International Journal of Food Sciences and Nutrition Innovations
Volume 1, Issue 1, 50-70.
e_ISSN: xxxx-xxxx
https://e-journal.gomit.id/ijfsni

Food Processing And Packaging Technology Innovations In Food Waste Reduction: A Systematic Review

Adityas Agung Ramandani*
Yuan Ze University, Taoyuan
TAIWAN

Eko Risdianto
University of Bengkulu
INDONESIA

Fadillah Eka Nuranisa
CV. Media Inti Teknologi Indonesia
INDONESIA

*** Corresponding author:**
Adityas Agung Ramandani, Yuan Ze University, Taoyuan, Taiwan. ✉adityasagung1212@gmail.com

Article Info

Article history:

Received: Maret 08, 2025
Revised: April 12, 2025
Accepted: June 01, 2025

Keywords:

Food Waste Reduction
Food Processing
Food Packaging
Sustainability
Innovations

Abstract

Background of study: Food waste is a critical global issue with significant economic, environmental, and social impacts. Approximately one-third of all food produced is wasted, contributing to over 3.3 billion tons of CO2 emissions annually and wasting 250 cubic kilometers of water each year. This systematic literature review (SLR) aims to explore recent innovations in food processing and packaging technologies that contribute to food waste reduction.
Methods: The approach used in this study is Systematic Literature Review (SLR) by following the PRISMA guidelines. Relevant articles are identified, filtered, and analyzed from various databases such as Scopus. Bibliometric analysis and visualization were carried out using the VOSviewer and Biblioshiny applications to map research trends, collaborations, and thematic focus in this field. A total of 127 articles were analyzed, revealing the latest trends in food packaging and processing innovations. The review includes studies on active and biodegradable packaging materials, as well as consumer behavior interventions that influence food waste reduction.
Result: 62.5% of studies focused on developing active and biodegradable packaging materials. Notable examples include the use of chitosan-based films that extended the shelf life of fresh produce by up to 10 days, and the application of antimicrobial packaging that reduced spoilage rates by 25% in perishable foods. 25% of studies reviewed behavioral interventions, such as consumer education campaigns that led to a 15% reduction in food waste in households. Innovations such as bio-based polymers and smart packaging have shown significant potential in minimizing food spoilage during transport and storage
Conclusion: The findings highlight the potential of material innovations in food packaging, but research gaps remain in scaling these technologies for industrial application and integrating them with consumer behavior strategies. Future research should focus on optimizing material properties for large-scale production, evaluating safety and toxicity, and exploring policy frameworks that incentivize the adoption of sustainable packaging solutions. This review underscores the need for cross-sector collaboration to drive impactful changes in food waste reduction and achieve sustainability goals.

To cite this article: Ramandani et al (2025). Title. Journal of Food Sciences and Nutrition Innovations, 1(1), 50-70.

INTRODUCTION

Food waste is a pressing global issue that compels urgent intervention due to its extensive economic, environmental, and social implications (Bourlieu & Guillard, 2020). Approximately one-third of all food produced for human consumption is wasted, resulting in significant financial losses across the supply chain and contributing to environmental degradation, particularly greenhouse gas emissions from decomposing food in landfills. The Food and Agriculture Organization (FAO) reported that food waste results in nearly 3.3 billion tons of CO2 emissions annually, emphasizing the urgency of addressing this problem. Additionally, the equivalent water wasted from food waste is estimated at about 250 cubic kilometers per year, underscoring the extensive resource depletion involved in food production (Sakaguchi et al., 2018).

The issue of food waste is multifaceted, manifesting at various stages from production to consumption, particularly within households (De Laurentiis et al., 2018). In developed nations, a significant percentage of

food waste occurs at the consumer level, often due to over-purchasing and a lack of awareness about proper food storage and consumption habits. Research indicates that excess food purchased by consumers leads to unnecessary waste, exacerbating resource depletion issues (Mahalik & Nambiar, 2010). Moreover, food waste in households accounts for a large portion of total waste and represents wasted energy and emissions invested in food production, processing, and transportation (Schanes et al., 2018); (Conrad et al., 2018). Addressing food waste requires examining consumer behavior and industry practices. Understanding the psychology behind food waste is crucial for developing effective interventions. Strategies such as better food production planning, waste measurement in restaurants, and consumer education on food storage and portion control are essential. Furthermore, harnessing food waste through recycling and bioconversion processes presents an opportunity to mitigate both waste and resource scarcity by converting food scraps into valuable products, including biofuels or animal feed (Wijayarathna et al., 2023);(Gmoser et al., 2020). Ultimately, combating food waste demands coordinated efforts across governmental, industrial, and individual levels to implement sustainable practices. Awareness and education regarding the ecological footprint of food waste, alongside developing policies aimed at reducing waste throughout the food supply chain, are essential for creating a more sustainable food system. Tackling this growing issue will help mitigate environmental harm and improve food security and resource efficiency on a global scale (Conrad et al., 2018);(Zhu et al., 2018).

Examining food waste reduction strategies in processing and packaging is crucial for several reasons, primarily centered on its economic, environmental, and social impacts. First, a significant portion of food waste occurs at the processing and packaging stages (Xiao, 2021). The Food and Agriculture Organization (FAO) has distinguished between food loss, which typically happens during the agricultural and processing stages, and food waste that occurs at retail and consumer levels. This highlights the importance of targeting reductions across the entire supply chain, including processing and packaging, to achieve sustainable practices as outlined in the United Nations' Sustainable Development Goal 12 (Pinela et al., 2024). During processing, the handling and storage of food products often lead to inefficiencies that result in food loss. Strategies that enhance the efficiency of processing methods can substantially reduce the amount of food that is discarded. For instance, effective food management practices, such as accurate forecasting and adjusting production levels to match demand, can minimize overproduction and subsequently reduce waste. Additionally, implementing technologies that improve food preservation, such as controlled atmosphere packaging, can extend product shelf life and reduce spoilage during transport and storage (Gutiérrez et al., 2019).

Moreover, packaging plays a vital role in protecting food quality and preventing spoilage. Suboptimal packaging materials not only fail to preserve food but also contribute to food waste (Petersen & Solberg, 2020). Research has demonstrated that innovative packaging solutions, such as biodegradable and recyclable materials, can significantly lower the environmental impact associated with food waste while also appealing to environmentally conscious consumers (Molina-Besch et al., 2019). The European Commission has emphasized the need for eco-friendly packaging solutions as part of its broader Circular Economy Strategy, pointing toward the legislative revisions that aim to encourage sustainable practices across the food supply chain (Aldaco et al., 2020); (Molina-Besch & Pålsson, 2020). Furthermore, consumer behavior is influenced by packaging design and how food is presented. Adjusting factors such as packaging size or offering take-out containers can lead to reduced plate waste in food service establishments. Studies suggest that tailoring portions to consumer preferences can minimize leftover food, thereby contributing directly to waste reduction strategies in restaurants and catering services (Alcorn et al., 2020); (Iori et al., 2022).

By reducing food waste through improvements in processing and packaging is not only essential for minimizing environmental degradation but is also economically advantageous (Verghese et al., 2015). It requires collaboration among various stakeholders in the food industry to adopt and implement effective strategies that maintain product integrity while also considering consumer behavior and preferences (Mirabella et al., 2014). A holistic approach that encompasses better technology, design, and consumer education is pivotal for fostering sustainable food practices that can contribute significantly to our efforts in mitigating food waste. The aim of this Systematic Literature Review (SLR) is to address the main research question, which seeks to identify the most effective strategies for reducing food waste in food processing and packaging. Through a comprehensive review of relevant studies and innovations, this research intends to uncover the strategies that have proven to be successful in minimizing food waste at various stages of production, from processing to packaging. By synthesizing findings from multiple sources, this study will provide valuable insights into the best practices, technologies, and approaches that can be adopted to tackle food waste, ultimately contributing to more sustainable and efficient food systems (Vanderroost, 2014).

This research can provide significant contributions to both the food industry and waste management policies by identifying effective strategies for reducing food waste in processing and packaging (Ciccullo et al., 2021). By highlighting innovative technologies and practices that minimize waste, the findings can guide food manufacturers in adopting more sustainable production methods, reducing costs, and improving their environmental footprint. Additionally, the insights derived from this review can inform policymakers in designing and implementing regulations that encourage waste reduction, promote circular economy principles,

and support the transition toward eco-friendly packaging solutions. Ultimately, this study aims to foster a more sustainable and resource-efficient food industry, while also contributing to global efforts to reduce food waste and mitigate its environmental impact.

METHOD

Research Design

SLR Approach

This study uses a systematic review approach to assess and analyze innovations in food processing and packaging in the context of waste reduction. This approach follows the **Prisma** (Preferred Reporting Items for Systematic Reviews) guidelines which have proven to be effective in ensuring that the literature selection and synthesis process is carried out in a transparent and structured manner. The data is visualized using the VOSviewer application, which displays relationships between articles, authors, and topics in the form of Overlay Visualization and Network Visualization. This visualization is very helpful in understanding the patterns of linkages in the literature analyzed. As a complement, the data was also analyzed using Elicit AI, a web-based platform that supports the process of drafting research questions, literature reviews, and evidence-based decision-making. Before using Elicit AI, the previously cleaned CSV file is filtered back using Microsoft Excel to identify the articles available in PDF format.

