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Response surface methodology in postharvest and food technology research: A bibliometric assessment

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ABSTRACT

This bibliometric study revealed research trends in the global usage of response surface methodology (RSM) in postharvest and food technology, focusing on optimizing fruit and vegetable quality, storage, and shelf life. Data were retrieved from the Scopus database covering the years 2015 to 2024. A total of 2157 relevant publications were included. The Bibliometrix R-package and VOSviewer were used to analyze publication patterns, author networks, country collaborations, and thematic analysis. The results indicated a significant increase in publications, with an annual growth rate of 9.16% and a peak of 319 in 2024. Document analysis identified the most impactful studies in this field, with top-cited articles focusing on spray drying, pectin extraction, and phenolic encapsulation. India recorded the most publications, while the highest number of international collaborations was between the United States and China. Thematic analysis revealed the keywords "optimization", "storage," and "shelf-life" as the major themes driving research in this field. This bibliometric analysis provides an overview of the current state of RSM in these productive research areas and suggests future opportunities for innovation and collaboration to reduce food loss and waste while increasing agriculture and food sustainability.

1. Introduction

Response surface methodology (RSM), first introduced by Box and Wilson in 1951, comprises a set of mathematical and statistical techniques that can be applied to model and optimize processes with multiple variables (Kundu et al., 2024). RSM identifies optimal conditions using the fewest experimental runs, which often saves time and resources (Olabinjo, 2024). Experimental designs such as Central Composite Design (CCD), Box-Behnken Design (BBD), and Doehlert Design allow RSM to structure experiments efficiently (Chaiwong et al., 2021; Szpisják-Gulyás et al., 2023) using second-order polynomial models that can explain system behavior and identify optimal parameters (Verdooren, 2017). This is particularly advantageous where natural variation is high and accuracy is important, such as in the postharvest phase of the agricultural business.

Reducing food loss and food waste, following the United Nations Sustainable Development Goal (SDG) 12.3, focuses on halving global food loss and waste by 2030 (Ardra & Barua, 2022). The Food and Agriculture Organization has estimated that one-third of all food for human consumption is either lost or wasted, amounting to 1.3 billion tons each year (Junaid & Gokce, 2024). Food loss usually occurs between the harvest and retail stages, typically due to a lack of proper postharvest handling (especially with perishable commodities such as fruits and vegetables) (Tao et al., 2024). Food waste, on the other hand, typically occurs at the retail and consumer levels, where food is wasted due to over-purchasing, poor storage, and poor food handling. Our lens

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of "postharvest and food" denotes that these are complementary challenges that highlight the importance of reducing loss throughout the entire food supply chain.

Research in postharvest science and technology focuses on improving storage, drying, and packaging systems to decrease upstream food loss. In this regard, RSM has been extensively applied to optimize storage possibilities, drying technologies, and packaging methods (Mohammed et al., 2024) to mitigate enzymatic browning, microbial proliferation, destructive textural changes, moisture loss, and loss of nutrition to maximize the shelf life and quality of perishable commodities (Sheibani et al., 2024; Sui et al., 2023). RSM has been applied to optimize a variety of postharvest treatments, including chemical, physical, and biocontrol treatments, to maintain product postharvest quality, minimize spoilage, and extend marketable life (Babaei Rad et al., 2025; Fenta et al., 2023; Wahid et al., 2025). Pairing RSM with new and existing preservation methods such as nanoencapsulation, edible coatings, bio-preservatives, and smart packaging has yielded further opportunities for mitigating postharvest loss and enhancing food safety (Al-Tayyar et al., 2020).

RSM is an important part of food science and technology, allowing researchers and technologists to investigate different processing parameters at once to enhance product quality, safety, functionality, and acceptance by consumers (Cano-Lamadrid et al., 2023). It is applied to optimize formulations in functional foods, fortification strategies, flavor enhancement, texture modification, and shelf-life extension (Mohammed et al., 2024). RSM also provides a structured experimental design, which reduces the total number of experiments and ensures that the results are repeatable. It can also add value by optimizing the extraction of bioactive compounds from underutilized agricultural by-products and crops, promoting the conversion of surplus produce into valuable ingredients (Ezeorba et al., 2024). Thus, RSM can effectively and sustainably improve food quality, reduce waste, and increase the potential of agricultural resources.

