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KNOWLEDGE DEVELOPMENT AND EMERGING TRENDS IN FOOD WASTE MANAGEMENT: A BIBLIOMETRIC STUDY

Siti Nurhafizah Saleeza Ramlee[1*], Zarina Kassim[2], Nurhaffiza Rahaman[3], Liley Afzani Saidi[4], Wan Su Emi Yusnita Wan Yusof [5], Rayyan Cheong Tian Ming[6], Siti Humaira Ramli[7]

[1] Department of Management, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: saleeza@upnm.edu.my
[2] Department of logistics and business study, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: zarina.kassim@upnm.edu.my
[3] Department of Management, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: nurhaffiza@upnm.edu.my
[4] Department of Management, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: liley.afzani@upnm.edu.my
[5] Department of Management, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: wansuemi@upnm.edu.my
[6] Department of Management, Faculty of Defence Studies and Management, National Defence University of Malaysia
Email: rayyanming@upnm.edu.my
[7] Faculty of Art and Design, UiTM Puncak Alam, Selangor, Malaysia.
Email: Siti7169@uitm.edu.my
[*] Corresponding Author

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Abstract:

The global issue of food waste has become a critical challenge in achieving environmental sustainability, food security, and efficient resource utilization. Despite increasing awareness, the management and reduction of food waste remain complex, requiring a comprehensive understanding of research progress and emerging trends in this domain. This research seeks to investigate the evolution of knowledge as well as emerging trends in food waste management through a bibliometric analysis of global research output. Data were collected from the Scopus database using advanced search strategies with keywords such as food waste, waste, management, strategy, reduction, knowledge, and awareness, yielding a total of 1,302 relevant publications. The data were refined and standardized using OpenRefine to ensure consistency

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and accuracy. Bibliometric indicators and trends were analyzed through the Scopus analyzer, while visualization maps—such as keyword co-occurrence, co-authorship, and citation networks—were generated using VOSviewer software to determine influential authors, key research themes, as well as collective networks. The findings reveal a significant increase in publication trends, particularly from 2015 to 2025, indicating growing global attention toward sustainable food waste management. The United Kingdom (UK), China, Italy, and the United States emerged as leading contributors with strong international collaborations. Major thematic clusters were identified around waste reduction technologies, circular economy strategies, and public awareness initiatives. The high citation rates of review papers and multidisciplinary studies highlight the expanding academic and policy relevance of this field. In conclusion, the study provides a comprehensive overview of the intellectual landscape, identifying evolving research directions and collaborative patterns that contribute to advancing sustainable solutions for food waste management. These insights offer valuable implications for policymakers, researchers, and practitioners seeking to enhance global food system sustainability.

Keywords:

Food Waste, Waste, Management, Strategy, Reduction, Knowledge, Awareness

Introduction

Food waste management has become a vital focus area within sustainable development efforts, largely due to the escalating global food waste crisis and its adverse environmental, economic, as well as social impacts. Each year, millions of tons of food are discarded, resulting in significant greenhouse gas emissions, resource inefficiency, and environmental degradation (Danya et al., 2024; Meegoda et al., 2025). In response, the United Nations' Sustainable Development Goal (SDG 12.3) calls for a significant reduction of food waste and loss throughout the supply chain by 2030, particularly at the retail and consumer stages (Munir, 2022). This growing concern has led to the creation of innovative methods as well as technologies to minimize food waste and transform it into valuable resources, thereby promoting a circular economy (Alonso-Muñoz et al., 2022; Do et al., 2021). The knowledge structure of food waste management has evolved significantly over the years, with a focus on understanding consumer behavior, technological interventions, and lifecycle management. Bibliometric analyses have revealed emerging trends in food waste behavior, emphasizing the vital importance of digital technology in minimizing food waste (Abidin et al., 2024). Studies have also emphasized the importance of education and training programs to influence consumer behavior towards sustainable consumption. The integration of social and economic innovations in food waste management has been identified as a key area for future research, aiming to provide environmentally sustainable solutions (Al-Obadi et al., 2022).

Current progress in food waste valorization has focused on converting waste into marketable products through biotechnological processes. Food waste biorefineries have become a promising approach, converting discarded materials into biofuels, biochemicals, as well as bio-based materials. By applying circular economy principles, these biorefineries aim to minimize waste generation as well as optimize resource use, thereby reducing greenhouse gas emissions and environmental pollution. Various valorization pathways, including microbial and enzymatic conversion technologies, have been explored to enhance the practicality and

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effectiveness of transforming food waste into valuable products (Danya et al., 2024; Usmani et al., 2021). Although significant progress has been made, issues such as feedstock variability and process optimization remain, necessitating further research and development.