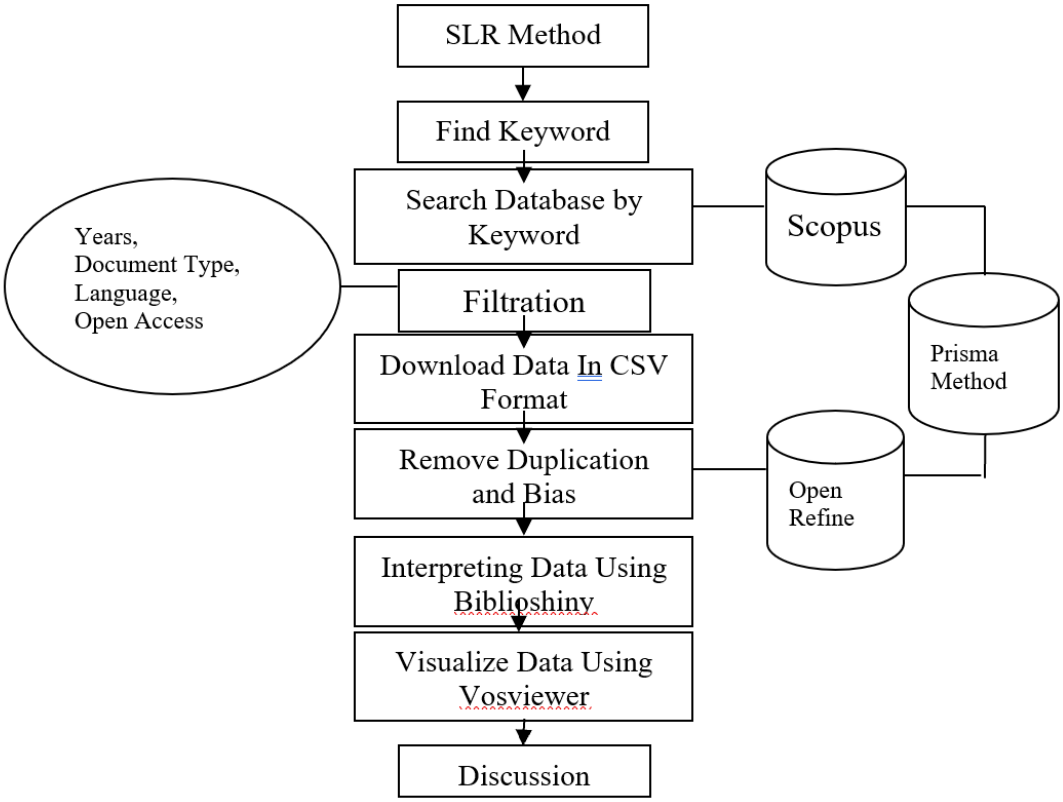


Figure 1. Research Method Flow Diagram

As part of this method, a prism flowchart will be used to illustrate the article selection process, from the number of articles found to the number that is ultimately included in this review. This diagram helps to show transparency in the selection process and provides a clear picture of how the literature has been screened based on established criteria.

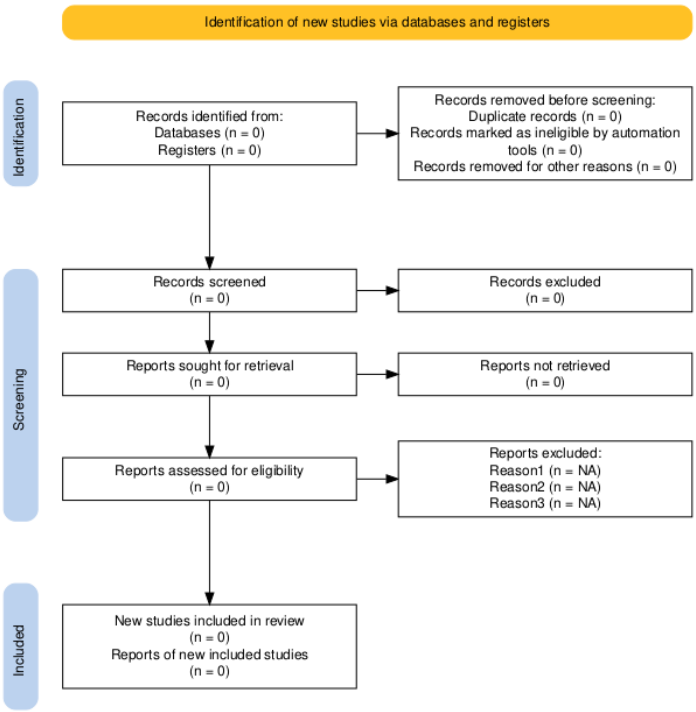


Figure 2 Prisma Systematic Literature Review Method

One of the main components of PRISMA is the PRISMA flowchart), which is used to describe the steps of the identification, screening, feasibility assessment, and inclusion studies that are included in systematic observation. This chart describes the number of studies found through databases and other sources, the number removed due to duplication or irrelevance, the number that are inaccessible, and the reason for submitting studies that don't meet the criteria. Thus, PRISMA not only displays the transparency of the review process, but also helps to minimize bias and increase the credibility of research results.

Population and the methods of sampling; Instrumentation

The population in this study is all scientific articles that discuss food processing innovations, environmentally friendly packaging technology, and food waste reduction strategies. Samples were taken using the purposive sampling method using keywords such as "food waste reduction", "food packaging innovation", and "sustainable food processing". The validity and reliability of the instrument are guaranteed because the articles taken are peer-reviewed publications from reputable databases such as Scopus.

Instrument

The research instruments used are in the form of a checklist of inclusion and exclusion criteria that are compiled to ensure that the selected articles are relevant and in accordance with the research objectives. The inclusion criteria set include articles published within a maximum period of ten years, namely between 2014 and 2024, articles must be written in English, have a focus on studies on innovations in food processing, packaging, or food waste reduction strategies, and the articles must be available in full text so that they can be analyzed in depth.

Procedures and if relevant, the time frame

The research procedure began with an article search conducted from May to June 2025 through the Scopus database. The research process follows the PRISMA stages, starting from the identification of articles using predetermined keywords, then screening through a review of titles and abstracts, followed by feasibility evaluation based on full-text readings, until finally articles that are worthy of analysis are obtained. Bibliometric visualization and analysis were performed using VOSviewer and Biblioshiny software to map research trends, author collaboration, and thematic focus.

Analysis plan

The data in this study was analyzed using bibliometric analysis to map the trends of research topics, collaborations between authors, and the most contributing publication sources in this field. In addition, content analysis was also carried out to identify various strategies and innovations proposed in the articles studied. To strengthen the results of the analysis, network visualization and overlay visualization techniques were used to describe the relationship between research topics and the contributions of each author. This study does not use conventional statistical tests because the approach is qualitative based on literature, so the main focus is on mapping and synthesis findings from published studies.

Scope and/or limitations of the methodology you used

The scope of this research includes scientific articles indexed in the Scopus database with a focus on the topic of food processing and packaging that contributes to the reduction of food waste. However, this study has some limitations. One of them is the potential for publication bias that arises because it only uses one database source, namely Scopus, so there is a possibility of missing relevant research published in other sources. In addition, this study does not include studies of grey literature such as industry or policy reports that have not been formally published in scientific journals. Another limitation is the absence of empirical evaluation of the effectiveness of innovation implementation discussed in a real-world or industrial-scale context, so the findings are conceptual and require further validation through applied research.

RESULTS AND DISCUSSION

Results

Kajian Bibilometrik

In the bibliometric analysis, the search strategy used used Scopus data sources related to this research theme. From several keywords selected, 5 keywords were chosen, namely keywords for a broad search for digital literacy, a focus on digital literacy in online learning, and keywords for articles that discuss the influence of literacy on learning outcomes.

Table 1. Keywords of Disbursement

Search Topics	Keywords	Number of Articles (2015-2025)	Total Articles
Food Sustainability Strategies	" food waste sustainability" AND "food waste minimization"	62	133
Food Waste in Packaging	“Innovations in Food Packaging”	35	
Circular Economy in Food	"circular economy food systems"	1	
Sustainability in Food Industry	"green technologies in food industry"	1	
Food Packaging Innovations	"eco-friendly packaging solutions"	34	

Reduce duplicate data

With the use of data from the 5 files of the search results of the keywords above that are exported, it is compressed zip and then entered into open refine. This application is used to filter data, especially to see whether or not there is data obtained from search results. In addition, this application can also be used to eliminate keyword bias contained in the data obtained where initially the data was obtained as many as 133 articles, when entered into open refine to 127 articles.

Metadata	Description	Missing Counts	Missing %	Status
AB	Abstract	0	0.00	Excellent
C1	Affiliation	0	0.00	Excellent
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
DI	DOI	1	0.79	Good
CR	Cited References	2	1.57	Good
RP	Corresponding Author	8	6.30	Good
DE	Keywords	10	7.87	Good
ID	Keywords Plus	48	37.80	Poor
LA	Language	127	100.00	Completely missing
WC	Science Categories	127	100.00	Completely missing

Figure 3. The meta data on DE/Keyword is good

Furthermore, the process of interpreting bibliometric data can be carried out using the Biblioshiny application as follows. The main information data as a whole is the information obtained in the following image.

Table 2. Key information on the data sheet

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2005–2025
Sources (Journals, Books, etc)	94
Documents	127
Annual Growth Rate %	16.71
Document Average Age	3.8
Average citations per doc	50.37
References	9764
DOCUMENT CONTENTS	
Keywords Plus (ID)	993
Author's Keywords (DE)	493
AUTHORS	
Authors	531
Authors of single-authored docs	5
AUTHORS COLLABORATION	
Single-authored docs	5
Co-Authors for Doc	4.5
International co-authorships %	36.22
DOCUMENT TYPES	
Article	79
Conference paper	8
Review	40

Table 2. presents key information regarding the metadata of scientific publications in the period 2005 to 2025. In this period, 127 scientific papers were published, coming from 94 sources such as journals, books, and others, with an annual growth rate of 16.71%. The average age of the document is 3.8 years, indicating that the majority of publications are still relatively new and relevant. Each document obtained an average of 50.37 citations, which indicates a fairly high level of influence or visibility among academics. The total references used reached 9,764, reflecting the depth of the study and the strong level of literature interconnectedness. In terms of content, there are 993 terms on Keywords Plus and 493 keywords provided by the author, which shows the diversity of topics and research focus.

