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MAPPING THE LANDSCAPE OF RESEARCH ON SUSTAINABLE AND INNOVATIVE SOLUTIONS FOR FOOD WASTE MANAGEMENT: A BIBLIOMETRIC ANALYSIS

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ABSTRACT

The goal of this bibliometric analysis is to present a thorough picture of the state of research on creative and sustainable approaches to managing food waste. It provides insightful information about the present and potential future orientations of this multidisciplinary area by examining co-authorship patterns, highly cited authors, eminent institutions, recurrent keywords, and co-citation networks. A comprehensive bibliometric analysis encompassing a range of topics, including publication output, subject areas, author contributions, and international collaborations, is carried out by the study using the Scopus database and the VOSviewer programme. The results demonstrate the interdisciplinary nature of the area, the notable increase in research activity, and the main forces behind the development of novel and sustainable methods for managing food waste. In addition, the analysis points up possible gaps and avenues for more research, encouraging cooperation and knowledge sharing. Researchers, decision-makers, and those involved in the food industry can benefit greatly from this thorough bibliometric analysis, which offers a data-driven framework for developing future research agendas and approaches to address the global problem of food waste with creative and sustainable solutions.

KEYWORDS

publication trends, co-authorship networks, co-citation analysis, interdisciplinary research, VOSviewer, Scopus

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INTRODUCTION

Food waste has become a major worldwide issue with profound effects on the environment, the economy, and society. Food waste has become a major concern due to the world's population growth and the depletion of natural resources. Innovative and sustainable solutions are needed to solve this issue. The goal of this bibliometric study is to present a thorough picture of the state of research in this important field, highlighting the trends, well-known writers, and cooperative networks that influence present knowledge and future paths. Research initiatives in a wide range of fields, including engineering, policy studies, food science, and agribusiness, have increased in response to the pressing need to address food waste. This study aims to pinpoint the significant turning points and possible catalyst that have accelerated the expansion of research in this field by examining publication trends. It also looks at the kinds of papers and topics that have added to the corpus of knowledge, providing insights on the field's interdisciplinary nature.

This bibliometric study recognises the important contributions made by scholars and institutions by highlighting the authors who have published the most and the works that have received the most citations. It looks into the institutions that these well-known academics are affiliated with, which may help identify the top research hotspots and centres for creative and sustainable approaches to managing food waste. In addition, the examination explores the commonly recurring terms, offering an insight into the developing study subjects and areas of concentration.

To summarise, scientific advancement is often marked by collaboration. This study delves into the patterns of international co-authorship, revealing the worldwide networks and partnerships that have influenced the field of research. Furthermore, the relationships between authors and publications are traced by co-citation analysis, providing important insights on the field's intellectual structure and possible research communities. This bibliometric analysis attempts to provide a thorough and data-driven understanding of the research landscape by combining these different aspects. This understanding will help shape future research directions and collaborations in the search for creative and sustainable solutions to the global problem of food waste.

LITERATURE REVIEW

Waste generation particularly food waste is observed to be escalating in the 21st century corresponding to the constant advancement in technology, industrialisation as well as the growth in population [18-19]. Food waste is now considered to be a global issue which involves every aspect regarding it throughout the supply chain beginning from the production followed by the storage, processing, transportation and consumption as it attaches along with various implications [19-21]. Efficient food waste management is vital in order to overcome its contribution negatively to the environment as in most countries food waste ends up in landfill which is considered to be the most common method of food waste disposal which leads to the generation of greenhouse gases such as methane that elevates the rapid occurrence of climate change [23-24]. Besides emitting greenhouse gases to the atmosphere, landfilling of food waste highly pose a risk of soil pollution due to harmful leachate production that might contain heavy metals which further worsens the implication by affecting the quality of the groundwater that gradually gets into the surface water as time goes by [22-23]. The dichotomy of abundance and shortage exists alongside in our current global food systems. As the demand for food increases with the growth of population, it associates with high amount of food wastage throughout the entire supply chain, from production up to

consumers which technically incorporates the lifecycle of food [25-26]. Food waste is a ubiquitous and complex problem that embodies this unsettling truth.

Particular challenges occur at certain parts of the food supply chain, which then results in a large number of resources being squandered. Due to elements such as improper storage, aesthetic values, overharvesting to keep up with the demand, and logistical hurdles, significant amounts of agricultural yields are wasted during the production as well as the distribution phase aligning to the global estimate indicated by the Food and Agriculture Organisation of the United Nations (FAO) where roughly one-third of the food produced for human consumption is lost or wasted during the whole supply chain [27-29]. Following consumer consumption, a large amount of perfectly edible food becomes unfit for consumption due to household habits, expiration dates, and societal standards that lead to food waste. The Sustainable Food Systems International Panel of Experts (IPES) discovered that the European Union (EU) wastes approximately 20% of its food which is equivalent to 88 Million tonnes (Mt), costing 143 billion Euros a year in lost of resources and environmental effect [30-31]. In a similar vein, an estimated 165 billion US dollars worth of food is thrown out by Americans each year in which the uneaten food makes up about 40% of the country's solid municipal waste, which degrade in landfills and releases methane into the atmosphere at a rate of over 25% [32].