Technological innovations have played a pivotal role in advancing food waste management practices. Emerging advancements such as anaerobic digestion, co-digestion, composting, and enzymatic treatment have been developed to utilize food waste as a valuable resource (Usmani et al., 2021). These green techniques mitigate the hazardous impacts of food waste and contribute to the production of renewable energy, as well as nutrient-rich fertilizers (Meegoda et al., 2025). The optimization of operational parameters, including temperature, pH, pressure, and residence time, has significantly improved the yield of valuable products like methane, hydrogen, as well as platform chemicals (Usmani et al., 2021). Additionally, biodigesters have been identified as a sustainable alternative to traditional disposal methods, offering significant environmental and health benefits (Meegoda et al., 2025).

Effective food waste management requires comprehensive policy and regulatory frameworks that support the implementation of sustainable practices. Studies have highlighted the importance of establishing closer and more sustainable relationships with various stakeholders, including policymakers, industry practitioners, and consumers (Alonso-Muñoz et al., 2022). Regulatory measures and financial incentives can encourage the adoption of innovative waste management strategies, while public awareness campaigns can promote sustainable consumption behaviors (Adams et al., 2025). The development of indicators to measure the level of circularity in waste management and the fulfillment of established objectives is crucial for monitoring progress and ensuring accountability (Alonso-Muñoz et al., 2022). Collaboration across disciplines and between public and private sectors plays a crucial role in fostering innovation and promoting commercialization within food waste management (Danya et al., 2024).