In terms of author contributions, a total of 531 authors were involved in publications, but only five papers were written by one author independently, showing the dominance of collaboration in research. The average number of authors per document is 4.5, and about 36.22% of the total documents involve international

collaboration, which indicates that there is a significant cross-border cooperation. In terms of document type, scientific articles were the most dominant with 79 documents, followed by 40 documents in the form of reviews and 8 conference papers. This data as a whole shows that the field of study analyzed has dynamic growth, strong collaboration, and a fairly high level of influence in the international scientific community.

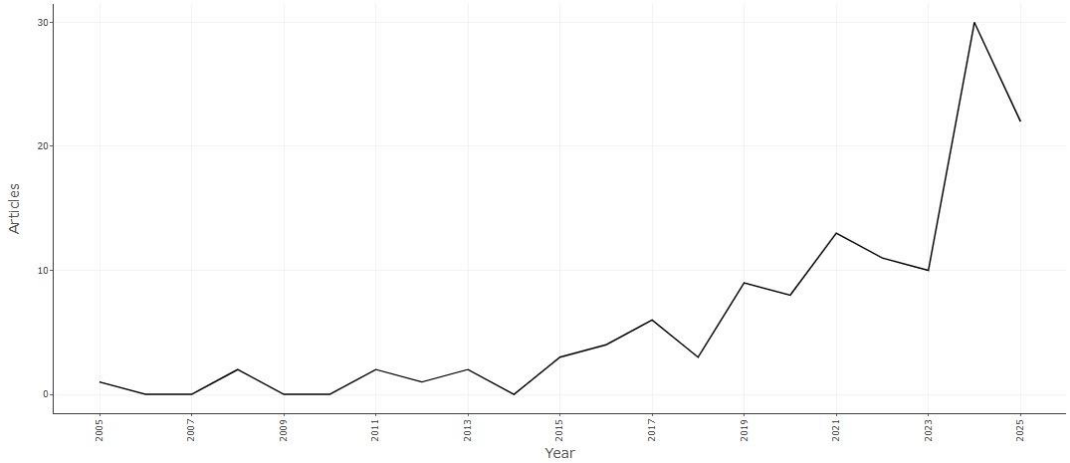


Figure 4. Year-over-year growth chart

It can be shown by the distribution of the data table as below.

Table 3. Growth every year.

Year	Articles
2005	1
2006	0
2007	0
2008	2
2009	0
2010	0
2011	2
2012	1
2013	2
2014	0

Figure 4 and table 3 shown provide an overview of the trend of scientific article publication by year during the period 2005 to 2025. Based on the table, the number of articles published at the beginning of the period (2005–2014) tends to be low and fluctuating. For example, in 2005 there was only 1 article, while in the following few years (2006, 2007, 2009, 2010, and 2014) there were no publications at all. The highest number of articles during the first decade reached only 2 articles, which occurred in 2008, 2011, and 2013. This shows that at first this research field did not receive significant attention or momentum from the scientific community.

However, the graph shows a fairly sharp increase after 2015. The growth trend is starting to look stable and consistently increasing, especially since 2018. The peak of publication occurs in 2024 with the number of articles reaching more than 30, before declining slightly in 2025. This sharp increase indicates that the observed topic or field of study is starting to receive wider attention from researchers. This could be due to the increased urgency of the research topic, the availability of research funding, or the relevance of the theme in a global and local context.

Overall, both the table and the graph indicate an exponential growth in the number of scientific publications, particularly in the last decade. This is in line with data from the previous table which shows an average annual growth rate of 16.71% and a fairly high level of international collaboration (36.22%). Thus, it can be concluded that this field of research has developed significantly in the last two decades and is increasingly attracting the attention of scientists from different parts of the world.

Here are the

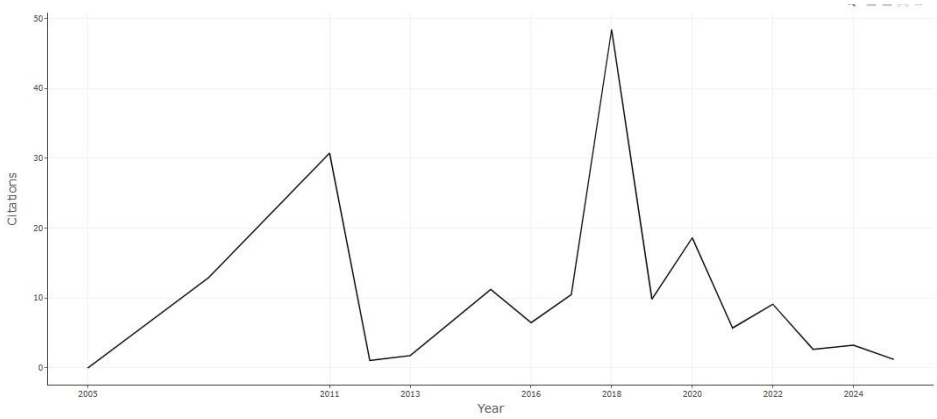
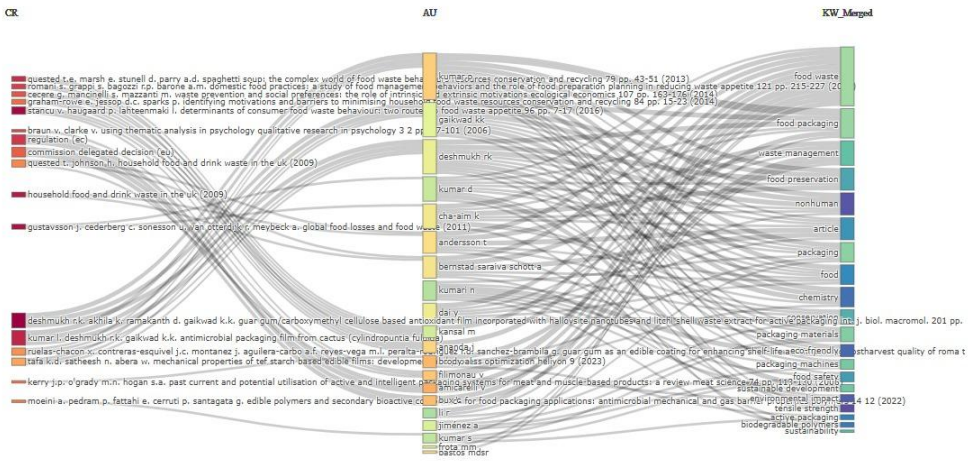


Figure 5. Graph of citations per year

The graph shows the trend in the number of citations to scientific articles from 2005 to 2025. Overall, the graph shows significant fluctuations from year to year, reflecting variations in the influence or level of readability of scientific papers in that period. In the early years (2005–2010), the number of citations increased steadily, suggesting that although the number of publications at the time was relatively small, some of them had a considerable impact in the scientific community. The initial peak was seen in 2011 with more than 30 citations.

However, after 2011 there was a drastic decline, especially in 2012 to 2013, which only recorded about 1–2 citations. After that, the trend gradually rose again until it reached a peak in 2018, with the number of citations almost touching the 50 mark. This indicates that articles published around that year have a high level of relevance and citation, most likely because the topics raised are relevant to important issues of the time or because of the high quality of their publications.

After 2018, the chart again shows a fairly sharp and fluctuating decline, with a gradual downward trend until 2025. This decline can be caused by several factors, such as the age of the article that is still too recent to get many citations or the reduced influence of recent publications on the academic community. Overall, this graph shows that although the number of publications increased significantly, not all articles immediately get a lot of citations, and time plays a significant role in the accumulation of scholarly citations. In addition, certain peaks reflect years in which scientific work greatly contributed to the development of science in the field.



Gambar 6. Diagram Three-Field Plot

Figure 6 above is a bibliometric visualization in the form of a Sankey diagram, which illustrates the relationship between three main elements in scientific publications: cited references (CR), authors (AU), and merged keywords (KW_Merged). This diagram aims to show the linkage between the most cited references, relevant authors, and the main topics or keywords that appear most frequently in the related literature. On the left side of the diagram (CR), a list of references or scientific works that are often used as references by other researchers is displayed. Among them are the work of Quested et al. (2013) on food waste, Gustavsson et al. (2011) on global food loss and waste, and the Commission of the European Communities (2006) which has a great influence in the field of food policy. These references are linked to a number of authors in the middle column (AU), such as Kumar, Deshmukh, Cha-am, and Bernstad, who often refer to these works in their research. The right column (KW_Merged) displays the main keywords used in these articles, such as food waste,

food packaging, waste management, food preservation, biodegradable polymers, and active packaging. The relationship between the columns shows that many authors raise interrelated issues, such as food waste and environmentally friendly food packaging, as well as preservation technology.

This diagram as a whole shows how the key literature forms the basis for recent research and how key relevant topics continue to develop. The thicker the connecting line between elements, the stronger the relationship between the reference, the author, and the topic. This indicates consistency in research interests and the development of thematic focus in the areas of food sustainability, active packaging, and food waste management over a period of time. This visualization is very useful in mapping the scientific landscape and identifying the centers of the most influential scientific contributions.