The detrimental impacts of food waste on the environment remain ongoing once it reaches consumers. One study that looked at the financial and environmental effects of food waste at university canteens, for example, revealed that regular food waste was the highest at 46.14%, highlighting the adverse consequences of food waste at the consumer level on the environment [33]. Furthermore, according to the UN Environment Programme's Food Waste Index Report 2021, consumer food waste accounts for a substantial amount of global food production and has a negative influence on the environment [34]. This situation further worsens when the food waste is eventually disposed of in a landfill, which increases the amount of methane produced onsite [35]. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) estimates that methane, a potent greenhouse gas that accelerates climate change by absorbing heat and raising temperatures, has 28 times the global warming potential (GWP) of carbon dioxide over a 100-year time horizon [36]. The United States Environmental Protection Agency (US EPA) has proven that landfilling has detrimental environmental consequences, with landfill methane emissions in the United States estimated to be approximately 107.7 MtCO2e in 2016, making it the third largest source of methane emissions (Fs).

Food waste management has significant effects on the environment and human health, making it a critical global issue. Historically, the disposal of food waste, which constitutes a substantial portion of municipal solid trash, has involved either landfilling or incineration, which has resulted in serious health and environmental consequences [37-38]. But in addition to releasing toxic chemicals like dioxins and methane [39], these conventional techniques make it more difficult to collect important nutrients and chemical compounds from the burned substrate, which lowers the substrate's economic worth [40-41]. It is therefore essential to investigate suitable techniques for managing food waste.

Anaerobic digestion is one viable method that has been the subject of current research and is shown to be a more environmentally friendly treatment choice than landfilling and incineration [40-43] as it produces digestate water and biogas, which serve as a source of energy and a liquid fertilizer [42]. Its environmental benefits are highlighted by the possible decrease of impact categories by more than 50% when anaerobic digestion treats over 40% of food waste and landfilling ends by 2050 [43]. Even though anaerobic digestion produces resources and energy efficiently [40], it is important to remember that it has disadvantages. According to studies, it utilises more freshwater than landfilling and incineration [44], and a major portion of its environmental impact is attributed to massive energy use [45].

Food waste is a plentiful source for the production of energy (biogas and biodiesel) and materials for improving soil (biochar and fertiliser) due to its organic richness and perishable nature [46-47]. There are numerous ways to address food waste, each with advantages and disadvantages of their own. For example, pyrolysis yields both biogas and solid biochar, providing a dual use of energy and soil amendment [48]. Gasification is an additional technique for producing syngas through the digestion of food waste, which expands the range of possible applications for food waste [49].

In conclusion, a move towards sustainable alternatives has been sparked by the pressing need to address the negative environmental effects of traditional food waste disposal techniques. Other than the food waste management aspect, the amount of wastage generated during the entire life cycle of food waste such as the primary production, processing, packaging, manufacturing, distribution, retail, and consumption should be considered the innovative strategies in order to maintain sustainability throughout the food chain [50].

RESEARCH QUESTIONS

RQ1: What are the publication trends in the research on sustainable and innovative solutions for food waste management over the years?

RQ2: Who are the authors with the highest number of publications in this field?

RQ3: What are the types of documents and their distribution based on the subject areas or disciplines?

RQ4: Who are the authors with the most highly cited publications in this field, and what are their institutional affiliations?

RQ5: What are the frequently occurring keywords related to sustainable and innovative solutions for food waste management?

RQ6: What are co-authorship countries' collaboration?

RQ7: How about network mapping based on co - citation by authorship?

METHODOLOGY

The combination, administration, and analysis of bibliographic data gleaned from scientific publications is known as bibliometrics [7–9]. Wu and Wu (2017) It includes sophisticated methods like document co-citation analysis in addition to standard descriptive data like publishing journals, publication year, and major author categorization. In order to provide a full bibliography and reliable results, a successful literature review requires an iterative process that includes the discovery of appropriate keywords, literature search, and careful analysis [11]. Considering this, the study aimed to concentrate on high-calibre publications since they provide insightful information about the theoretical stances influencing the development of the field of study. The study used the SCOPUS database for data gathering in order to guarantee data dependability [12–14]. Furthermore, only papers published in carefully peer-reviewed academic journals were taken into consideration, with books and lecture notes purposefully left out in order to guarantee the inclusion of high-quality publications [15]. Especially, Elsevier's Scopus, which is renowned for its broad coverage, made it easier to gather publications from 2023 to March 2024 for further examination.

DATA SEARCH STRATEGY

The search terms for article retrieval were determined by the study using a screening sequence. The study was initiated by collecting 69,756 articles online and querying the Scopus database using the keywords "sustainable OR innovative" AND "solution OR fix OR technology" AND food AND waste. Later, the query string was refined to focus specifically on sustainable and innovative solutions for food waste management. 1,132 articles from the final search string refinement were used for the bibliometric analysis. All publications pertaining to sustainable and innovative solutions for food waste management that were indexed in the Scopus database as of June 2024 were included in the research.