Bibliometric analysis is a systematic approach that helps understand the emergence and significance of RSM in postharvest and food systems technology. It combines the quantitative and qualitative evaluation of scholarly outputs and the intellectual structure of specific research areas, allowing visualization of research trajectories, productive authors, influential literature, collaborative networks, and emerging themes (Passas, 2024; You et al., 2024). Bibliometric studies provide a quantitative summary of the research output of an area through analyzing publication results, citation analysis, co-authorship analysis, and keyword co-occurrence analysis. The dissemination of RSM in agricultural and food research has grown substantially; however, a significant gap remains in comprehensive bibliometric studies on RSM applications in postharvest and food technology. A bibliometric analysis would have great value for the strategic development, publication identification, and future research.

Bibliometric studies related to postharvest research have included agri-food traceability (Hisjam et al., 2020), grain storage and packaging technologies (Kusuma, 2022; Rodriguez-Rojas et al., 2019), Artificial Intelligence (AI)-generated postharvest improvements (Fadiji et al., 2023), and halal food (Kusuma & Masithoh, 2023). Also, bibliometric studies in food science and safety also included studies on trends in food quality management (Zhu et al., 2024), AI applications in precision agriculture and agri-food traceability (Liu et al., 2023), impacts of climate change on agriculture and food production (Wu et al., 2023), and techniques in food waste (Zhang et al., 2018). Previous studies in food technology underscored the bibliometric analysis of RSM for many applications, such as optimization of carotenoid and pectin extraction using RSM (Cano-Lamadrid et al., 2023; Luiz Filho et al., 2022), measurement of RSM with observational data (Hadiyat et al., 2022), and the application of RSM to the biogas process (Djimtoingar et al., 2022). These studies have made significant contributions to their respective fields, but none have specifically addressed the role of RSM in optimizing postharvest and food technology. This absence underscores the need for a focused bibliometric analysis of RSM in these areas. A targeted investigation would offer valuable insights into food preservation, quality improvement, and sustainable practices in postharvest management, areas that remain underexplored in the existing literature.

This study conducted a comprehensive bibliometric analysis of the existing literature on the applications of RSM in postharvest and food technology. This analysis traced the development over time using notable contributions, primary institutions, international collaborations, and other prominent studies to identify patterns, gaps, and prospective pathways to steer further advances in the domain. The outcome of this study can assist researchers, policymakers, and industry stakeholders in terms of knowledge creation, increasing research visibility, and developing collaborative frameworks to reduce postharvest losses and enhance global food security.

2. Materials and methods

2.1. Data sources and collection

A bibliometric analysis of research trends worldwide that used RSM for postharvest and food technology areas was conducted on March 15, 2025, specifically focusing on fruit and vegetable quality, storage, and shelf life. Data were obtained from Scopus, accepted as the most widely used database of peer-reviewed literature across multiple fields of science. The search was conducted under the TITLE-ABS-KEY with the following search terms:

("RSM" OR "Response Surface Methodology") AND ("fruit" OR "vegetables" OR "quality" OR "shelf-life" OR "shelf life" OR "storage")

The search focused on articles, reviews, books, and book chapters published in English from 2015 to 2024. This provided the most relevant research publications for the bibliometric analysis (Bouzembrak et al., 2019; Schmidt et al., 2024). The subject area was restricted to agricultural and biological sciences to aid in data reliability. A manual cross-verification process was then employed to eliminate duplicate records and irrelevant studies and achieve a finalized, high-quality dataset for the bibliometric analysis.

2.2. Data extraction

To ensure a reliable and refined dataset, only research fully committed to the application of RSM in postharvest and food technologies was considered for bibliometric relevance. Two important themes were prioritized.

1. Optimization of fruit and vegetable storage and shelf life using RSM.
2. Quality improvement and technological advancements in food processing using RSM.

A total of 3208 publications were originally identified, with 2157 eligible for review at the screening stage (Fig. 1). Publications that did not focus on postharvest applications or those lacking methodological relevance to RSM were excluded.