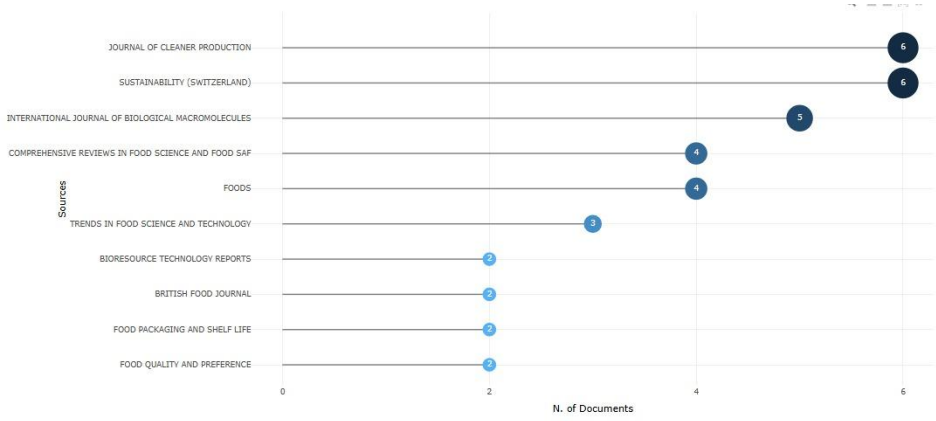
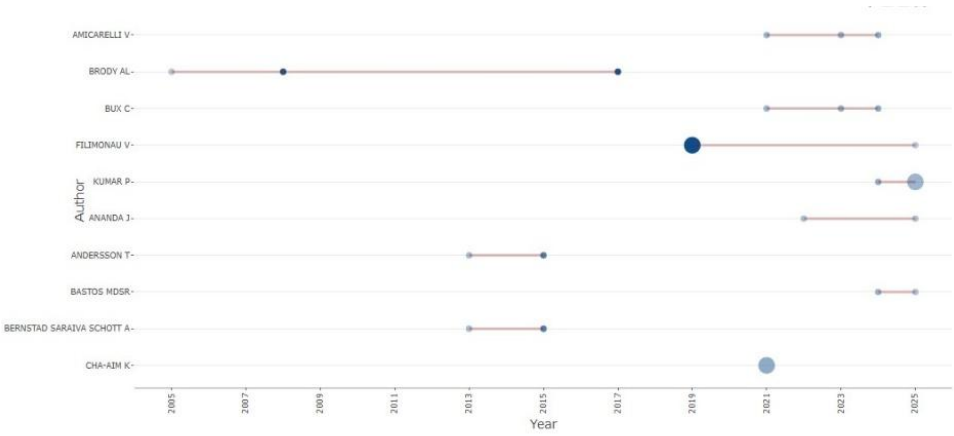


Figure 7. most relevant Source

Figure 7 is a visualization of publication distribution based on the number of documents (N. of Documents) published in various journal sources (Sources). This graph shows the top ten journals that were most productive in publishing articles related to the field of study during the period observed. This horizontal graph provides a clear picture of each journal's contribution to total publications. The two most prominent journals are the Journal of Cleaner Production and Sustainability (Switzerland), each publishing 6 documents, making them the main source for disseminating research results on relevant topics. In the next position is the International Journal of Biological Macromolecules with 5 documents, followed by Comprehensive Reviews in Food Science and Food Safety and Foods which each publishes 4 documents. Furthermore, Trends in Food Science and Technology contributed 3 documents, while the other four journals – Bioresource Technology Reports, British Food Journal, Food Packaging and Shelf Life, and Food Quality and Preference – published 2 papers each.

The interpretation of this graph shows that the research themes studied have received wide attention from internationally reputable journals, especially in the fields of sustainability, clean production, food technology, and biopolymer science. These journals are not only important forums for publication but also centers for the dissemination of knowledge that encourage the development of interdisciplinary research, especially in the issues of food sustainability, eco-friendly packaging, and food product quality. The high number of papers in some journals also indicates that these topics are included in the editorial priorities and global research agenda.

Data authors Production over Time.



Gambar 8. authors Production over Time

The image presents a visualization of the publication contributions of ten authors in the period 2005 to 2024, visualized through a timeline and circle size that represents the weight or impact of the publication. Author Brody AL. appears to have the longest publication time span, from 2006 to 2018, although the small circle size suggests that his annual contributions are stable but not overly dominant. Other authors such as Andersson T. and Bastos Mosri also contributed in a limited period, i.e. between 2013 and 2015, with a small circle size that reflects a relatively low influence.

Meanwhile, the most significant contribution was shown by Filimonau V., with a large dark blue circle in 2019 that signaled a peak of influence or a high number of publications. Filimonau V. also remained active in the following years until 2023, albeit in a smaller circle. Other authors such as Bux C., Kumar P., and Ananda J. began to be active in the period 2020 to 2023 with a fairly consistent trend of publications, although the circle size showed moderate to low impact. This shows that they are new contributors who have started to get involved in the field of research over the past five years.

In addition, Bernstão Saravia Schott A. and Oh-Ah K. are also authors who have been active since 2021. Although the timing of their contributions is relatively new, the sizable size of the circle at the beginning of their involvement suggests that the impact is quite significant. Author Amicarelli V. has only one publication in 2021 with a small circle, indicating limited engagement. Overall, this data shows that most authors have shown an increasing trend in publication in the last five years, and significant contributions do not always come from authors who are active in the long term, but also from those who have just joined but made a significant impact.

Countries

The following is the Author's Coreesponding by country.

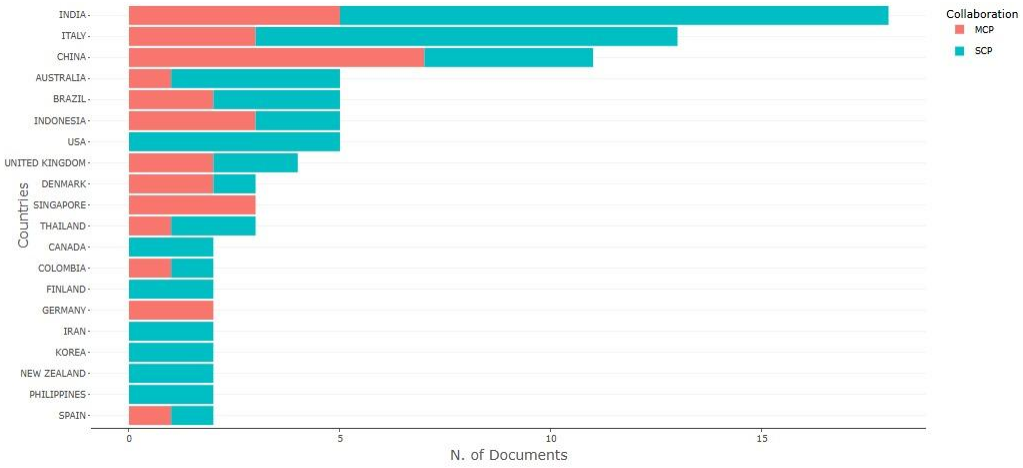


Figure 9. Author's Coreesponding by country

Figure 9 shows a visualization of the number of scientific papers by country, which are categorized by type of collaboration, namely SCP (Single Country Publications) and MCP (Multiple Country Publications). The horizontal axis indicates the number of documents, while the vertical axis lists the name of the country. Blue indicates a document written by an author from a single country (SCP), while pink indicates an international collaboration document (MCP).

The country with the highest number of documents is India, which dominates with more than 17 documents, the majority of which are domestic publications (SCPs), showing the dominance of research conducted domestically without outside collaboration. It is followed by Italy and China, which also show a high number of publications, but with a larger proportion of international collaborations (MCPs) than India. Countries such as Australia, Brazil, and Indonesia show moderate contributions, with a combination of SCP and MCP, signaling a balance between local and collaborative research. Indonesia itself has a relatively good contribution, with a slightly more number of SCPs than MCPs.

Meanwhile, countries such as the Philippines, Spain, Korea, Iran, and New Zealand have a low number of publications, but most of them come from the SCP. On the other hand, countries such as Denmark, the United Kingdom, and Singapore show a high tendency to conduct international collaboration (MCP). This shows that although the number of documents is not very large, these countries tend to be active in global collaboration networks. Overall, this graph shows that developing countries such as India and China dominate in terms of the quantity of publications, while developed countries tend to be more active in international collaboration, reflecting different approaches to scientific development.

The following is the data of the top 10 Countries' Scientific Production.

Tabel 4. top 10 Countries' Scientific Production.

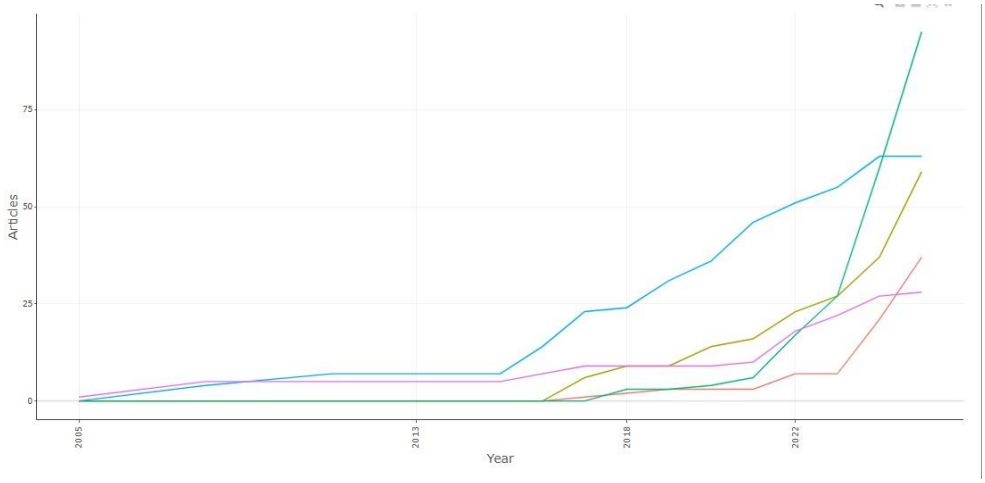
Country	Freq
India	95
Italy	63
China	59
Brazil	37
USA	28
Australia	23
Indonesia	23
UK	15
Singapore	13
Denmark	12

Table 4 above displays data on the frequency of the number of scientific papers by country. From the data, India occupies the top position with a total of 95 documents, showing that the country has the most contribution in the number of publications. This reflects the high level of research activity and scientific production of institutions or researchers in India. In second place is Italy with 63 documents, followed by China with 59 documents, both of which also reflect a high level of scientific productivity. These three countries stand out significantly compared to the other countries on the list. Brazil is fourth with 37 documents, followed by the United States (USA) which contributes 28 documents. Furthermore, Australia and Indonesia have the same contribution, as many as 23 documents each, showing that Indonesia is quite competitive and comparable to developed countries such as Australia in the context of scientific publications on this data. The UK (UK) has 15 documents, while Singapore and Denmark are at the bottom of this list, with 13 and 12 documents, respectively.