Table 1. Scopus Search String for Literature

Scopus	TITLE-ABS-KEY [(sustainable OR innovative) AND (solution OR fix OR technology) AND food AND waste) AND PUBYEAR > 2022 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English")] AND [LIMIT-TO (PUBSTAGE , "final")] AND [LIMIT-TO (SRCTYPE , "j")] AND [LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")]

Table 2. Selection Criteria for Literature Inclusion and Exclusion

Criterion	**Inclusion**	**Exclusion**
Timeline	2023-2024	<2023
Language	English	Non-English
Document Type	Article, Review	Non-Article
Source type	Journal	Book

DATA ANALYSIS

An approachable bibliometric programme called VOSviewer was created at Leiden University in the Netherlands by Nees Jan van Eck and Ludo Waltman [7], [8]. The tool, which is widely used for visualising and analysing scientific literature, is particularly good at producing density maps, clustering similar items, and making intuitive network visualisations. Because of its adaptability, researchers can analyse co-authorship, co-citation, and keyword co-occurrence networks, giving them a thorough grasp of the research landscape. The dynamic and efficient study of vast datasets is ensured by the interactive interface and ongoing updates. VOSviewer is an invaluable tool for researchers looking for insights into intricate research fields because of its capacity to compute metrics, customise visualisations, and work with a variety of bibliometric data sources.

VOSviewer's ability to convert complex bibliometric statistics into readable maps and charts is one of its most notable capabilities. The software is excellent at clustering related items, analysing keyword co-occurrence patterns, and creating density maps, with a focus on network visualisation. Its intuitive interface helps researchers by making it possible for both new and seasoned users to efficiently explore study landscapes. With its customisable visualisations and ongoing development, VOSviewer stays at the forefront of bibliometric analysis, providing insightful metrics computation. VOSviewer's versatility in handling various bibliometric data sources, including co-authorship and citation networks, makes it an essential tool for researchers looking to gain a deeper understanding of their fields of study.

Large datasets containing PlainText formatted data on the publication year, title, author name, journal, citation, and keywords were obtained from the Scopus database between 2020 and December 2023. We then used VOSviewer software version 1.6.19 to analyse these datasets. This software made it easier to analyse and create maps by applying VOS clustering and mapping algorithms. As a substitute for the Multidimensional Scaling (MDS) method, VOSViewer concentrates on placing objects in low-dimensional areas so that the distance between any two objects correctly indicates their similarity and relatedness [8]. VOSViewer and the MDS methodology are comparable in this regard [9]. While MDS focuses on computing similarity metrics like cosine and Jaccard indices, VOS uses a more appropriate technique to normalise co-occurrence frequencies. This technique is called the associatio strength (ASij), and it may be computed as [10]:

$$ASij \text{ ¼ } Cij$$

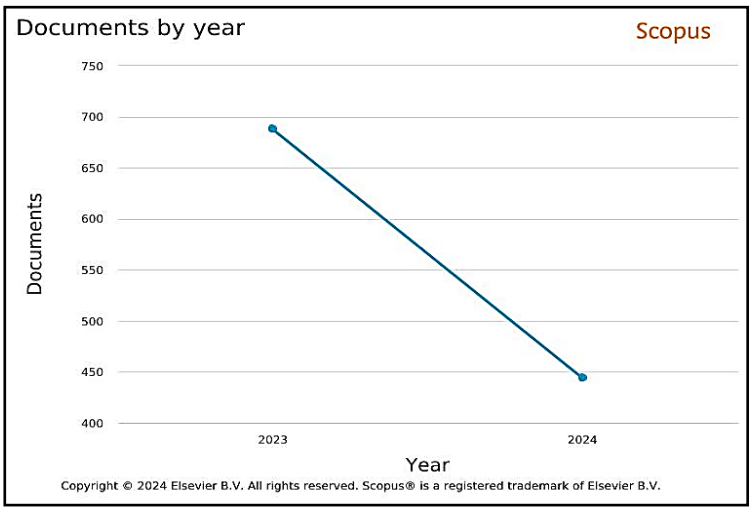
$$Wiwj$$

which is "proportional to the ratio between the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent and the observed number of co-occurrences of i and j on the one hand." Thus, after lowering the weighted total of the squared distances between each pair of items, VOSviewer arranges the items in the shape of a map with the aid of this index.

RESULTS AND FINDINGS

What are the research trends in online learning studies according to the year of 2023 till 2024?

Table 3. Distribution of Publications on Sustainable and Innovative Solutions for Food Waste Management by Year



Year	Number of publication	Percentages
2024	444	39.22
2023	688	60.78

An insightful understanding of the dynamics and trends in this topic may be gained from the bibliometric study of publications on Sustainable and Innovative Solutions for Food Waste. The information shows a significant amount of research output, with a noticeable peak in the last few years. With 688 articles, the year 2023 stands out in particular since it accounts for an impressive 60.78% of all the publications examined. The increase in publications indicates a notable resurgence of scholarly effort and interest, maybe due to technological improvements and their growing incorporation of food waste related knowledge into social behaviours. Nevertheless, it's important to note that, despite 2023's dominance, 2024 nevertheless shows a strong presence with 444 articles, suggesting that research production is still accelerating.

It is noticeable that there was a significant drop in the number of publications indexed in Scopus between 2023 and 2024. This negative trend raises the issue of what reasons could be responsible. A number of factors, such as adjustments to research funding or priorities, difficulties faced by academic institutions or researchers, changes in publishing trends or practices, transient anomalies or data discrepancies in the Scopus database, could account for the observed decline in publication output.

Who wrote the most number of articles?