2.3. Bibliometric analysis

This study conducted bibliometric analyses utilizing the Bibliometrix R-package (version 4.3.2), an open-source software for quantitative research in bibliometrics. Bibliometrix was developed by Aria and Cuccurullo (Aria & Cuccurullo, 2017), programmed in R language, and includes an extensive range of tools for statistical analysis and science mapping. Biblioshiny, a web-based interface for bibliometric analysis to help users with limited coding knowledge. Biblioshiny allows users to import bibliographic data from large scientific databases such as Scopus and Web of Science in different formats (Bibtex, CSV, and Plain Text). Biblioshiny also allows users to filter the dataset for a more rigorous analysis. In this study, Biblioshiny was utilized to import bibliographic

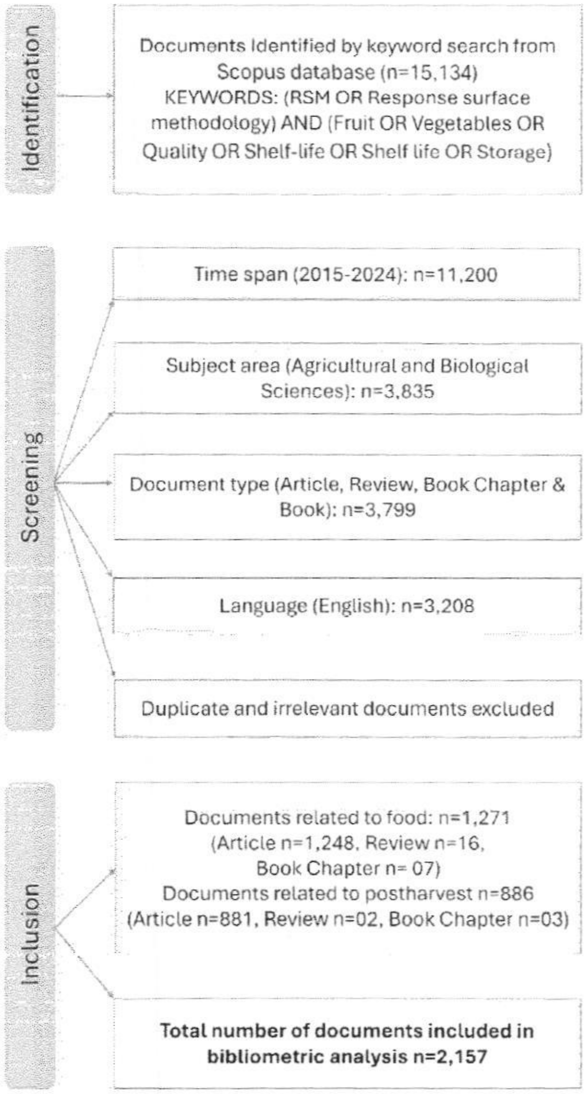

Fig. 1. Selection process for the bibliometric analysis of RSM in postharvest and food technology.

data from Scopus in CSV format for the initial exploratory analysis.

This research also used VOSviewer (version 1.6.20), available as open-source software. VOSviewer, specific software for generating and visualizing bibliometric networks, was developed by Van Eck and Waltman (Van Eck & Waltman, 2014) and used to create network visualizations to explore links between the various bibliometric units such as journals, papers, citations, authors, and countries. The network visualizations produced by VOSviewer included circular node maps for each analytical unit, with nodes of different sizes representing the varying relative importance of the analytical units. Lines connecting the nodes represent relationships between the different analytical units, while the thickness of the connecting lines represents the strength of these relationships. The nodes were also grouped into clusters indicated by colors that suggested collaboration patterns or thematic links within bibliometric datasets. Network visualizations provide the reader with an understanding of trends in scientific collaboration and the content and themes behind key research outputs.

3. Results

3.1. An overview of RSM research performance statistics in postharvest and food technology

Fig. 2 illustrates the RSM research output in postharvest and food technology that has shown significant growth over the past decade. Between 2015 and 2024, 2157 documents were published across 339 sources, demonstrating an annual growth rate of 9.16 %. The average document age was 4.79 years, indicating that most studies were relatively recent. The research has also gained strong academic engagement, with an average of 17.34 citations per document and 84,472 references cited across these publications. In terms of research content, 8507 keywords and 5194 author keywords were identified, reflecting the diverse thematic areas covered by RSM applications in postharvest and food research. Authorship analysis revealed that 7342 authors contributed to this research, with only 34 single-authored documents. The co-authorship rate was 4.81 authors per document, indicating a high level of collaboration, while 20.82 % of the publications involved international co-authorship, suggesting substantial global research engagement in this field. Most documents were research articles (2129), followed by reviews (18) and book chapters (10), indicating that this field is primarily driven by experimental research and methodological progress.

