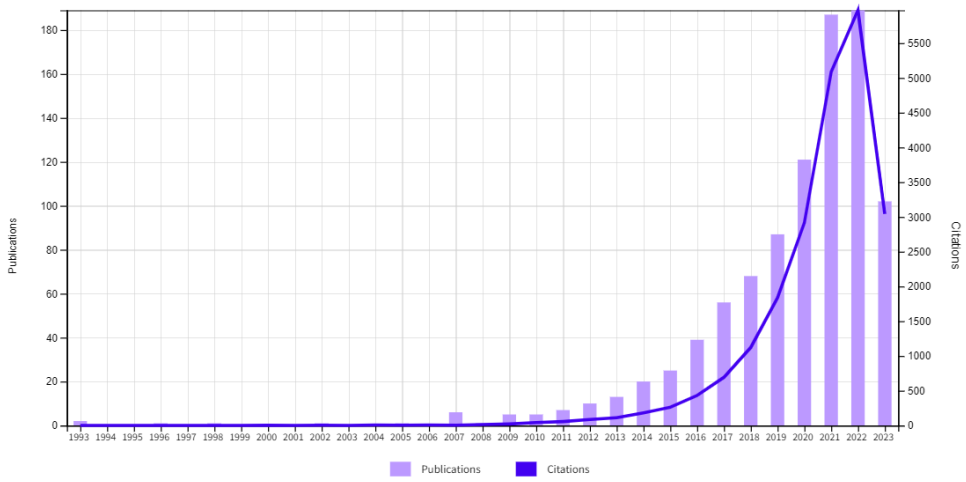

Figure 1. Number of publications and citations on food waste reduction and digital technology (source: Web of Science).

Co-citation

Out of the 46,444 cited references, 40 documents met a threshold of 16 citations. These 40 documents created three clusters. The top 3 documents based on total link strength (TLS) were Parfitt *et al*. (2010) (251 TLS), Gustavsson *et al*. (2011) (180 TLS), and Zhang *et al*. (2014) (87 TLS). The threshold was determined by several trials on the database to achieve a robust and suitable thematic network map visualisation. It must not be too high, causing over-filtering and missing crucial publications and thematic maps. At the same time, it should not be too low which may cause under-filtering and lead to cluster redundancy and insignificant themes (Geng *et al*., 2020). The top ten documents in co-citation analysis are presented in Table 2.

The network visualisation of co-citation is illustrated in Figure 2. The three clusters are visibly independent of one another, indicating unique thematic clusters of the past knowledge structure in the topic. The clusters were labelled based on inductive interpretation by revisiting representative articles in the clusters, and synthesised based on common themes and research streams presented. The following discusses the clusters based on the past and influential themes in food waste reduction and technology adaption:

i. Cluster 1 (red): With 15 documents, this cluster was labelled “Challenges of food waste management”. Managing food waste poses several barriers and challenges. Food waste was higher in developed countries than in developing countries (Papargyropoulou *et al*., 2014). One of the reasons is the lack of harvesting technologies, poor storage and lack of transport, and extreme climate conditions. According to Priefer *et al*. (2016), a rigorous approach should be implemented instead of the soft approach like round tables, awareness, and information platforms, such as suspending subsidies on food, economic incentives, and amendments to regulations. From 52 food-sharing cases, Michelini *et al*. (2018) suggested three models, including the

Table 2. Top ten documents in co-citation analysis.

No.	Reference	Scope	Source	Citation	Total link strength
1	Parfitt *et al.* (2010)	Food waste within food supply chains: Quantification and potential for change to 2050.	Philosophical Transactions of The Royal Society B: Biological Sciences	80	251
2	Gustavsson *et al.* (2011).	Global food losses and food waste.	Food and Agriculture Organization	70	180
3	Zhang *et al.* (2014).	Reviewing the anaerobic digestion of food waste for biogas production.	Renewable and Sustainable Energy Reviews	47	87
4	Thyberg and Tonjes (2016)	Drivers of food waste and their implications for sustainable policy development.	Resources, Conservation and Recycling	41	177
5	Papargyropoulou *et al.* (2014).	The food waste hierarchy as a framework for the management of food surplus and food waste.	Journal of Cleaner Production	39	141
6	Schanes *et al.* (2018)	Food waste matters - A systematic review of household food waste practices and their policy implications.	Journal of Cleaner Production	30	107
7	Zhang *et al.* (2007).	Characterisation of food waste as feedstock for anaerobic digestion.	Bioresource Technology	30	78
8	Food and Agriculture Organization (FAO) (2013)	Food wastage footprint: Impacts on natural resources.	Food and Agriculture Organization	29	87
9	Pham *et al.* (2015)	Food waste-to-energy conversion technologies: Current status and future directions.	Waste Management	26	79
10	Chen *et al.* (2008)	Inhibition of anaerobic digestion process: A review.	Bioresource Technology	25	36