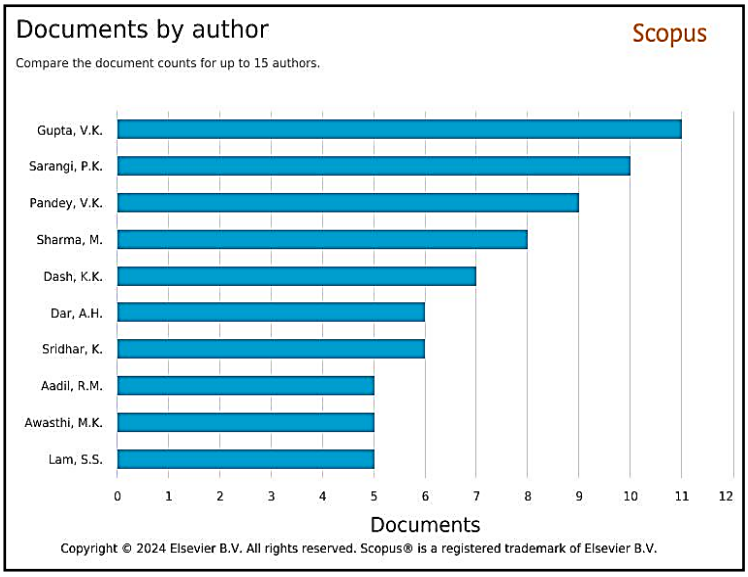


Figure 2. Top 10 Authors Contributing to Research on Sustainable and Innovative Solutions for Food Waste Management

Table 4. Leading Authors and Their Publication Output in Sustainable and Innovative Food Waste Management Research

Author name	Number of Article	Percentages
Gupta, V.K.	11	0.17
Sarangi, P.K.	10	0.15
Pandey, V.K.	9	0.14
Sharma, M.	8	0.12
Dash, K.K.	7	0.11
Dar, A.H.	6	0.09

Sridhar, K.	6	0.09
Aadil, R.M.	5	0.08
Awasthi, M.K.	5	0.06

The bibliometric analysis reveals key contributors in the field of sustainable and innovative solutions for food waste management, as depicted in the table and bar chart. Notably, Gupta, V.K. emerges as the leading researcher with 11 publications, constituting 0.17% of the total articles analyzed. Their prolific output underscores their significant impact on the discourse surrounding sustainable and innovative approaches to address food waste. Following closely are Sarangi, P.K. with 10 publications (0.15%), Pandey, V.K. with 9 publications (0.14%), and Sharma, M. with 8 publications (0.12%). These authors' substantial contributions highlight their dedication and expertise in this research domain. Several other researchers, including Dash, K.K. with 7 publications (0.11%), Dar, A.H. and Sridhar, K. with 6 publications each (0.09%), Aadil, R.M. with 5 publications (0.08%), and Awasthi, M.K. with 5 publications (0.06%), have also made notable contributions to the body of literature on sustainable and innovative solutions for food waste management.

This bibliometric analysis shows the range of research activities in this topic in addition to identifying writers who are prolific. The distribution of publications among different experts suggests a collaborative and multidisciplinary approach to address food waste through creative and sustainable solutions, which is noteworthy. Furthermore, the constancy in the quantity of articles produced by multiple researchers highlights the continuous curiosity and persistent work in investigating new ways to tackle this worldwide problem. The combined efforts of these researchers provide a solid basis for future developments in the field of sustainable and creative approaches to managing food waste, suggesting a bright future for the creation of strategies that both reduce food waste and advance sustainability. These academics' combined efforts from a range of disciplines and backgrounds have the potential to revolutionise how food waste is managed, which will ultimately lead to a more resource-conscious and sustainable future.

What are the type of document by subject of research?

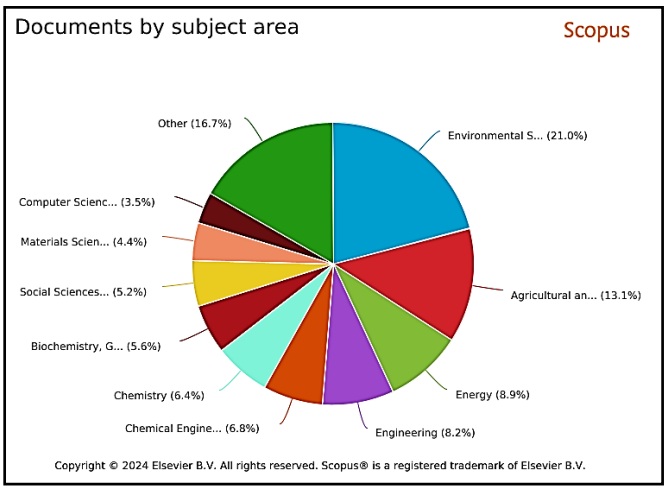


Figure 3. Distribution of Research Documents by Subject Area in Sustainable and Innovative Food Waste Management

The pie chart illustrates the distribution of research documents across various subject areas related to sustainable and innovative solutions for food waste management.