Overall, this data shows that most publications come from countries in Asia and Europe, with significant contributions from India, Italy, and China. Countries such as Indonesia, despite being among the developing countries, have been able to show a fairly strong role in scientific publications. This shows the great potential of Southeast Asian countries in increasing academic involvement at the global level, especially when supported by international collaboration and national research capacity building.

Countries' Production over Time

The following is the data on Countries' Production over Time. The data can be seen in the graph below.



Gambar 10. Grafik Countries' Production over Time

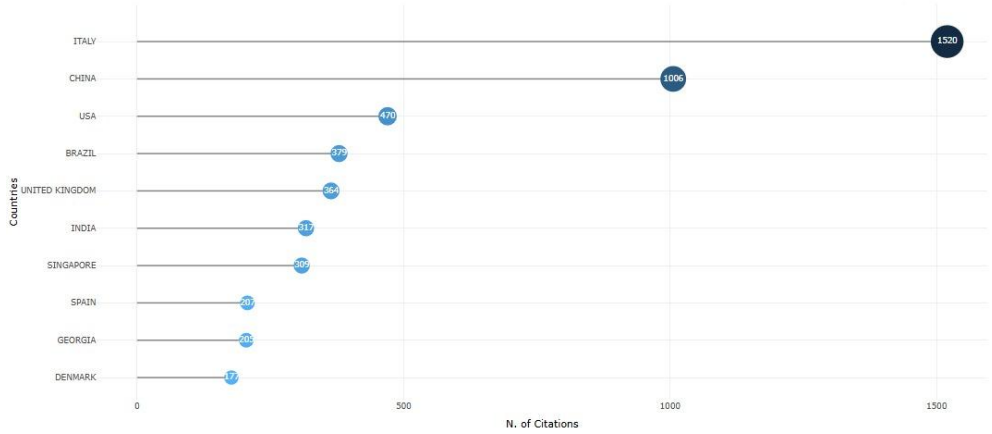
Figure 10 illustrates the development of the number of articles published from 2005 to around 2024 for five different topics or categories, each represented by a different colored line. In general, the graph shows that in the initial period between 2005 and 2013, the number of articles published was still very small and tended to be stagnant. Almost all lines are at a low level, indicating that the topics studied have not received significant

attention. However, changes began to be seen around 2018, where there was a fairly sharp increase on some specific topics. This indicates that starting that year, interest in research in these fields began to grow drastically.

One of the lines, which is light blue, shows the most significant spike, especially after 2018, and reached the highest figure in 2024 with more than 75 articles. This shows that the topic represented by the light blue line is the most dominant and researched compared to the others. On the other hand, the green and yellow lines have also shown a sharp increase in recent years, especially after 2021. Both almost matched the number of articles from light blue topics in the final years of the graph, indicating that there was a fairly tight competition of research interest among the topics. Meanwhile, the pink and purple lines show more stable and slower growth, which indicates that the topics remain in demand but are not experiencing as drastic a surge in attention as the other three lines.

Overall, this graph illustrates that after a long period of stagnation, there was a significant increase in the number of scientific publications starting in 2018. These changes are most likely influenced by technological developments, increasing scientific awareness, or global issues relevant to the topics being researched. This surge in publications reflects the dynamics and shift in focus in the world of academia and research, which is increasingly responsive to the needs of the times.

Most Cited Countries

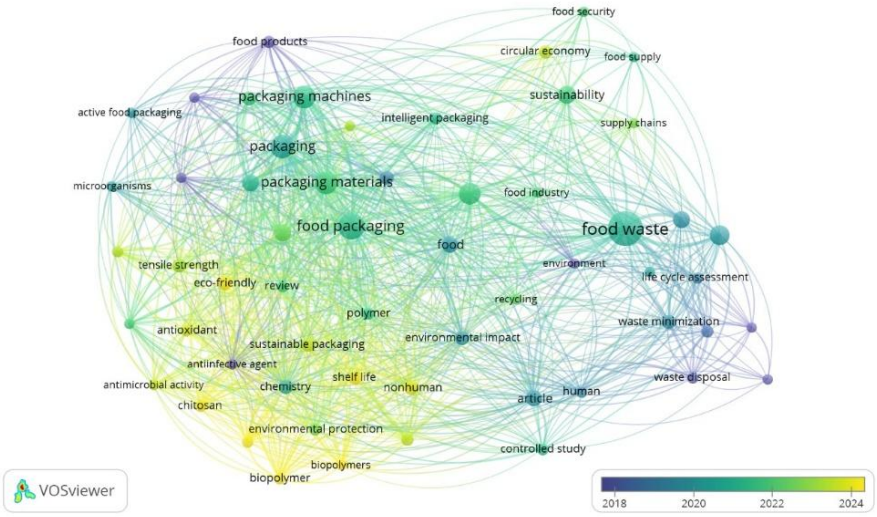


Gambar 11. Most Cited Countries

Figure 11 above shows a horizontal bar chart that illustrates the number of citations received by publications from different countries. The horizontal axis shows the number of citations, while the vertical axis lists the names of countries. Each country is represented by a blue circle that shows the citation value numerically. From this graph, it can be seen that Italy (Italy) is the country with the highest number of citations, reaching 1,520 citations, placing it far above other countries. It was followed by China (China) in second place with 1,006 citations, which also showed a great contribution in terms of scientific influence through citations. The United States (USA) is in third place with 470 citations, followed by Brazil (379 citations) and the United Kingdom (United Kingdom) with 364 citations. These three countries have fairly balanced citation rates, reflecting active participation in scientific publications although not as large as the top two countries. In the middle position are India (317 citations) and Singapore (309 citations), which show moderate but significant contributions. Meanwhile, Spain and Georgia obtained 207 and 205 citations, respectively, indicating that they are beginning to have an influence in the academic literature although still below the major countries.

At the bottom of the list is Denmark, with 177 citations, which, although the least number on this list, still shows a contribution to the field of research. This graph as a whole reflects the level of scientific influence of each country based on the number of citations their publications receive. This can demonstrate the quality and global relevance of the research produced in those countries, with Italy and China appearing to be the major leaders in this area.

Overlay visualization



Gambar 12. Overlay visualization

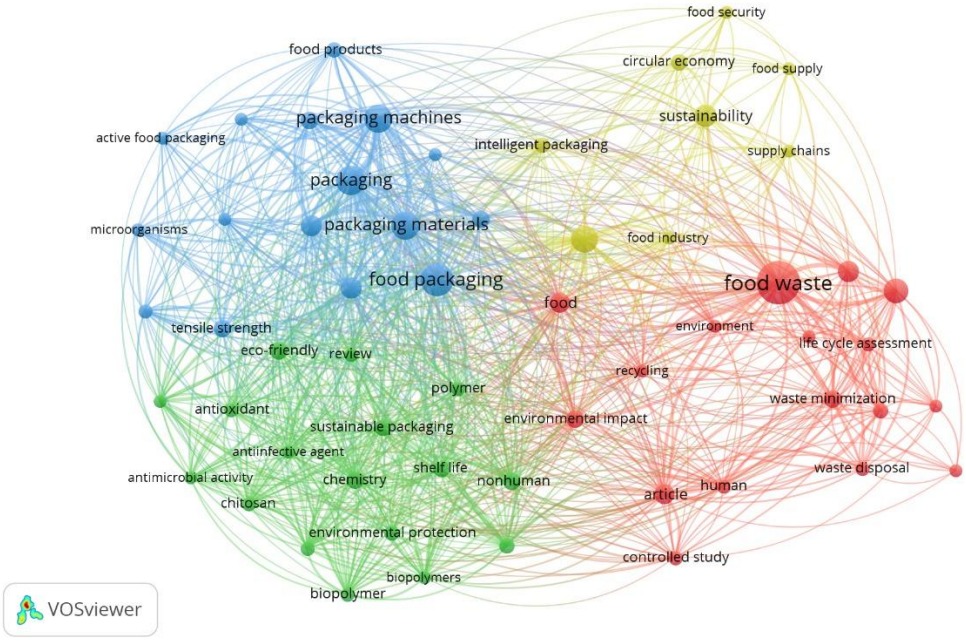
Figure 12 is a bibliometric mapping visualization created using the VOSviewer software, and illustrates the relationship between research topics related to "food packaging" and "food waste" based on the analysis of co-occurrence keywords from scientific publications. Each point (node) on the map represents a keyword, while the connecting lines between the nodes indicate the relevance or frequency of simultaneous occurrence between these topics in a single document. Node size indicates the level of importance or frequency with which a keyword appears—the larger the size, the more often it appears. The color node represents the average publication year of an article that includes that keyword, with a color scale from blue (older, around 2018) to yellow (newer, closer to 2024).

From this visualization, it can be seen that the topics of "food packaging", "food waste", "packaging materials", and "packaging machines" are the center of attention in the map due to the large size of the nodes and their central position. This shows that these topics are very often researched and have a lot to do with other keywords. The dominant green color on the main topics indicates that most of the research in this area was conducted between 2020–2022.