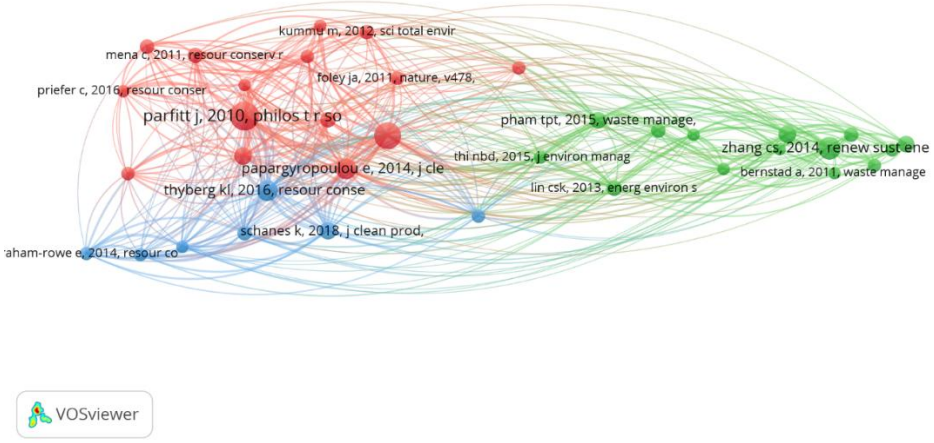

Figure 2. Co-citation of technology in food waste reduction.

sharing-for-money model, a B2C for-profit model to reduce food waste towards generating higher revenue; sharing charity model, where food collection management is given to non-profit organisations; and sharing for the community model, a P2P model by sharing food among consumers.

ii. Cluster 2 (green): With 14 documents, this cluster was labelled "Technological approach in food waste management". Xu *et al*. (2018) proposed multiple strategies to enhance food waste management technology using anaerobic digestion instead of traditional disposal methods of incineration, landfilling, and composting. These methods included control foaming, co-digestion, process design, and addition of micronutrients. Pham *et al*. (2015) synthesised the technologies used for food-waste-to-energy conversion involving thermochemical and biological technologies. Thi *et al*. (2015) suggested an integrative management system to face environmental and sanitary problems caused by food waste. The system comprised a public development program and waste resource recycling promotion program to achieve environmental treatment toward food waste through a zero-waste policy.

iii. Cluster 3 (blue): With seven documents, this cluster was labelled "Determinants of food waste behaviour among consumers". Understanding the determinants of food waste leads to better in-depth intervention to reduce food waste among the population. According to Quested *et al*. (2013), food waste behaviour is complex for several reasons. It is unrelated to waste prevention behaviour, and marks a habitual element toward emotion. Compared to other pro-environmental behaviour such as recycling, food waste has less 'visibility' to the public, for instance, neighbours. Schanes *et al*. (2018) suggested more specific attention to psychology-related and social practice theory towards different disciplinary perspectives. The determinants of food waste generation rely on understanding household practices to design food waste prevention and mitigation strategies. Graham-Rowe *et al*. (2014) discovered, through a semi-structured interview with UK household food purchasers, two categories of motives among household food waste reduction which were (1) waste concerns, and (2) doing the 'right' thing. This cluster suggested an urgent need to identify and determine food waste behaviour predictors that could mitigate and prevent further food waste behaviour among consumers.

Table 3 summarises the bibliographic coupling analysis, including cluster number and colour, labels, number of publications, and representative publications.

Co-word analysis

Applying the same database, the co-word analysis presented 38 out of 4,901 keywords that met 32 thresholds, resulting in two clusters. Same with

Table 3. Co-citation analysis on food waste behaviour reduction.

Cluster no. and colour	Cluster label	No. of publication	Representative publication
1 (red)	Challenges of food waste management	15	Papargyropoulou *et al*. (2014), Priefer *et al*. (2016), Michelini *et al*. (2018)
2 (green)	Technological approach to food waste management	14	Xu *et al*. (2018), Pham *et al*. (2015), Thi *et al*. (2015)
3 (blue)	Determinants of food waste behaviour among consumers	7	Quested *et al*. (2013), Schanes *et al*. (2018), Graham-Rowe *et al*. (2014)

co-citation, the clusters were tried several times to ensure that the network map produced a robust and stable cluster representing the appropriate cluster map. Table 4 illustrates the top 15 keywords in food waste reduction behaviour. The highest co-occurred keywords were food waste (449 occurrences), management (117 occurrences), and anaerobic digestion (106 occurrences). These keywords represent the network map depicted in Figure 3.