- Environmental Science (21.0%) emerges as the most prominent subject area, indicating a strong focus on environmental aspects of food waste management solutions. This could encompass research on topics such as the environmental impact of food waste, sustainable waste treatment methods, and the development of eco-friendly technologies for food waste valorization.
- Agricultural and Biological Sciences (13.1%) occupy the second position, highlighting the importance of agricultural practices and biological processes in addressing food waste challenges. Studies in this area might explore topics like post-harvest food loss prevention, bio-based waste conversion techniques, and the development of sustainable agricultural systems to minimize waste generation.
- Energy (8.9%) and Engineering (8.2%) are also well-represented, suggesting research efforts aimed at developing energy-efficient and innovative engineering solutions for food waste management. This could involve studies on waste-to-energy technologies, process optimization, and the design of sustainable waste management infrastructure.
- Chemical Engineering (6.8%) and Chemistry (6.4%) contribute to the body of knowledge by investigating chemical processes and techniques for food waste treatment, valorization, and conversion into valuable products or biofuels.
- Biochemistry, Genetics, and Molecular Biology (5.6%) and Social Sciences (5.2%) play a role as well, potentially exploring topics such as the biochemical and genetic aspects of food waste valorization, as well as the social, economic, and policy implications of food waste management strategies.
- Materials Science (4.4%) and Computer Science (3.5%) are also represented, indicating research efforts focused on developing novel materials and computational approaches for sustainable food waste management solutions.
- The remaining slice, "Other" (16.7%), encompasses a diverse range of subject areas that have contributed to this multidisciplinary field of research.

The fact that research is being conducted in a variety of fields highlights how complex creative and sustainable approaches to managing food waste are. It draws attention to the necessity of an interdisciplinary and collaborative approach that incorporates knowledge from the social sciences, engineering, chemistry, environmental sciences, and other relevant domains. Researchers may have a thorough grasp of the difficulties and potential solutions in this field by examining the contributions from these various topic areas. This will ultimately aid in the creation of more efficient and long-lasting methods for managing food waste.

Table 5. Breakdown of Subject Areas Contributing to Sustainable and Innovative Food Waste Management Research

Subjects area	No. of publications	Percentages (%)
Environmental Science	528	20,99
Agricultural and Biological Science	330	13,12
Energy	225	8,95
Engineering	205	8,15
Chemical Engineering	172	6,84
Chemistry	162	6,44

Biochemistry, genetics and Molecular Biology	142	5,65
Social Sciences	131	5,21
Material Sciences	110	4,37
Computer Sciences	89	3,54
Medicine	69	2,74
Immunology and Microbiology	68	2,70
Business, Management and Accounting	56	2,23
Physics and Astronomy	38	1,51
Health Professions	32	1,27
Pharmacology, Toxicology and Pharmaceutics	32	1,27
Economics, Econometrics and Finance	31	1,23
Nursing	19	0,76
Mathematics	18	0,72
Multidisciplinary	16	0,64
Earth and Planetary Sciences	13	0,52
Decision Sciences	12	0,48
Veterinary	10	0,40
Arts and Mumanities	2	0,08
Neuroscience	2	0,08
Psychology	2	0,08
Dentistry	1	0,04

The data shows publication numbers and percentages across 24 subject areas for research on artificial intelligence in teaching and learning.

Key Observations:

- Environmental Science has the highest number of publications at 814 (19.17% of total). This suggests that research on sustainable and innovative solutions for food waste management is most prevalent in fields related to environmental studies and ecological conservation.
- Agricultural and Biological Sciences follows closely with 787 publications (18.53% of total). This reflects the significant role of agricultural practices, biological processes, and related disciplines in addressing food waste issues and developing sustainable management solutions.
- Engineering has a sizable number of publications at 451 (10.62% of total). Engineering principles, technologies, and innovative design approaches are being applied to develop efficient systems and infrastructure for food waste management.
- Computer Science (405 publications, 9.54%) and Chemistry (344 publications, 8.10%) also have notable publication outputs. This indicates the application of computational methods, data analytics, and chemical processes in analyzing and treating food waste, as well as developing innovative solutions.
- Subject areas like Social Sciences (210 publications, 4.94%), Materials Science (192 publications, 4.52%), and Chemical Engineering (162 publications, 3.81%) have moderate

levels of publication output, suggesting interdisciplinary approaches to food waste management involving social, material, and chemical engineering aspects.

- Subject areas such as Mathematics (18 publications, 0.42%), Astronomy (15 publications, 0.35%), and Neuroimedicine (9 publications, 0.21%) have relatively low publication numbers, indicating potential gaps or opportunities for further research in applying mathematical models, astronomical data, or neuroscience principles to food waste management solutions.

Overall, the table offers a thorough overview of how research papers are distributed over a range of topic areas, making it possible to identify both areas with a large output of research and those that have room for expansion and additional investigation.

Who is the top 10 authors based on citation by research?

Table 6: Top 10 Most Cited Articles in Sustainable and Innovative Food Waste Management Research

Authors	Title	Year	Source title	Cited by
Yang M.; Chen L.; Wang J.; Msigwa G.; Osman A.I.; Fawzy S.; Rooney D.W.; Yap P.-S.	Circular economy strategies for combating climate change and other environmental issues	2023	Environmental Chemistry Letters	138
Hassoun A.; Aït-Kaddour A.; Abu-Mahfouz A.M.; Rathod N.B.; Bader F.; Barba F.J.; Biancolillo A.; Cropotova J.; Galanakis C.M.; Jambrak A.R.; Lorenzo J.M.; Måge I.; Ozogul F.; Regenstein J.	The fourth industrial revolution in the food industry—Part I: Industry 4.0 technologies	2023	Critical Reviews in Food Science and Nutrition	89
Hoang A.T.; Sirohi R.; Pandey A.; Nižetić S.; Lam S.S.; Chen W.-H.; Luque R.; Thomas S.; Arıcı M.; Pham V.V.	Biofuel production from microalgae: challenges and chances	2023	Phytochemistry Reviews	79
Rifna E.J.; Misra N.N.; Dwivedi M.	Recent advances in extraction technologies for recovery of bioactive compounds derived from fruit and vegetable waste peels: A review	2023	Critical Reviews in Food Science and Nutrition	74
Peng X.; Jiang Y.; Chen Z.; Osman A.I.; Farghali M.; Rooney D.W.; Yap P.-S.	Recycling municipal, agricultural and industrial waste into energy, fertilizers, food and construction materials, and economic feasibility: a review	2023	Environmental Chemistry Letters	69
Hegab H.; Khanna N.; Monib N.; Salem A.	Design for sustainable additive manufacturing: A review	2023	Sustainable Materials and Technologies	67