Keywords such as "sustainability", "circular economy", and "eco-friendly" appear in greenish-yellow colors, suggesting that these are newer research directions and are trending today. This indicates an increase in attention to environmental and sustainability issues in the context of food packaging. On the other hand, keywords such as "waste disposal", "life cycle assessment", and "waste minimization" were in the blue-to-purple spectrum, suggesting that although important, these topics were more discussed in previous research, around 2018–2020.

Topic clusters are also clearly visible—for example, there are keyword groups related to material properties and food safety such as "antimicrobial activity", "chitosan", and "biopolymer" that show the research focus on active and environmentally friendly packaging materials. Meanwhile, on the other hand, there are clusters related to systemic and policy aspects such as "food supply", "food security", and "supply chains", which show a macro research approach to the issue of food waste.

Network Visualization.



Gambar 13. Network Visualization

Figure 13 shown is a visualization of keyword co-occurrence networks from scientific publications analyzed using VOSviewer software. This visualization shows how different topics or terms in the research relate to each other based on the frequency of co-occurrence in the same document. Each point (node) represents one keyword, while the size of the point describes how often that keyword appears. The connecting lines show the strength of the relationships between keywords, and the colors of the dots describe clusters—that is, groups of topics that are closely related to each other. In this visualization, four main clusters are seen that represent major focuses in related research fields. The red cluster, which is on the right side, is centered on the topic of "food waste" and includes keywords such as life cycle assessment, waste minimization, waste disposal, environment, and recycling. This cluster highlights the researchers' attention to food waste management, environmental impacts, and systemic approaches to reducing it. On the top left side, the blue cluster reflects the focus on food packaging technology and innovation, with keywords such as packaging, packaging machines, packaging materials, and active food packaging. This cluster shows that there is a technical study related to packaging processes and equipment.

The green cluster, which is on the lower left side, focuses more on sustainable and functional packaging materials, such as biopolymer, chitosan, antioxidant, eco-friendly, and antimicrobial activity. It reflects concern for food safety and environmental protection through material innovation. Meanwhile, the yellow cluster at the top focuses on the issue of food system sustainability at large, with keywords such as sustainability, circular economy, food security, and food supply. This cluster shows a macro approach to challenges in food production and distribution systems.

Interestingly, keywords such as "food" and "food packaging" were at the midpoint of the visualization and became the link between the clusters, suggesting that they were both central topics in the overall study analyzed. Overall, the map provides a clear picture that research on food packaging and food waste is developing in a multidisciplinary manner, encompassing technical, environmental, and sustainability policy aspects, which are interconnected in one broad research ecosystem.

SLR Study.

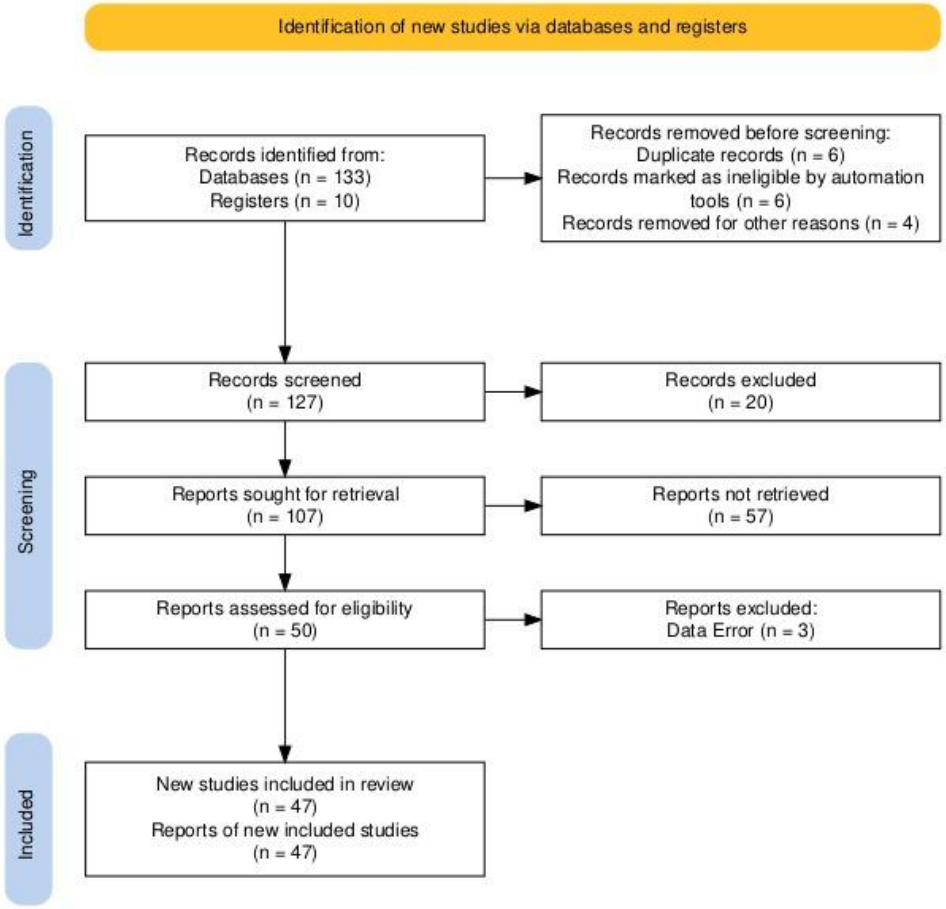
Of the 127 data obtained, 107 will be focused on the type of article.

Table 5. Number of Documents by Publication Type.

A	Kind	Sum
1	Article	107
2	Conference Paper	13
3	Reviews	7

Total	127

Results of the prism method



Gambar 14. Results of the prism method.

Based on the PRISMA diagram image above, the process of identification and study selection was carried out systematically to ensure the quality and relevance of the literature included in the review. In the initial stage, a total of 143 records were successfully identified, consisting of 133 records from the database and 10 records from the register. Furthermore, the data cleanup process was carried out by deleting 16 records before the filtering stage, which included 6 duplicates, 6 records that were not qualified by the automation tool, and 4 records that were deleted for other reasons. This resulted in 127 records that are worthy of further screening.

At the screening stage, a total of 127 records were checked, and 20 of them were issued because they did not meet the criteria. A total of 107 reports were then sought for further review, but 57 reports could not be obtained (not retrieved). Of the 50 reports that were successfully reviewed to assess feasibility, as many as 3 reports were forced to be issued due to data errors.

Finally, 47 new studies were successfully included in the systematic review and all of them were also represented in the form of reports of new included studies with the same number, namely 47. This rigorous selection process shows how a systematic approach can minimize bias and ensure that only relevant, valid, and high-quality literature is used as a basis for the preparation of reviews.

Table 6. Classification of Research Methods

Category	Number of Papers	Percentage	Sample Paper
Experimental Studies	5	62.5%	Antioxidant Properties...; Adsorption and Desorption...; Assessment of Fibers...; Antimicrobial Plates...; Waste-Derived Fillers...
Literature Reviews	2	25%	Recent Breakthroughs...; Trash to Treasure...

Category	Number of Papers	Percentage	Sample Paper
Survey-Based Studies	1	12.5%	Food Waste Perception in Italy and Poland...
Policy/Legislative Reviews	0 (1 not in the main classification)	0% (N/A)	EU Legislations on Food Waste... (Termasuk dalam Literature Reviews)

Based on the data in the Methodology Classification Table above, it can be interpreted that of the total 8 papers analyzed, the majority used the Experimental Studies methodology as many as 5 papers or equivalent to 62.5%. The dominance of this experimental methodology shows that the focus of research in the studied topic is more directed towards the development of new materials and testing in the laboratory, as reflected in the example of papers related to antioxidant properties, adsorption and desorption processes, fiber assessment, antimicrobial plates, and the use of waste as fillers. The Literature Reviews methodology occupies the second position with 2 papers or 25%, which shows the need to summarize and analyze existing findings related to the issues raised. One of the papers that falls into this category is a review of the latest developments and a study on waste utilization. The Survey-Based Studies methodology was found in only 1 paper or 12.5%, which highlighted a public perception-based approach or opinion survey, as seen in the research on food waste perception in Italy and Poland. This suggests that approaches involving respondents or field data are still relatively few in the studies analyzed. Meanwhile, in the Policy/Legislative Reviews category, there is actually one paper that discusses EU legislation related to food waste, but due to the similarity of approach with Literature Reviews, this paper is incorporated into that category so that it is not counted as a separate main methodology category.

From this interpretation, it can be concluded that research on this topic emphasizes more on technical and experimental aspects than on policy or social aspects, which can be seen from the high proportion of experimental research. It also reflects the tendency of scientists to seek practical solutions through material and technological innovations. Nevertheless, the existence of literature reviews and survey-based studies shows an awareness of the importance of a multidimensional approach, including understanding the social context and policy developments.

Table 7. Main Finding Classification

Discovery Categories	Number of Papers	Percentage	Sample Paper
Improved Material Properties	5	62.5%	Antioxidant Properties...; Adsorption and Desorption...; Assessment of Fibers...; Antimicrobial Plates...; Waste-Derived Fillers...
Effectiveness of Packaging Technology	2	25%	Recent Breakthroughs...; Trash to Treasure...
Socio-Economic & Behavioral Factors	1	12.5%	Food Waste Perception in Italy and Poland...
Policy & Regulation Analysis	1	12.5%	EU Legislations on Food Waste...

Based on the data in the Main Finding Classification Table, it can be interpreted that of the total 8 papers analyzed, most or as many as 5 papers (62.5%) focused on the category of Material Property Improvement. The dominance of these findings reflects the researchers' primary concern for the development of sustainable packaging materials, particularly in terms of improving mechanical, thermal, and functional properties. Examples of papers in this category show various innovations such as increased tensile strength, thermal stability, to the antibacterial activity of the material, for example the use of Calotropis natural fibers that increase the porosity of PVA/PVP composites. The Packaging Technology Effectiveness category occupies the second position with 2 papers (25%), which shows the research focus on assessing the performance of packaging technology in extending the shelf life of products or reducing food waste. One example is the use of PBS/geraniol plates which have been proven to be able to extend the shelf life of bread by up to 5–10 days. The findings in this category confirm the importance of technological innovation as part of food waste reduction solutions.