Figure 3 presents the network structure of the co-word analysis. It visibly shows three clusters representing three different themes. In accordance with the author's inductive interpretation, the three clusters were assigned the appropriate labels. This co-word analysis only produced two clusters, suggesting that only two primary themes emerged on future trends of food waste and technology. Past studies have shown that it is possible to produce two clusters in bibliometric analysis (Rodrigues and Franco, 2020; Fauzi *et al.*, 2023b).

Table 4. Top 15 keywords in co-word analysis.

Keyword	Occurrence	Total link strength
Food waste	449	1141
Management	117	386
Anaerobic digestion	106	420
Anaerobic-digestion	85	307
Lifecycle assessment	83	296
Energy	81	303
Sustainability	80	198
Biogas	76	316
Municipal solid-waste	68	246
Performance	66	212
Methane production	59	239
Waste	59	106
Quality	58	101
Co-digestion	55	217
Technologies	54	175

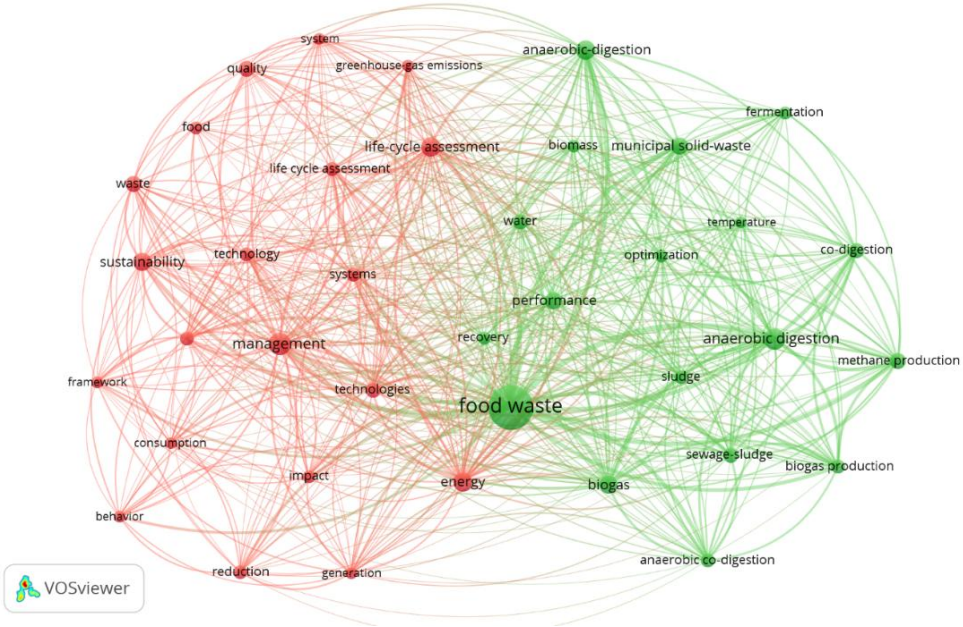

Figure 3. Co-word analysis on food waste reduction and technologies.

i. Cluster 1 (red): With 20 keywords, cluster 1 was labelled "Lifecycle management of food waste technologies". Fan *et al*. (2023) developed a mixed technology for environmental impact analysis of food waste treatment. Mixed technologies exhibited better cost-benefit efficiency compared with single treatment. According to Sridhar *et al*. (2021), converting food waste to bio-based liquid or gaseous fuel could be an attractive option for meeting the demand for fuel by slowing down the depletion of fossil fuel resources. Based on the lifecycle analysis, these technologies included landfill, incineration, anaerobic digestion, composting, biochemical, and pyrolysis, which have been assessed alongside recent emerging technologies such as supercritical water gasification and hydrothermal carbonisation. Lin *et al*. (2022) synergised the life cycle assessment and mathematical optimisation in developing an economic and environmental food waste management framework. Anaerobic digestion was the most favoured method, reducing the health impact on humans and the ecosystem by 146% compared to open landfills.