Sharma J.K.; Kumar N.; Singh N.P.; Santal A.R.	Phytoremediation technologies and their mechanism for removal of heavy metal from contaminated soil: An approach for a sustainable environment	2023	Frontiers in Plant Science	66
Peydayesh M.; Bagnani M.; Soon W.L.; Mezzenga R.	Turning Food Protein Waste into Sustainable Technologies	2023	Chemical Reviews	63
Versino F.; Ortega F.; Monroy Y.; Rivero S.; López O.V.; García M.A.	Sustainable and Bio-Based Food Packaging: A Review on Past and Current Design Innovations	2023	Foods	63
Jung H.; Shin G.; Kwak H.; Hao L.T.; Jegal J.; Kim H.J.; Jeon H.; Park J.; Oh D.X.	Review of polymer technologies for improving the recycling and upcycling efficiency of plastic waste	2023	Chemosphere	62

What are the popular keywords related to the study?

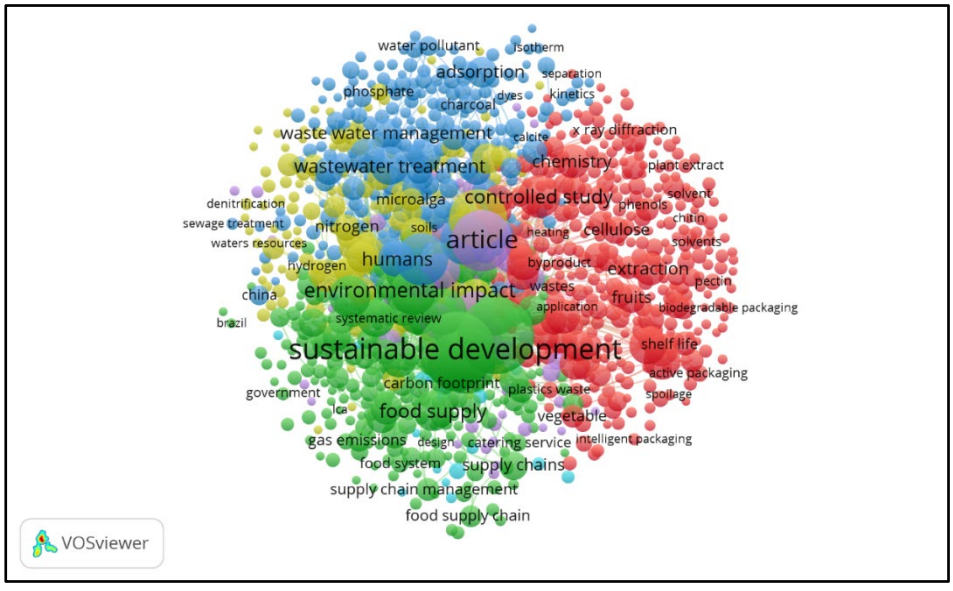


Figure 4. Network visualization map of keywords' co-occurrence

The analysis of popular keywords related to sustainable and innovative solutions for food waste management reveals several notable trends. "Wastewater treatment" and "waste water management" emerge as the most frequently occurring keywords, with substantial total link strengths, indicating their centrality in the discourse. This suggests a significant interest and focus on managing and treating wastewater generated from various sources, including food waste. Within the wastewater treatment domain, "adsorption" stands out with a high occurrence and considerable link strength, reflecting the growing interest in adsorption techniques for removing pollutants and contaminants from wastewater. Additionally, terms such as "dyes," "charcoal," "kinetics," and "isotherm" demonstrate a keen interest in exploring various adsorbents and their kinetic behavior in wastewater treatment applications.

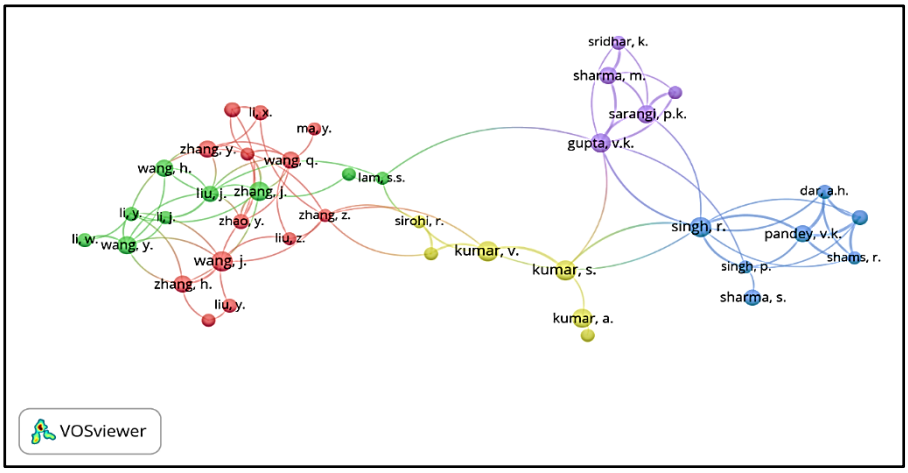


Figure 5. Co-citation Network Analysis of Authors in Sustainable and Innovative Food Waste Management Research