Meanwhile, the categories of Socio-Economic Factors & Behavior and Policy & Regulation Analysis were each represented by only 1 paper (12.5%). Research in the socio-economic category highlights how people's perceptions and behaviors—for example related to age and gender—can affect awareness of food waste, as shown in studies of food waste perception in Italy and Poland. On the other hand, research in the policy category recommends the need for an integrated regulatory framework at the EU level to support food waste

reduction efforts. It is interesting to note that the percentage of total categories exceeds 100% because some papers have findings that cover more than one category. This shows that some research is multidimensional and not limited to just one aspect. Overall, the interpretation of this data shows that current research is still very focused on material innovation, while behavioral, social, and policy issues that are actually very important in the implementation of solutions in the field are still relatively underexplored. This signals a great opportunity to broaden the focus of research to include a more holistic approach.

Table 8. Classification of Study Desaign

Category: Study Design	Number of Papers	Presentase	Sample Paper
Experimental Research	5	62.5%	Antioxidant Properties...; Adsorption and Desorption...; Assessment of Fibers...; Antimicrobial Plates...; Waste-Derived Fillers...
Systematic Review	2	25%	Recent Breakthroughs...; Trash to Treasure...
Cross-sectional Survey	1	12.5%	Food Waste Perception in Italy and Poland...
Policy Analysis	1	12.5%	EU Legislations on Food Waste...

Based on the data in the Study Design Classification Table, it can be interpreted that of the total 8 papers analyzed, most or as many as 5 papers (62.5%) used the Experimental Research approach. This dominance of experimental research reflects the researchers' primary focus on the development of new materials and technologies, particularly through variable manipulation and testing in the laboratory. Examples of this category include research on the manufacture of chitosan-based packaging films tested through thermogravimetric analysis (TGA), as well as various other studies evaluating material properties such as mechanical strength, absorbency, and antibacterial activity. The next category is Systematic Review, which includes 2 papers or 25% of the total. Studies in this category are instrumental in systematically summarizing and analyzing existing literature to identify trends, gaps, and future research opportunities. One example is a review of the application of cold plasma technology in food packaging, which provides comprehensive insights into the development of sustainable technology. Furthermore, one paper (12.5%) each was included in the Cross-sectional Survey and Policy Analysis categories. Cross-sectional surveys represent studies that use questionnaires to collect data at a given time, such as research on students' perceptions of food waste issues in Italy and Poland. Meanwhile, Policy Analysis includes an evaluative review of policies and regulations, for example an analysis of EU legislation related to food waste reduction. These two categories show that there are efforts to integrate social and policy aspects into research, but the portion is still very small compared to laboratory-based research.

It should be noted that the total percentage exceeds 100% because some papers have study designs that cover more than one category. This interpretation confirms that currently research in this field is still very dominated by experimental approaches and technology development, while behavioral, social, and policy aspects that are also crucial for the implementation of sustainable solutions still receive less attention. Therefore, future research opportunities are wide open to expand the scope of study towards a more balanced multidisciplinary.

Table 9. Future Research Classification

Categories Future Research Recommendations	**Number of Papers**	**Presentase**	**Example Recommendations**
Material & Formulation Optimization	5	62.5%	Development of waste-based fillers, optimization of active ingredient concentrations
Scaling up & Industrial Applications	4	50%	Large-scale production trials, commercialization
Safety & Toxicity Analysis	3	37.5%	Study of migration of active substances, health impacts
Behavioral Intervention & Education	2	25%	Student education programs, awareness campaigns

Categories Future Research Recommendations	Number of Papers	Presentase	Example Recommendations
Policies & Regulations	2	25%	Development of sustainable packaging standards

Based on the Future Research Classification Table, it can be interpreted that the main focus of future research recommendations from the eight papers analyzed is still dominated by technical aspects, especially in the category of Material Optimization & Formulation, which appeared in 5 papers (62.5%). Recommendations in this category generally lead to improvements in material composition, such as the development of waste-based fillers and optimization of active ingredient concentrations to improve the performance of packaging materials. This indicates that the sustainable packaging technology being studied is still in the refinement and development stage of the basic formulation. Furthermore, Industrial Scale Up & Application became the second most category with 4 papers (50%), demonstrating the urgency to bring research results from laboratory scale to real implementation in industry. Recommendations in this category include mass production trials and commercialization of products, such as in research related to PBS/geraniol antimicrobial plates. This indicates a gap between the development of technology and the readiness for its widespread implementation.

Safety & Toxicity Analysis also received significant attention, appearing in 3 papers (37.5%). Recommendations in this category highlight the importance of ensuring the safety of packaging materials, including studies of migration of active substances and their impact on health. The existence of this category suggests that although material innovations continue to evolve, the safety aspect still needs to be thoroughly researched before it is widely adopted. The other two categories, namely Behavioral Intervention & Education and Policy & Regulation, each appeared in 2 papers (25%). Recommendations in this category show the beginning of attention to social and political aspects, such as the importance of educational programs to increase consumer awareness and the need for harmonization of sustainable packaging regulations at the national or international level. Despite its smaller portion, the existence of this category signifies that non-technical approaches are beginning to be recognized as an important part of supporting the implementation of sustainable packaging technologies.

It should be noted that the total percentage exceeds 100% because a single paper can provide more than one type of recommendation. Overall, this interpretation suggests that while the main focus is still on technical development, there is a promising trend towards a more holistic approach to research, which includes aspects of security, community behavior, and policy. This table thus provides a comprehensive overview of the direction and needs of future more integrated research.

Table 10.Classification Summary

Category Summary	Number of Papers	Presentase	Sample Summary
Sustainable Material Development	6	75%	Development of biopolymer-based active packaging with improved functional properties
Food Waste Reduction Solutions	5	62.5%	Technology to extend shelf life and spoilage indicators
Aspects of Consumer Behavior	2	25%	Study of perceptions and demographic factors on food waste
Policy Analysis	1	12.5%	Evaluation of the regulatory framework for food waste management

Based on the data in the Research Summary Classification Table, it can be interpreted that the majority of research, which is as much as 6 out of 8 papers (75%), focuses on Sustainable Material Development. This shows that the top priority in this field is still focused on the innovation and synthesis of environmentally friendly packaging materials with improved functional properties, such as thermal stability, antioxidant activity, or antimicrobial capabilities. An example is the development of chitosan-based packaging that is able to withstand temperatures up to 180°C while offering antioxidant protection. The second category that also stands out is Food Waste Reduction Solutions, which appear in 5 papers or 62.5%. Research in this category generally highlights the role of packaging technology, such as the use of antimicrobial plates, in extending the shelf life of food products and reducing food waste. These findings show a close link between material innovation and practical efforts to reduce food spoilage and waste. Meanwhile, the Consumer Behavior aspect was covered in only 2 papers (25%), which highlighted the importance of social and psychological factors, such as perception and demographics, in influencing food waste behavior. Research in this category found

differences in perceptions of food waste based on age and gender, an issue that has important implications for social interventions.

The least explored category is Policy Analysis, which appears in only 1 paper (12.5%). This research focuses on the evaluation of the regulatory system related to food waste management, for example the need to integrate food waste reduction policies at the EU level. These research gaps show that policy aspects, while crucial to the implementation and scalability of solutions, are still not a major concern among researchers. It is important to note that some papers can fall into more than one category, so the total percentage exceeds 100%. Overall, the interpretation of this data shows the dominance of technical and material research in support of sustainability, but also shows the need for a balance with studies that examine the social and policy dimensions in order to create more comprehensive and widely applicable solutions.

Contribution

The main contribution of this research lies in the mapping and in-depth analysis of technological innovations in food processing and packaging that can reduce food waste throughout the supply chain. The study not only identifies current trends in packaging technologies, such as the use of biodegradable and active packaging, but also provides insight into how these innovations can be implemented more broadly on an industrial scale. By focusing on the development of sustainable and efficient packaging materials, this study reinforces the argument that technology-based solutions have great potential to extend the shelf life of food, reduce spoilage, and ultimately reduce food waste that occurs at the distribution and consumption stages. In addition, the study also fills a gap in the literature that lacks a focus on the linkages between technological innovation and policies that can support the adoption of these solutions at the global level. These findings make an important contribution for stakeholders, from industry, policymakers, and consumers, to foster cross-sectoral collaboration that can accelerate the transition to a more sustainable and low-waste food system.

Implication

The implications of this study are very broad, both for the food processing industry, public policy, and household consumption practices. For the industry, the findings of this study demonstrate the importance of adopting more environmentally friendly and efficient packaging technologies, such as biodegradable materials and active packaging, which not only extend the shelf life of products but also reduce food waste during distribution. This can help companies to reduce financial losses caused by food waste as well as increase competitiveness through more sustainable solutions. On the other hand, for policymakers, this research provides a basis for designing policies that encourage the adoption of innovative technologies in food packaging and processing, such as incentives for companies that develop and implement sustainable solutions. In addition, findings on the influence of consumer behaviour also suggest that better education programmes can help reduce food waste at the household level, providing an opportunity for policies that educate the public on effective ways to manage food and reduce waste. Overall, the implications of this study encourage the implementation of technology-based solutions that can contribute to significant reductions in food waste, support global sustainability goals, and strengthen the circular economy in the food sector.

Limitation.