ii. Cluster 2 (green): With 18 keywords, this cluster was labelled "Food waste in municipal solid waste management". In many countries, food waste contributes the highest percentage of waste (Liu *et al*., 2020). Municipal solid waste is an inevitable crisis caused by human activity by-products across the globe (Das *et al*., 2021). One of the main components of food waste, kitchen waste, is a controversial issue due to its source's dispersion and social cost (Yu and Li, 2020). It was suggested that managing kitchen waste should be directed towards source draining, source reduction, and subsequently, source separation. The environmental performance of municipal sewage management could be maximised through the treatment of aerobic composting or anaerobic digestion of food waste at the source (Liu *et al*., 2020). According to Zhu *et al*. (2021), the cost to treat 1,000 kg of food waste is equal to 350 RMB (approximately 45 - 50 USD), which includes asset investment (compost machine, vehicles) and operation costs (electric, salary, and others).

A summary of the co-word analysis is presented in Table 5, comprising cluster number and colour, cluster labels, number of keywords, and representative keywords.

Table 5. Summary of co-word analysis on food waste reduction and technology.

Cluster no. and colour	Cluster label	No. of keyword	Representative keyword
1 (red)	Lifecycle management of food waste technologies.	20	Management, technologies, systems, lifecycle assessment, sustainability.
2 (green)	Food waste in municipal solid waste management.	18	Food waste, biogas, sludge, anaerobic digestion, performance, municipal solid waste.

Implications

Theoretical implications

The implying theoretical basis of the present review was the difference between food waste behaviour and food waste reduction behaviour. Despite that, the present review focused on food waste behaviour in relation to reduction. As suggested by the search strings employed, most of the retrieved studies were based on food waste behaviour rather than food waste reduction behaviour. Nevertheless, the determinants for both behaviours were rather similar, corresponding to the nature of the behaviour. Diana *et al*. (2023) suggested that there were several determinant factors for food waste behaviour. This included socioeconomics and demography, consumer behaviour, food quality and safety, and psychology. Aydin and Yildirim (2021) found that shopping habits and moral attitudes were the two most significant predictors of food waste. Individuals who shop responsibly and buy goods according to their needs report less food waste. While

individuals who believe throwing away food is wrong and does not match their self-image, tend to waste food less. Chen (2023) reported that food shopping routines and situational factors were predictors of food waste behaviour. For instance, shopping routines during weekends and festive holidays influence how consumers purchase goods and raw materials, usually more than normal, leading to higher possibilities of food waste. Situational factors included creating the urge for consumers to buy in bulk for celebrations and gatherings, often ending in over-purchasing. Furthermore, certain promotions and limited-time purchases created by sellers could also result in consumers' decision in impulsive buying behaviour, without actual needs. These situations lead to excessive food waste behaviour, increasing the likelihood of spoiled and unused purchasing items. These determinants can be identified and determined through monitoring systems towards consumer behaviour.

Cluster 3 in bibliographic coupling and clusters from the co-word analysis suggested that intervention in human behaviour was the most crucial aspect. Understanding food waste behaviour requires understanding the determinants of food waste behaviour among consumers. Several studies have proven that the theory of planned behaviour (TPB) was effective in predicting individual food waste behaviour (Coşkun and Özbük, 2020; Bhatti *et al*., 2023; Chen, 2023) and food waste reduction intention/behaviour (Heidari *et al*., 2020; Lin and Guan, 2021; Mumtaz *et al*., 2022). Bhatti *et al*. (2023) discovered that environmental concern and time pressure significantly influenced consumers' attitudes toward food waste reduction during the holy month of Ramadan and the Eid festival in Pakistan. Mariam *et al*. (2022) suggested that focusing on specific behaviour regarding the use of leftovers was effective in encouraging food waste reduction behaviour among adolescents.

Among the determinants of food waste behaviour, norms are among the strongest in predicting food waste and food waste reduction behaviour. Norm is usually embedded within the TPB model when evaluating consumers' food waste and waste reduction behaviour. In the study context, a moral norm is defined as the perception of a moral obligation to reduce household food waste (Oehman *et al*., 2022). For instance, moral norms are crucial in prediction as they make consumers feel guilty and uncomfortable when they waste food (Chen, 2023). Injunctive norms can be expressed as subjective norms within TPB (Aydin and Aydin, 2022). It refers to the steps and actions taken to prevent societal pressure and perceived social when it comes to food waste. There are still gaps in identifying whether moral norms can impact an individual's food waste reduction, particularly concerning leftovers and the role of emotion in waste decisions (Talwar *et al*., 2022). Zheng *et al*. (2023) applied the nudge theory as an information nudge approach to reduce food waste during consumption. It was found that negative-framed messages were effective when combined with injunctive norms, while positive-framed work was effective with descriptive norms. Mumtaz *et al*. (2022) discovered that there were several crucial factors in consumers' waste reduction intention in restaurants, including awareness of consequences, social norms, anticipated positive emotions, and environmental knowledge.