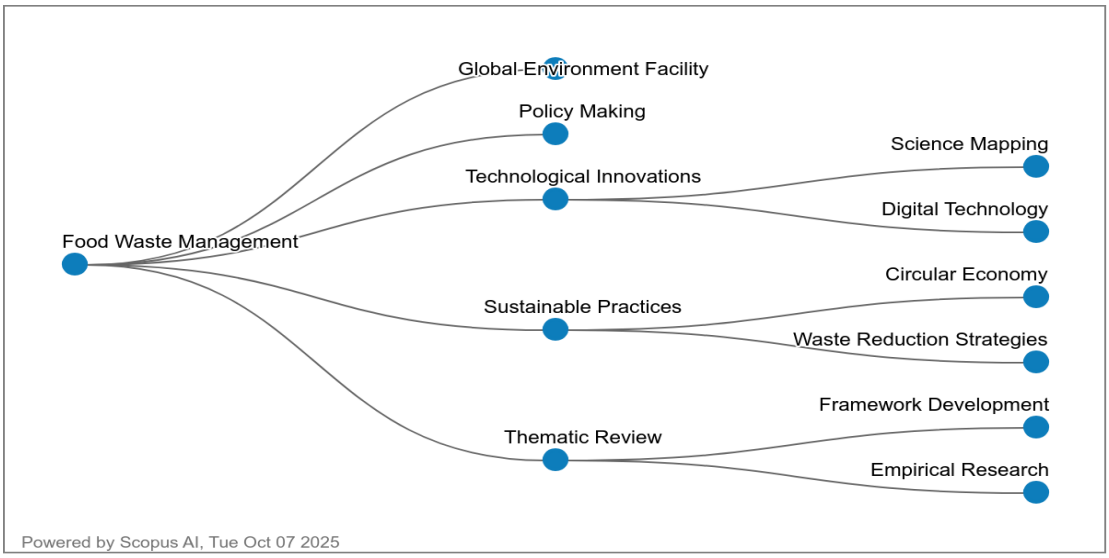

Figure 1: Concept Map Of Key Components Food Waste Management

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Figure 1 illustrates the concept map of "Knowledge Development and Emerging Trends in Food Waste Management," highlighting the multidimensional growth of research in this domain. The central theme of food waste management connects with several emerging focus areas, including policy development, sustainable practices, technological innovations, and thematic analyses. Technological innovations, supported by digital technology and science mapping, indicate the growing importance of data-driven and technology-based solutions for managing food waste efficiently. Similarly, sustainable practices emphasize the integration of circular economy principles and waste reduction strategies to achieve long-term environmental and economic sustainability. Policy making and global environmental initiatives further demonstrate the strategic role of governance and international collaboration in shaping effective waste management systems. Moreover, thematic reviews and framework development supported by empirical research reflect efforts to establish theoretical foundations and practical models for future studies. Overall, the concept map underscores a dynamic, interdisciplinary field that integrates technology, sustainability, policy, and research innovation to advance global food waste management practices. In conclusion, the development of knowledge and emerging trends in food waste management reflects an increasing awareness of the importance of developing sustainable approaches to tackle the worldwide food waste crisis. Technological innovations, valorization pathways, and comprehensive policy frameworks are critical components of effective food waste management strategies. By integrating principles of the circular economy and promoting interdisciplinary collaboration, stakeholders can contribute to a more resilient and sustainable future by tackling the environmental as well as economic issues associated with food waste. Ongoing research, technological advancements, as well as strong policy support are essential for achieving SDGs and advancing broader sustainability objectives.

Research Question (5 RQ)

RQ1: What are the research trends in food waste management studies when analyzed by year of publication?
RQ2: Which articles represent the most highly cited contributions in the field of food waste management?
RQ3: Which countries and institutions are the leading contributors to food waste management research based on publication output?
RQ4: What are the most frequently occurring and influential keywords associated with food waste management research?
RQ5: What are the patterns of co-authorship and international collaboration among researchers in the field of food waste management?

Methodology

Bibliometrics serves as a rigorous methodological approach for collecting, structuring, as well as analyzing bibliographic information from scientific literature (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). While traditional bibliometric analyses often emphasize descriptive indicators such as publication outlets, temporal distribution, and author productivity (Wu & Wu, 2017), more advanced techniques, including document co-citation analysis, enable deeper insights into the intellectual structure and knowledge evolution of a research field. Conducting a rigorous literature review requires an iterative and structured process starting with the selection of relevant keywords, proceeding through comprehensive database searches, and culminating in a detailed analysis. This methodological rigor facilitates the construction of

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a comprehensive and reliable bibliography while ensuring valid outcomes (Fahimnia et al., 2015). In this research, priority was given to high-impact publications, as these works offer critical perspectives and theoretical contributions that shape scholarly discourse. To enhance reliability and validity, Scopus was chosen as the primary database due to its broad coverage and recognized accuracy (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). Only peer-reviewed journal articles were considered, with books and lecture notes intentionally excluded to preserve academic rigor (Gu et al., 2019). Publications indexed between 2015 and October 2025 were systematically retrieved and analyzed using Elsevier's Scopus database.

Data Search Strategy

The data collection for this study was carefully planned and carried out using the Scopus database, which is well known for its extensive repository of high-quality, peer-reviewed scientific publications. To ensure analytical precision and thematic relevance, an advanced search query was applied using the string: TITLE-ABS-KEY ("food waste" AND waste AND (management OR strategy OR reduction) AND knowledge OR awareness) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE, "English"). This strategic approach targeted publications containing the specified terms within their titles, thereby focusing on studies that explicitly addressed the nexus of *food waste, management, strategy, reduction, knowledge,* and *awareness*, rather than those that referenced these concepts only tangentially.

To capture the most recent developments and evolving research trends, the publication range was restricted to 2015–2025, effectively filtering out outdated works that might not reflect current policy directions, technological innovations, or methodological frameworks in food waste management. The search was further confined to English-language publications to enhance consistency, accessibility, and comparability of findings. A rigorous inclusion and exclusion protocol was implemented—retaining only peer-reviewed journal articles and omitting books, conference papers, as well as review articles—to maintain methodological robustness and empirical reliability. Studies falling outside the core thematic scope were systematically omitted to ensure focus and coherence. Following this meticulous filtering and validation process, completed in October 2025, a total of 1,302 relevant journal articles were finalized for bibliometric analysis.

Table 1: The Search String

Scopus	TITLE-ABS-KEY ("food waste" AND waste AND (management OR strategy OR reduction) AND knowledge OR awareness) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (LANGUAGE , "English")

Table 2: The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2015 – 2025	< 2014

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Data Analysis

VOSviewer, an easy-to-use bibliometric analysis software created by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands, has become one of the most widely adopted tools for bibliometric mapping and visualization (van Eck & Waltman, 2010, 2017). Renowned for its capability to form clear network diagrams, group related items into clusters, and produce density maps, the software offers researchers a powerful platform to explore and analyze scientific literature. Its versatility extends across multiple applications, including examining co-authorship networks, co-citation relationships, as well as keyword co-occurrence patterns, offering a holistic view of research domains. With its interactive interface and ongoing updates, VOSviewer ensures that users can dynamically and efficiently engage with large datasets.