3.2. General publication trends

RSM research output trends in postharvest and food technology indicate an increasing number of published articles from 2015 to 2024, ranging from 145 in 2015 to 319 in 2024. This increase was due to the utilization of RSM in postharvest food techniques, with a drastic growth in publications from 206 to 264 between 2020 and 2021. The highest number of documents was published in 2024, indicating the expanding importance of RSM optimization in the fields of postharvest and food technology (Fig. 3).

3.3. Source analysis

As shown in Table 1, the bibliometric analysis determined 2157 documents published in 339 journals. Among these, the top 10 sources accounted for a significant proportion of the research on RSM applied to postharvest and food technology. The Journal of Food Processing and Preservation led with 160 articles, followed by the Journal of Food Science and Technology (129 articles) and LWT (122 articles). Other key contributors included Foods (108), Food Chemistry (106), Journal of Food Measurement and Characterization (102), Journal of Food Process Engineering (80), Industrial Crops and Products (55), Food Science and Nutrition (49), and Journal of Food Science (39). These journals, published by leading academic publishers such as Wiley (4), Elsevier (3), Springer (2), and MDPI (1) focus on various aspects of food preservation, processing techniques, food safety, and quality. The presence of open-access features in several journals increases the exposure, reach, and overall accessibility of research to the public and the global scientific community.

3.4. Document analysis

Document analysis is a powerful tool for understanding how research evolves and which studies shape a field. Analyzing published research helps to uncover the most influential work using RSM in the postharvest and food technology fields. The most cited article was a review that explored trends in the spray drying of fruit and vegetable juices (Shishir et al., 2017). The 364 citations and an average of over 40 citations per year resonated with research on drying technology and process optimization. This was closely followed by a research article examining the optimization of pectin extraction from grapefruit peel using

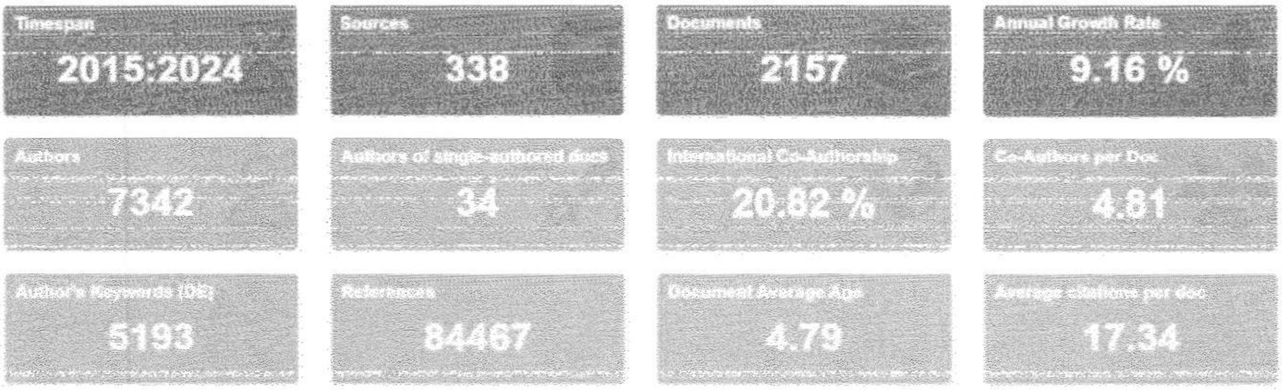

Fig. 2. Research performance statistics on RSM in postharvest and food technology using Biblioshiny.