Managerial implications

Awareness is more susceptible at the early stage. Nurturing youngsters through awareness and education is the best measure for inculcating food waste reduction behaviour. Children should be given training and practices on making a food list on food purchasing, food value, and the consequences of food waste on the larger ecosystem. On the other hand, more than awareness is needed to prevent food waste behaviour among the elders (Aka and Buyukdag, 2021). The government should adopt an active policy on food waste training for different categories, such as married couples and female consumers who are more likely to be involved in food waste behaviour (Aka and Buyukdag, 2021). Mariam *et al*. (2022) designed an educational intervention strategy through a "Food waste lab" to increase awareness among consumers as a crucial component in climate change. The lab works by increasing the likelihood of participants utilising their taste for the judgement of criterion edibility and eating leftovers. It is considered an educational intervention on personal behaviour through food literacy and practical skills in preventing food waste behaviour.

One of the effective measures to reduce food waste is through supply chain management. In the context of designing a minimum waste plan, Vizzoto *et al*. (2021) suggested that households and the food service sector should maximise the use of leftovers by consuming the established resources. Secondly, the menus should be appropriate according to the weather

and season. Integration of supply chain management leads to a better food system and chain. This integration involves a comprehensive operations-based activity at the meso and macro levels, including energy management, climate, environment, and infrastructure (Luo *et al*., 2022). Barbosa (2021) suggested that blockchain technology embedded with the Internet of Things (IoT) and advanced information and communication technology managed to facilitate food security regarding information security, traceability and manufacturing.

Limitations

There are several limitations of the present review. First, it was focused on the scope of food waste reduction behaviour from the technology perspective, and did not stress the role of technology as much as food waste behaviour. In other words, the themes produced in the co-citation and co-word analysis produced clusters within food waste behaviour itself rather than the relation with technology in reducing food waste. The technological aspect should be emphasised more than the food waste itself. One of the reasons is that food waste is associated with consumer behaviour that cannot be solved using digital technology. Second, the present review included journal publications, leaving out other sources such as books, book chapters, conference proceedings, and others. Relevant themes might have been missed from these publications on the overall scientific network of food waste behaviour reduction and its associated technology. Third, the findings of the present work depended solely on the WoS database. There might be slight differences in the cluster interpretation if other databases were also applied such as Scopus, PubMed, or Dimension. Hence, future studies could further explore the differences in the themes of food waste behaviour in relation to technology usage.

Future research avenues

Since food waste is being viewed from the perspective of behaviour, future studies should strengthen the understanding based on the theoretical underpinning. Among the theories that can explain this behaviour is the TPB. Several studies have adopted an extended TPB to understand the phenomenon (Coşkun and Özbük, 2020; Aydin and Aydin, 2022; Chen, 2023). Despite that, the theoretical integration with other theories in understanding food waste behaviour from a technological perspective is lacking in the literature. TPB could be integrated with the technology-organisation-environment (TOE) (Tornatzky and Fleischer, 1990) to comprehensively understand food waste behaviour from the technological perspective. Furthermore, other technological adoption theories, such as the unified theory of acceptance and use of technology (UTAUT) (Venkatesh *et al*., 2003) and diffusion of innovation theory (Rogers, 2003), can be adapted to infuse the innovation trait among consumers. Aramyan *et al*. (2021) discovered that innovations have great potential to prevent and reduce food waste along the supply chain.

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Conclusion

The present review has provided a clear and unravelling overview of food waste reduction based on digital technologies. With the emerging sustainability issues, including food security, climate change, and pollution, practitioners and policymakers need to develop certain measures to reduce food wastage. The approach of science mapping through bibliometric analysis provides a novel understanding of food waste reduction based on past and future trends. The findings suggested that past studies have converged on the challenges of food waste management, the technological approach to food waste management, and the determinants of food waste behaviour among consumers. The future trends suggest a much-specified theme related to the lifecycle management of food waste technologies and food waste in municipal solid waste management. Food waste behaviour is an indispensable topic that every government agency and stakeholder must face to mitigate the issues. Understanding the underlying past themes and future trends would facilitate future researchers in developing comprehensive measures to overcome food waste management for a better tomorrow.

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