A distinctive strength of VOSviewer lies in its ability to convert complex bibliometric data into clear, visually interpretable maps and charts. Focused heavily on network visualization, the software is particularly effective at clustering related elements, identifying keyword co-occurrence patterns, as well as generating density-based visual maps. Its accessibility makes it suitable for both novice and experienced researchers, while its customizable visualizations and robust metric computations further enhance scholarly inquiry. The software's adaptability to diverse bibliometric data sources—spanning co-authorship, citation, and keyword networks—solidifies its role as an indispensable tool in bibliometric research.

For this study, datasets including details such as publication year, title, authors, journal, citation counts, and keywords were obtained from the Scopus database in PlainText format, covering the years 2015 to October 2025. The data were analyzed using VOSviewer version 1.6.20, with clustering and mapping techniques employed to generate bibliometric maps. Unlike traditional Multidimensional Scaling (MDS), VOSviewer situates items within low-dimensional spaces where the distance between items accurately represents their relatedness and similarity (van Eck & Waltman, 2010). While sharing conceptual similarities with MDS (Appio et al., 2014). VOSviewer diverges by adopting a more effective normalization method for co-occurrence frequencies. Specifically, it applies the Association Strength (AS_{ij}), defined as:

$$AS_{ij} = \frac{C_{ij}}{w_i w_j},$$

where CijC_{ij}Cij represents the observed co-occurrences of items *i* and *j*, and wiw_iwi and wjw_jwj refer to their respective occurrence frequencies. This measure reflects "the ratio of the actual number of co-occurrences between *i* and *j* to the expected number of co-occurrences assuming statistical independence" (Van Eck & Waltman, 2007). By employing this approach, VOSviewer ensures that the generated maps accurately capture the underlying structure of research domains, reinforcing its position as a leading tool in bibliometric and scientometric.

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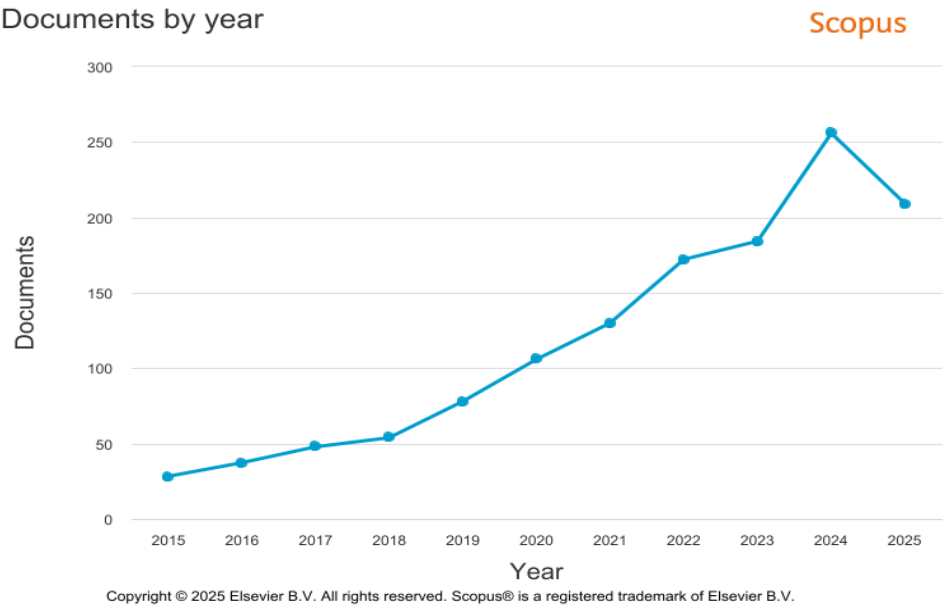

Figure 2: Number Of Documents Based on Year Publication

The publication trend on *"Knowledge Development and Emerging Trends in Food Waste Management"* from 2015 to 2025 demonstrates a significant and consistent increase in scholarly attention toward this field. The data show that research output has grown steadily from only 28 publications in 2015 to 209 in 2025, marking almost an eightfold increase over a decade. The upward trend became particularly notable after 2018, with publications rising sharply from 54 in 2018 to 106 in 2020. This surge can be attributed to increasing global awareness of food security, sustainability goals, and environmental protection efforts, which have positioned food waste management as a key research and policy priority. The year 2021 onward shows a marked acceleration, reflecting the integration of circular economy principles, SDGs, and technological innovations in waste management systems.