Furthermore, the keyword "phosphate" exhibits a strong link with "wastewater treatment," highlighting research efforts in removing phosphate compounds, which can contribute to eutrophication in water bodies. The presence of the keyword "controlled study" underscores the importance of conducting systematic experiments and investigations to evaluate the effectiveness of different wastewater treatment methods and technologies. Notably, while traditional waste management concepts like "sewage treatment" and "denitrification" are present, they exhibit relatively lower link strengths compared to wastewater treatment-related terms, indicating a shift towards a stronger focus on wastewater management and treatment in the context of food waste. Moreover, the analysis highlights the intersection of food waste management with various themes and challenges. "Plant extract," "pectin," and "chitosan" emerge as prominent keywords, emphasizing the growing interest in exploring natural and bio-based materials for wastewater treatment and other sustainable solutions. The terms "solvents," "extraction," and "byproduct" underscore the importance of solvent-based extraction processes for valorizing byproducts or waste streams, contributing to the development of innovative and sustainable solutions.

Additionally, the keyword "biodegradable packaging" is closely linked to terms like "fruits," "vegetables," and "shelf life," reflecting research efforts in developing sustainable packaging solutions to reduce food waste and extend the shelf life of fresh produce. Furthermore, the presence of keywords such as "sustainable development," "carbon footprint," "food system," and "supply chains" highlights a broader consideration of sustainability principles, environmental impact assessments, and the integration of innovative solutions into food supply chain management.

Overall, the analysis underscores the multifaceted nature of sustainable and innovative solutions for food waste management, encompassing wastewater treatment and management, exploration of natural materials and extraction processes, development of sustainable packaging, and integration into food systems and supply chains, all while addressing environmental impacts and promoting sustainable development.

Network mapping based on co-citation by authorship?

The co-citation analysis by authorship provides valuable insights into the scholarly landscape of sustainable and innovative solutions for food waste management. Notably, certain authors exhibit significant link strengths, reflecting their influential contributions to the field. Authors like "lam, s.s."

and "kumar, v." stand out with dense interconnections, indicating widespread acknowledgment and citation of their work within the academic community. These authors likely have made substantial contributions to advancing research and practices related to food waste management solutions. Moreover, the presence of authors with diverse surnames, such as "zhang," "wang," "li," and "kumar," underscores the international and multicultural nature of research in this domain, drawing from expertise across various regions and backgrounds.

Additionally, the analysis reveals clusters of closely connected authors, suggesting collaborative research efforts or research groups working on related topics. For instance, the cluster around "zhang, y." and "wang, q." indicates a potential research team or collaboration network focusing on specific aspects of food waste management solutions. Similarly, the cluster around "kumar, s." and "singh, r." may represent another research group or collaboration network contributing to this field. These clusters highlight the importance of interdisciplinary collaboration and the formation of research teams to address complex challenges related to food waste management. Furthermore, the analysis shows authors with varying degrees of connectivity, suggesting different levels of collaboration and citation patterns. Authors like "li, x." and "ma, y." have fewer connections, indicating potential opportunities for increased collaboration or recognition within the scholarly community. On the other hand, authors like "gupta, v.k." and "sarangi, p.k." exhibit stronger connections, suggesting their work has been more widely cited and acknowledged.

Overall, the co-citation analysis highlights the contributions of key authors, the collaborative nature of research in sustainable and innovative solutions for food waste management, and the diversity of perspectives and expertise involved in this field. This analysis underscores the importance of interdisciplinary collaboration, international collaboration, and the formation of research teams to drive progress and innovation in addressing the global challenge of food waste.

What are co-authorship countries' collaboration?

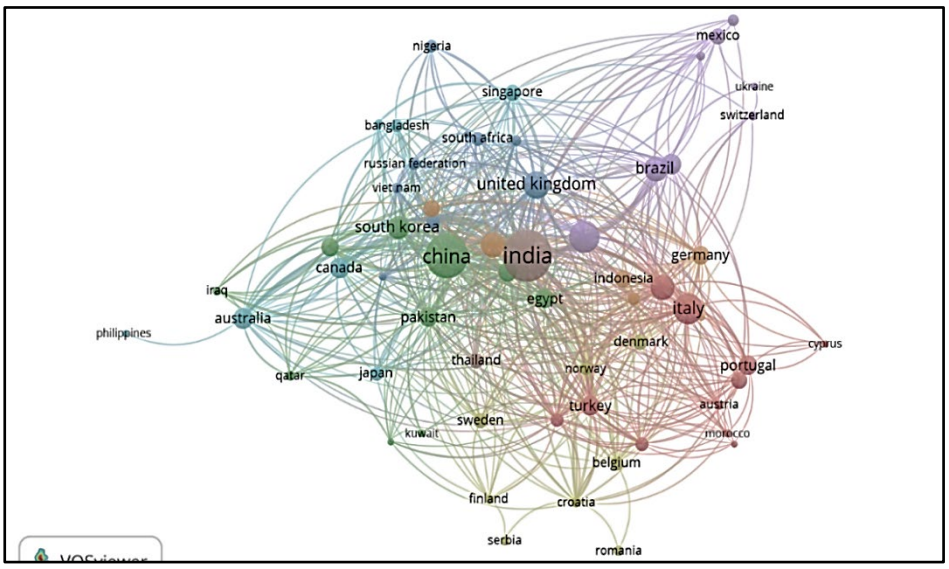


Figure 6. Global Collaboration Network in Sustainable and Innovative Food Waste Management Research