The main limitation of the study lies in the greater focus on technological innovations in food packaging and processing, while other aspects such as supportive public policies or changes in consumer behavior are still limited in its analysis. Although this research has included various studies related to the development of packaging materials, there has been no in-depth evaluation of the challenges of implementing this technology on an industrial scale or its impact on the overall food supply chain. In addition, most of the studies analyzed are still limited to laboratory approaches or small experiments, which require further verification in larger, complex industrial conditions. Another limitation is the lack of empirical data related to consumer responses to changes in food packaging and whether these technological solutions are socially acceptable. Therefore, more research is needed to explore the integration between technology, policy, and changing consumer behavior in effectively reducing food waste.

Sugestion

The suggestion for future research is to expand the scope of the study by integrating social and consumer behavioral aspects in food waste reduction. Further research can examine how public policies supporting sustainable packaging innovations can influence the adoption of these technologies at the industry level. In addition, it is important to explore the long-term impact of active and biodegradable packaging technologies in the context of mass production and global food distribution, as well as conduct trials on an industrial scale to assess their effectiveness in reducing food waste. The research could also further explore the interactions between consumer behavior and packaging design, as well as how consumer education about food

management can raise awareness and reduce food waste. Further, more holistic research that combines technology, policy, and consumer behavior analysis can provide more comprehensive and sustainable solutions in reducing food waste

CONCLUSION

This systematic literature review confirms that the problem of food waste is a complex and multidimensional challenge, involving technological, environmental, economic, social, and policy aspects. The analysis shows that most of the current research is still dominated by technological innovations, particularly the development of sustainable food packaging materials and cutting-edge food processing techniques that aim to extend shelf life and minimize spoilage. These innovations have shown significant potential in reducing food waste through improved material functions, such as antimicrobial activity, barrier properties, and biodegradability. However, behind these technological advances, this study also highlights the limitations of integrating social, behavioral, and policy approaches in the existing literature. Research that delves into consumer behavior, psychological factors that cause waste, and policy frameworks are still relatively few. This gap is an important challenge, given that the successful implementation and social acceptance of technological solutions is highly dependent on behavior change, increased public awareness, and support from adequate regulations. In addition, the results of this study show that there is an urgent need to go beyond laboratory-scale research towards the application of industrial scale and commercialization of innovative technologies. Bridging this gap requires closer collaboration between academia, industry, policymakers, and civil society to ensure that the resulting innovations are not only technically feasible, but also economically feasible, socially acceptable, and environmentally sustainable. Other findings also show that food waste management is gaining increasing attention in the context of circular economy principles and the global sustainability agenda, particularly those aligned with the United Nations Sustainable Development Goals (SDGs), especially SDG 12 on Responsible Consumption and Production. This underscores the need for a multidisciplinary approach that integrates materials science, environmental science, behavioral science, economics, and policy governance. In this regard, future research should adopt a more holistic perspective, emphasizing cross-sector collaboration, lifecycle assessment, and integration of social innovation alongside technological advancements. In addition, policy harmonization, international cooperation, and educational interventions will be crucial in accelerating the transition to a zero-waste food system. By overcoming the fragmentation in current food waste reduction research and practices, it will open up opportunities to present transformational solutions that make a real contribution to food security, climate change mitigation, and sustainable use of natural resources at the global level.

ACKNOWLEDGMENT

Acknowledgements are extended to all those who have provided support, assistance, and contributions throughout the course of this research. Whether in the form of academic guidance, data provision, facilities, or moral support, every form of help has been invaluable to the smooth progress and success of this study. Special thanks are also given to the co-authors for their unwavering support and significant contributions to the Systematic Literature Review process. All forms of involvement are deeply appreciated as essential components in achieving the results of this Systematic Literature Review.

AUTHOR CONTRIBUTION STATEMENT

Author 1, Author 2, and Author 3 made significant contributions to all stages of this research, including the design of the methodology, data collection, data analysis, and interpretation of the results. All three authors were actively involved in drafting and critically reviewing the manuscript to ensure scientific validity and content integrity. All authors have read and approved the final version of the manuscript prior to submission for publication.

REFERENCES

Alcorn, M., Vega, D., Irvin, R., & Páez, P. (2020). Reducing Food Waste: An Exploration of a Campus Restaurant. British Food Journal, 123(4), 1546–1559. https://doi.org/10.1108/bfj-03-2020-0165

Aldaco, R., Hoehn, D., Laso, J., Margallo, M., Ruiz-Salmón, I., Cristóbal, J., Kahhat, R., Villanueva-Rey, P., Bala, A., Batlle-Bayer, L., Fullana–i–Palmer, P., Irabien, Á., & Vázquez-Rowe, I. (2020). Food Waste Management During the COVID-19 Outbreak: A Holistic Climate, Economic and Nutritional Approach. The Science of the Total Environment, 742, 140524. https://doi.org/10.1016/j.scitotenv.2020.140524

Bourlieu, C., & Guillard, V. (2020). Innovative and sustainable food packaging: Developments and future

challenges. Current Opinion in Food Science, 35, 121–126. https://doi.org/10.1016/j.cofs.2020.02.002
Ciccullo, F., Pero, M., Caridi, M., Gosling, J., & Purvis, L. (2021). Integrating the environmental and social sustainability pillars into the food supply chain. Sustainable Production and Consumption, 26, 367–378. https://doi.org/10.1016/j.spc.2020.12.014
Conrad, Z., Niles, M. T., Neher, D. A., Roy, E. D., Blackstone, N. T., & Jahns, L. (2018). Relationship Between Food Waste, Diet Quality, and Environmental Sustainability. Plos One, 13(4), e0195405. https://doi.org/10.1371/journal.pone.0195405
De Laurentiis, V., Corrado, S., & Sala, S. (2018). Quantifying household waste of fresh fruit and vegetables in the EU. Waste Management, 77, 238–251. https://doi.org/10.1016/j.wasman.2018.04.001
Gmoser, R., Fristedt, R., Larsson, K., Undeland, I., Taherzadeh, M. J., & Lennartsson, P. R. (2020). From Stale Bread and Brewers Spent Grain to a New Food Source Using Edible Filamentous Fungi. Bioengineered, 11(1), 582–598. https://doi.org/10.1080/21655979.2020.1768694
Gutiérrez, D., Fernández, L., Rodríguez, A., & García, P. (2019). Role of Bacteriophages in the Implementation of a Sustainable Dairy Chain. Frontiers in Microbiology, 10. https://doi.org/10.3389/fmicb.2019.00012
Iori, E., Masotti, M., Falasconi, L., Risso, E., Segré, A., & Vittuari, M. (2022). Tell Me What You Waste and I'll Tell You Who You Are: An Eight-Country Comparison of Consumers' Food Waste Habits. Sustainability, 15(1), 430. https://doi.org/10.3390/su15010430
Mahalik, N. P., & Nambiar, A. N. (2010). Trends in food packaging and manufacturing systems and technology. Trends in Food Science & Technology, 21(3), 117–128. https://doi.org/10.1016/j.tifs.2009.12.006
Mirabella, N., Castellani, V., & Sala, S. (2014). Current options for the valorization of food manufacturing waste: a review. Journal of Cleaner Production, 65, 28–41. https://doi.org/10.1016/j.jclepro.2013.10.051
Molina-Besch, K., Wikström, F., & Williams, H. (2019). The environmental impact of packaging in food supply chains—Does life cycle assessment of food provide the full picture? International Journal of Life Cycle Assessment, 24(1), 37–50. https://doi.org/10.1007/s11367-018-1500-6
Molina-Besch, K., & Pålsson, H. (2020). A Simplified Environmental Evaluation Tool for Food Packaging to Support Decision-making in Packaging Development. Packaging Technology and Science, 33(4–5), 141–157. https://doi.org/10.1002/pts.2484
Petersen, B., & Solberg, S. Ø. (2020). Reducing food waste: A literature review on the food supply chain. Resources, Conservation and Recycling, 152, 104489. https://doi.org/10.1016/j.resconrec.2019.104489
Pinela, J., Añibarro-Ortega, M., & Barros, L. (2024). Food Waste Biotransformation Into Food Ingredients: A Brief Overview of Challenges and Opportunities. Foods, 13(21), 3389. https://doi.org/10.3390/foods13213389
Sakaguchi, L., Pak, N., & Potts, M. D. (2018). Tackling the Issue of Food Waste in Restaurants: Options for Measurement Method, Reduction and Behavioral Change. Journal of Cleaner Production, 180, 430–436. https://doi.org/10.1016/j.jclepro.2017.12.136
Schanes, K., Dobernig, K., & Gözet, B. (2018). Food Waste Matters - A Systematic Review of Household Food Waste Practices and Their Policy Implications. Journal of Cleaner Production, 182, 978–991. https://doi.org/10.1016/j.jclepro.2018.02.030
Vanderroost, M. (2014). Intelligent food packaging: The next generation. Trends in Food Science & Technology, 39(1), 47–62. https://doi.org/10.1016/j.tifs.2014.06.001
Verghese, K., Lewis, H., Lockrey, S., & Williams, H. (2015). Packaging's role in minimizing food loss and waste across the supply chain. Packaging Technology and Science, 28(7), 603–620. https://doi.org/10.1002/pts.2127
Wijayarathna, E. R. K. B., Mohammadkhani, G., Moghadam, F. H., Berglund, L., Ferreira, J. A., Adolfsson, K. H., Hakkarainen, M., & Zamani, A. (2023). Tunable Fungal Monofilaments From Food Waste for Textile Applications. Global Challenges, 8(3). https://doi.org/10.1002/gch2.202300098
Xiao, L. (2021). A review on sustainable food packaging: Materials, active and intelligent packaging. Food Research International, 140, 109981. https://doi.org/10.1016/j.foodres.2020.109981
Zhu, S., Gao, H., & Duan, L. (2018). Latest Research Progress on Food Waste Management: A Comprehensive Review. Iop Conference Series Earth and Environmental Science, 153, 62043. https://doi.org/10.1088/1755-1315/153/6/062043