The peak in 2024, with 256 publications, followed by a slight decline in 2025, may suggest stabilization in research intensity as the field matures and diversifies into specialized areas such as digital technology applications, policy frameworks, and empirical assessments. The surge in recent years can also be linked to global sustainability agendas, including the UN's 2030 Agenda for Sustainable Development and the growing interest in zero-waste initiatives. Furthermore, interdisciplinary collaborations between environmental science, policy, and technology fields have expanded research scope, driving innovation in sustainable waste solutions. Overall, the data reflect increasing recognition of food waste management as a crucial area for achieving environmental sustainability and resource efficiency.

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Table 3: Most Cited Author

Authors	Title	Year	Source title	Cited by
(Whitmee et al., 2015)	Safeguarding human health in the Anthropocene epoch: Report of the Rockefeller Foundation-Lancet Commission on planetary health	2015	The Lancet	1984
(Hamed et al., 2016)	Industrial applications of crustacean by-products (chitin, chitosan, and chitooligosaccharides): A review	2016	Trends in Food Science and Technology	942
(Pham et al., 2015)	Food waste-to-energy conversion technologies: Current status and future directions	2015	Waste Management	597
(Parizeau et al., 2015)	Household-level dynamics of food waste production and related beliefs, attitudes, and behaviours in Guelph, Ontario	2015	Waste Management	508
(Meegoda et al., 2018)	A review of the processes, parameters, and optimization of anaerobic digestion	2018	International Journal of Environmental Research and Public Health	502
(Thi et al., 2015)	An overview of food waste management in developing countries: Current status and future perspective	2015	Journal of Environmental Management	480
(Čičková et al., 2015)	The use of fly larvae for organic waste treatment	2015	Waste Management	434
(Scherhaufer et al., 2018)	Environmental impacts of food waste in Europe	2018	Waste Management	411
(Caldeira et al., 2019)	Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis	2019	Resources, Conservation and Recycling	379
(Jribi et al., 2020)	COVID-19 virus outbreak lockdown: What impacts on household food wastage?	2020	Environment, Development and Sustainability	376

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The ten most referenced publications in *Food Waste Management* reflect a blend of environmental sustainability, technological innovation, and behavioral research that has shaped global knowledge in this domain. The most cited article, Whitmee et al. (2015) in *The Lancet,* with 1,984 citations, underscores the broader context of planetary health and its link to sustainable food systems, illustrating how food waste is interconnected with global environmental and health challenges. Highly cited works such as Hamed et al. (2016) with 942 citations and Pham et al. (2015) with 597 citations established the significance of technological solutions like waste-to-energy conversion and the valorization of by-products, which align with circular economy principles and sustainable resource utilization. Similarly, Meegoda et al. (2018) and Scherhaufer et al. (2018) focused on anaerobic digestion and environmental impacts in Europe, demonstrating the growing interest in efficient, eco-friendly waste management technologies and policy frameworks supporting sustainability goals. The strong citation counts of Jribi et al. (2020) and Caldeira et al. (2019) emphasized the global attention toward food waste issues in times of crisis and systemic analysis of waste along supply chains. Their relevance grew as the COVID-19 pandemic reshaped household consumption patterns and sustainability discussions. Early influential research, including Thi et al. (2015) and Parizeau et al. (2015), provided foundational perspectives on waste management in developing countries and consumer behavior, both of which remain central to modern sustainability research. The consistent citation growth across diverse journals like *Resources, Waste Management*, *Journal of Environmental Management*, as well as *Conservation and Recycling,* reflects a multidisciplinary integration of environmental science, technology, and social behavior. This demonstrates that food waste management has evolved into a mature, cross-sectoral research field essential for achieving global sustainability and circular economy targets.