The analysis of co-authorship countries' collaboration in the field of sustainable and innovative solutions for food waste management reveals several key insights. Notably, countries such as China, India, and the United Kingdom emerge as prominent contributors, with high numbers of documents, citations, and substantial total link strength. China stands out with a dense network of connections, suggesting a significant level of research output and collaboration in this domain. This indicates a strong research ecosystem and active engagement in exploring sustainable and innovative solutions for food waste management. Similarly, India exhibits a notable presence, with a considerable number of connections, highlighting its growing influence and contributions to this field. Additionally, countries like the United Kingdom, Germany, and Italy demonstrate significant collaboration and engagement in research endeavors related to food waste management solutions, as evidenced by their respective network connections and link strengths. This collaborative landscape underscores the global interest and effort in addressing the challenge of food waste through innovative and sustainable approaches.

Furthermore, the analysis reveals disparities in research output and collaboration across different countries. While some countries, like China and India, show strong research activity and collaboration networks, others exhibit relatively fewer connections and lower levels of engagement in this field. For instance, countries like Nigeria, Bangladesh, and Iraq have fewer links, reflecting less involvement or perhaps nascent research endeavors in sustainable and innovative solutions for food waste management. This indicates potential opportunities for these countries to strengthen their engagement and collaboration in research initiatives related to this domain, potentially through partnerships with more established research hubs. Overall, the analysis highlights both the collaborative nature of research in this field and the varying levels of engagement and collaboration among different countries, signaling avenues for further exploration and cooperation to advance sustainable and innovative solutions for food waste management on a global scale.

DISCUSSION AND CONCLUSIONS

The present bibliometric analysis provides a comprehensive overview of the research landscape in sustainable and innovative solutions for food waste management. By employing the Scopus database and the VOSviewer software, this study offers valuable insights into various aspects of this multidisciplinary field, including publication trends, influential authors, prominent institutions, recurring keywords, co-authorship patterns, and co-citation networks. The analysis reveals a significant growth in research activities related to sustainable and innovative solutions for food waste management, with a notable surge in publications in recent years. This surge can be attributed to the increasing awareness of the environmental, economic, and social implications of food waste, as well as the advancements in technology and innovation that facilitate the development of sustainable solutions.

One of the key findings of this study is the interdisciplinary nature of the field, as evidenced by the diverse range of subject areas contributing to the body of knowledge. Environmental Science, Agricultural and Biological Sciences, Engineering, Computer Science, and Chemistry emerge as the most prominent subject areas, indicating the multifaceted approach required to address the complex challenge of food waste management. This interdisciplinary collaboration is essential for fostering innovative solutions that integrate environmental, agricultural, technological, and scientific perspectives. The analysis of highly cited authors and their institutional affiliations highlights the influential contributors and research hotspots driving advancements in this field. The identification of these key players and institutions can facilitate future collaborations, knowledge exchange, and the dissemination of best practices.

The keyword analysis provides valuable insights into the evolving research topics and areas of focus within the field of sustainable and innovative solutions for food waste management. Keywords such as "wastewater treatment," "adsorption," "biodegradable packaging," and "supply chains" indicate a strong emphasis on developing sustainable waste management techniques, exploring natural and bio-based materials, and integrating innovative solutions into food supply chain management. Additionally, the presence of keywords related to sustainability principles, environmental impact assessments, and food systems underscores the holistic approach adopted by researchers in addressing this multifaceted challenge.

Furthermore, the co-authorship network analysis reveals the global collaborations and partnerships that have influenced the field, highlighting both the well-established research hubs and the emerging contributors. The identification of these collaborative networks can foster future international collaborations, knowledge sharing, and the exchange of best practices, ultimately accelerating the development of sustainable and innovative solutions for food waste management. The co-citation analysis by authorship provides insights into the intellectual structure of the field, identifying potential research communities and influential works that have shaped the discourse. This analysis can serve as a valuable resource for researchers to navigate the existing literature, identify relevant citations, and build upon the collective knowledge within the field.

In conclusion, this bibliometric analysis presents a comprehensive and data-driven understanding of the research landscape in sustainable and innovative solutions for food waste management. By synthesizing various aspects, including publication trends, author contributions, subject areas, keyword occurrences, co-authorship patterns, and co-citation networks, this study offers a holistic perspective on the current state and future directions of this crucial field. The findings highlight the multidisciplinary nature of the research, the influential contributors, and the global collaborations driving advancements in sustainable and innovative approaches to food waste management. This analysis serves as a valuable resource for researchers, policymakers, and stakeholders in the food industry, providing a solid foundation for shaping future research agendas, fostering collaborations, and addressing the global challenge of food waste through sustainable and innovative solutions.

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