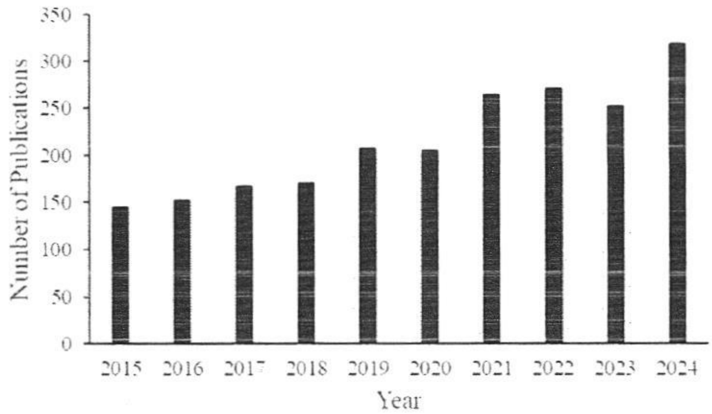

Fig. 3. Annual scientific production of RSM in postharvest and food technology in the last decade on the Scopus database.

Table 1
Top 10 Journals publishing research on RSM in postharvest and food technology from 2015 to 2024.

Journal	Publisher	Articles	Open access	Best rank and percentile (Scopus)
Journal of Food Processing and Preservation	Wiley	160	Yes	Q1 (77 %) in 2024
Journal of Food Science and Technology	Springer	129	No	Q1 (86 %) in 2024
LWT	Elsevier	122	Yes	Tier 1 (96 %) in 2024
Foods	MDPI	108	Yes	Tier 1 (99 %) in 2024
Food Chemistry	Elsevier	106	No	Tier 1 (98 %) in 2024
Journal of Food Measurement and Characterization	Springer	102	No	Q1 (80 %) in 2024
Journal of Food Process Engineering	Wiley	80	Yes	Q2 (72 %) in 2024
Industrial Crops and Products	Elsevier	55	No	Tier 1 (92 %) in 2024
Food Science and Nutrition	Wiley	49	Yes	Q1 (78 %) in 2024
Journal of Food Science	Wiley	39	Yes	Q2 (73 %) in 2024

ultrasound-assisted heating (Wang et al., 2015), which earned 328 citations, showing a strong interest in sustainable and efficient extraction methods. A paper on phenolic extraction and encapsulation techniques was third with 237 citations (Saikia et al., 2015). The remaining top-cited publications covered a range of topics including oil extraction from papaya seeds, pectin recovery from banana and passion fruit peels, and stabilization of anthocyanins in food products. Each study demonstrated strong citation performance, ranging from 187 to 233 total citations, reflecting the growing importance of combining RSM with green technologies and functional food development (Table 2).

3.5. Author analysis

3.5.1. Top authors by publications

The number of authors contributing to research in this field was 7342, reflecting a broad and diverse scholarly community. The majority (80.7 %) were single-publication authors, each contributing only one paper. This finding suggested that, while many researchers engaged with the topic, a smaller core group drove the research activity. Only 1416 authors published more than one document, and an even smaller subset (135) produced more than five publications, highlighting a highly concentrated group of prolific contributors.

Among the leading contributors, Li J, Li Y, and Singh A were the most productive, each with 21 publications, followed closely by Liu Y, (20 papers) and Wang Y and Zhang Y, each with 19 publications. Wang J and Wang Z contributed 18 documents apiece, while Chakraborty S, Chen J, and Kumar V completed the top tier with 17 publications each. The publication counts of these top authors, offer a snapshot of the most prolific authors in the domain as shown in Table 3.

3.5.2. Top authors by citations

Table 3 illustrates the analysis of total citation counts that provided meaningful insights into the academic influence of individual researchers in the field. The top 10 authors based on citations are listed in Table 3. Ferreira ICFR led with an impressive 651 citations, reflecting

Table 2
Top 10 most influential publications based on citations in the field of RSM in postharvest and food technology.