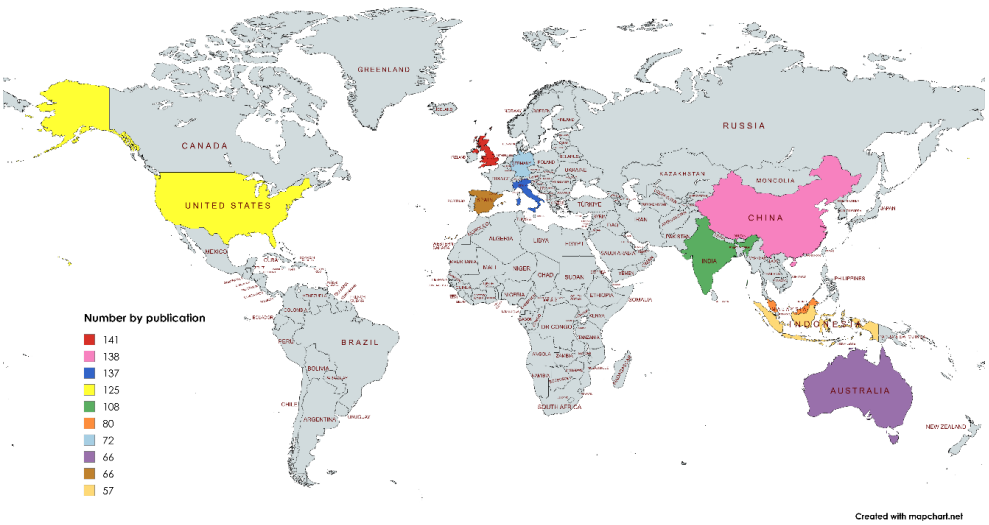

Figure 3: Country Mapping Based on Number of Publications

The publication distribution by country reveals that the United Kingdom (UK) (141) leads global research output in food waste management, closely followed by China (138) and Italy (*137)*. This dominance reflects the UK and Europe's strong policy frameworks and academic focus on sustainability, circular economy, and waste reduction under the European Union's environmental directives. Italy's high contribution also aligns with its active participation in EU-funded initiatives and food sustainability programs. Similarly, China and the United States

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demonstrate robust engagement due to their growing environmental concerns, industrial-scale food production, and technological advancements in waste management. India's significant contribution (108 publications) indicates increasing attention to food security, waste reduction, and sustainable agriculture, driven by national policies addressing food loss and resource efficiency.

Meanwhile, Malaysia (80), Germany (72), Australia (66), Spain (66), and Indonesia *(57)* show emerging yet meaningful contributions, reflecting growing regional awareness and research investments in sustainability. Malaysia and Indonesia's rise in publication activity highlights Southeast Asia's growing commitment to addressing food waste challenges tied to population growth, food security, and urbanization. Germany, Australia, and Spain, known for their strong environmental research networks, continue to play vital roles through cross-national collaborations and applied sustainability projects. Overall, the data indicate that research productivity is highly correlated with governmental initiatives, funding availability, and national priorities toward achieving the UN SDGs, particularly those focused on responsible consumption and production (SDG 12).

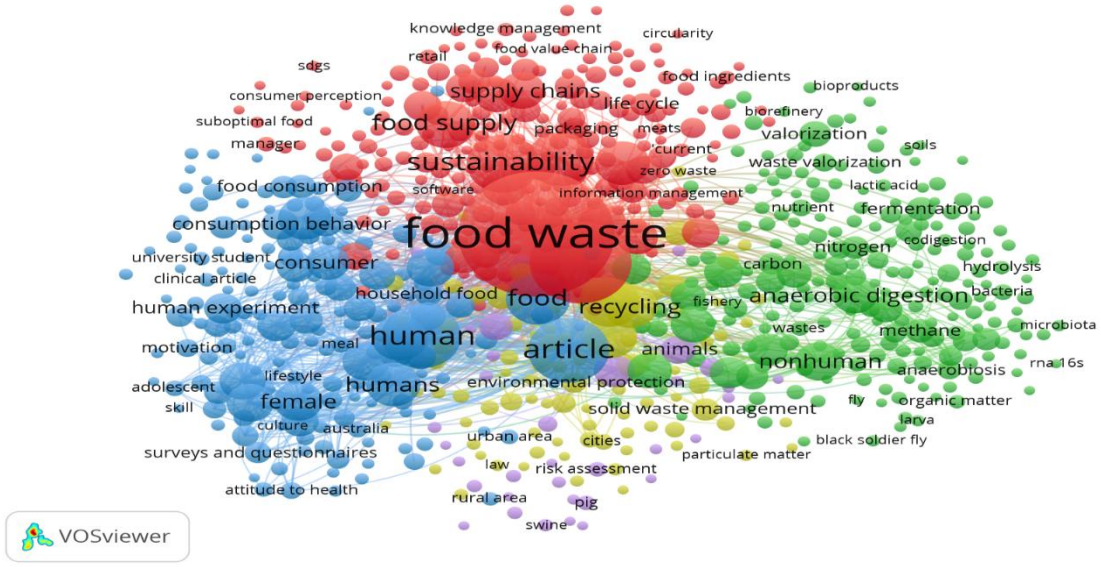

Figure 4: Keywords Associated with Food Waste Management Research

The co-occurrence analysis of author keywords in VOSviewer identifies the frequency and relationships among terms that appear together across publications, offering insight into the conceptual structure of research themes. Using *full counting* means each occurrence of a keyword in a paper is counted equally, reflecting its true frequency in the dataset. In this study, the *minimum threshold of 5* ensured that only relevant and commonly used keywords were included out of 7,114 total keywords, resulting in 736 that met the criteria. Setting a *minimum cluster size of 5* led to the formation of *five distinct clusters*, each representing interconnected research topics. This configuration highlights dominant themes and interconnections between them, showing how specific areas, including sustainability, food waste management, waste-to-energy technologies, as well as consumer behavior, are linked within the broader discourse of environmental management.

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The findings significantly contribute to the existing knowledge by illustrating the development as well as the interdisciplinarity of food waste research. High-frequency keywords such as *"food waste" (865)*, *"waste management" (365)*, and *"sustainability" (190)* demonstrate the field's strong alignment with global sustainability goals, reflecting the urgency of addressing waste reduction and environmental impact. The appearance of terms like *"circular economy," "consumer behavior," "anaerobic digestion,"* and *"food security"* indicates the integration of environmental, technological, and social perspectives. The clustering outcome reveals a multidisciplinary network—linking waste management technologies, human behavioral studies, and sustainable consumption patterns—thereby mapping the intellectual landscape of this research domain. Ultimately, the co-occurrence analysis offers a systematic overview of research trends, identifies emerging topics, and helps scholars recognize potential areas for innovation and cross-disciplinary collaboration.

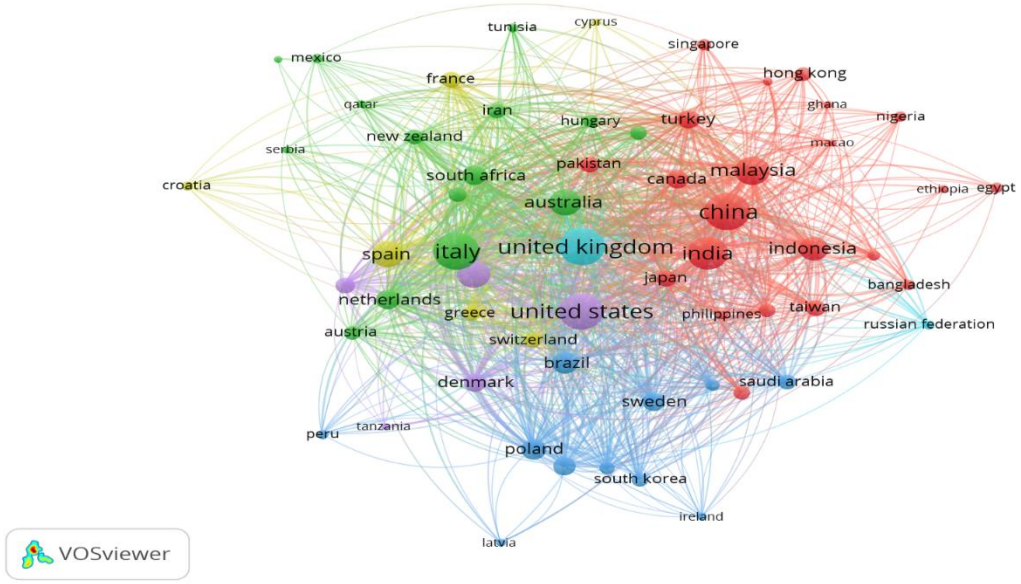

Figure 5: Co-Occurrence Analysis of Countries

The concept of *co-occurrence co-authorship by countries* in VOSviewer represents the collaborative relationships among nations based on joint scientific publications. It visualizes how researchers from different countries contribute collectively to the same body of work within a specific research domain. Each node in the map represents a country, while the size of the node represents its research productivity (number of publications), as well as the connecting lines represent international collaborations. The closer and thicker the lines between countries, the stronger their cooperative research relationship. This mapping allows researchers to identify global research hubs, the strength of international partnerships, and the diffusion of scientific knowledge across regions. By setting a *full counting method*, each country involved in a publication receives equal credit, accurately representing the degree of participation. Applying a *minimum threshold of 5 documents* ensured that only countries with significant research activity were included out of 105 total, with *61 countries meeting the threshold*. A *minimum cluster size of 5* resulted in *six distinct clusters*, each signifying regional or thematic collaboration patterns.

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The findings demonstrate an extensive and dynamic global collaboration network in food waste management research, led by highly productive countries like *China,* the *UK, Italy, alongside the United States*, which dominate publication output and achieve high citation counts—indicating global research influence and leadership. These countries serve as key nodes in connecting other regions, promoting the transfer of technology, policy innovation, and sustainable practices. Emerging contributors such as *Malaysia, India, and Indonesia* also show growing visibility, reflecting Southeast Asia's increasing engagement in sustainability-focused research. The formation of six clusters illustrates geographically and economically driven collaborations, where European countries, for instance, form a dense network driven by EU environmental policies, while Asian countries increasingly collaborate through shared sustainability goals and food security concerns. Overall, this co-authorship analysis enriches the body of knowledge by highlighting how international cooperation accelerates innovation, strengthens research capacity, and fosters the global advancement of food waste management solutions aligned with the SDGs.

Conclusion

The primary objective of this bibliometric analysis was to examine the development of research trends, knowledge structures, and emerging themes in food waste management from 2015 to 2025. The study aimed to identify global publication trends, leading contributors, and collaborative networks, while mapping key research directions that define the development of this field. Through systematic data collection and analysis, the research sought to answer fundamental questions regarding how scholarly interest in food waste management has progressed and what factors have shaped its current intellectual landscape.

The findings reveal a steady and substantial increase in scholarly publications on food waste management, reflecting the growing global commitment to sustainability and responsible resource utilization. The analysis identified China, the UK, Italy, as well as the United States as the most productive countries, with extensive international collaborations that enhance research impact and knowledge exchange. Thematic mapping highlighted several dominant clusters, particularly those related to waste reduction technologies, circular economy strategies, public awareness, and behavioral change. The co-occurrence and co-authorship analyses demonstrated that food waste management has evolved into a multidisciplinary research domain, integrating environmental science, policy studies, engineering, and social behavior research.

This research makes an important contribution to advancing the understanding of food waste management by offering a comprehensive overview of the field's intellectual evolution and its global research dynamics. It provides a structured knowledge base that can guide future studies and policy decisions. By highlighting emerging themes such as circular economy practices, valorization technologies, and consumer engagement, this study enhances conceptual clarity and strengthens the empirical foundation for developing sustainable strategies in food waste reduction. The implications of these findings extend beyond academic research. The identified trends and collaborations can inform policymakers, industries, and community stakeholders in designing more effective waste management systems. The emphasis on circular economy principles and technological innovation highlights the potential for integrating sustainable practices into food production and consumption systems. These insights can serve as a foundation for developing cross-sectoral frameworks that balance environmental sustainability with economic efficiency.

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Despite its comprehensive scope, this research has various limitations. The research drew exclusively from the Scopus database, which, despite its extensive coverage, may omit pertinent studies indexed in other sources. In addition, focusing only on English-language journal articles may have constrained the inclusion of regional research published in other languages. Upcoming studies could broaden the dataset by incorporating additional databases and applying mixed-method approaches, combining bibliometric techniques with content analysis to capture deeper thematic insights. Further investigation into the role of emerging technologies such as artificial intelligence, big data analytics, and digital platforms in food waste management may also enrich understanding of the field's future direction.

In summary, this bibliometric analysis emphasizes the vital importance of research on food waste management in advancing global sustainability agendas. It highlights the rapid evolution, increasing interdisciplinarity, and international cooperation that characterize this domain. By illuminating current knowledge patterns and research frontiers, the research offers meaningful insights for scholars, policymakers, as well as practitioners committed to achieving sustainable food systems. Bibliometric analysis remains an essential tool for mapping scientific progress and shaping future research pathways toward more effective and sustainable management of global food resources.

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