Title	Year & Journal	First author	Type of article	Total citations	Total citations per year	DOI	References
Trends of spray drying: A critical review on drying of fruit and vegetable juices	2017, Trends in Food Science & Technology	Shishir MR	Review	364	40.44	10.1016/j.tifs.2017.05.006	(Shishir et al., 2017)
Ultrasound-assisted heating extraction of pectin from grapefruit peel: optimization and comparison with the conventional method	2015, Food Chemistry	Wang W	Research	328	29.82	10.1016/j.foodchem.2015.01.080	(Wang et al., 2015)
Optimisation of phenolic extraction from Averrhoa carambola pomace by response surface methodology and its microencapsulation by spray and freeze-drying	2015, Food Chemistry	Saikia S	Research	237	21.55	10.1016/j.foodchem.2014.08.064	(Saikia et al., 2015)
Optimisation of ultrasound-assisted extraction of oil from papaya seed by response surface methodology: oil recovery, radical scavenging antioxidant activity, and oxidation stability	2015, Food Chemistry	Samaram S	Research	233	21.18	10.1016/j.foodchem.2014.08.068	(Samaram et al., 2015)
Optimization of pectin extraction from banana peels with citric acid by using response surface methodology	2016, Food Chemistry	Oliveira TÍ	Research	231	23.10	10.1016/j.foodchem.2015.08.080	(Oliveira et al., 2016)
Optimization of conventional and ultrasound assisted extraction of flavonoids from grapefruit (*Citrus paradisi* L.) solid wastes	2015, LWT	Garcia-Castello EM	Research	211	19.18	10.1016/j.lwt.2015.07.024	(Garcia-Castello et al., 2015)
Extraction of pectin from passion fruit peel assisted by ultrasound	2016, LWT	De Oliveira C	Research	203	20.30	10.1016/j.lwt.2016.03.027	(de Oliveira et al., 2016)
Novel approaches mediated by tailor-made green solvents for the extraction of phenolic compounds from agro-food industrial by-products	2018, Food Chemistry	De los Angeles	Research	198	24.75	10.1016/j.foodchem.2017.06.150	(de los Angeles Fernandez et al., 2018)
Optimization of the ultrasound-assisted extraction of anthocyanins and total phenolic compounds in mulberry (*Morus nigra*) pulp	2017, Food Chemistry	Espada-Bellido E	Research	197	21.89	10.1016/j.foodchem.2016.09.122	(Espada-Bellido et al., 2017)
Loading of anthocyanins on chitosan nanoparticles influences anthocyanin degradation in gastrointestinal fluids and stability in a beverage	2017, Food Chemistry	He B	Research	187	20.78	10.1016/j.foodchem.2016.10.120	(He et al., 2017)

Table 3
Top 10 prolific authors in terms of number of publications, citations, and h-index in the field of RSM in postharvest and food technology.

Author analysis by publications		Author analysis by citations		Author analysis by h-index	
Author	Number of publications	Author	Total citations	Author	h-index
Li J	21	Ferreira ICFR	651	Chen J	11
Li Y	21	Xu Y	571	Pradhan RC	11
Singh A	21	Barros L	552	Wang J	11
Liu Y	20	Barreiro MF	468	Wang X	11
Wang Y	19	Prieto MA	468	Ferreira ICFR	10
Zhang Y	19	Shishir MR	463	Li Y	10
Wang J	18	Wang Z	435	Liu Y	10
Wang Z	18	Wang W	433	Wang Z	10
Chakraborty S	17	Chen J	419	Zhang Y	10
Chen J	17	Cao Y	392	Li J	9

the broad impact of their research. Close behind was Xu Y with 571 citations, followed by Barros L (552), highlighting their strong presence in studies related to functional foods and natural antioxidants. Barreiro MF and Prieto MA who studied sustainable food processing and analytical techniques received 468 citations, tying for the fourth position and indicating consistent scholarly engagement. Shishir MR, recognized for research on spray drying and juice powders, also made a significant impact with 463 citations. Wang Z and Wang W were key contributors, earning 435 and 433 citations, respectively, largely through research on extraction optimization and postharvest technologies. Chen J (419) and Cao Y (392) rounded out the top ten. These highly cited authors have helped shape current research directions and continue to influence advances in postharvest and food technology.

3.5.3. Top authors by h-index

The real impact of an author can be evaluated by their h-index because author productivity is not always linked to the impact of their publications. In this study, the overall author h-index, considered all relevant articles published by the author. Specific emphasis was given to articles exclusively appearing in the sample, further identifying those with the greatest influence in each case (Arias-Cárdenas et al., 2024). Based on the h-index, a valuable metric reflecting the productivity and consistent impact of a researcher, the top 10 authors in this study demonstrated a strong scholarly presence in postharvest and food technology research using RSM. Leading the list were Chen J, Pradhan RC, Wang J, and Wang X each with an h-index of 11, indicating that they authored at least 11 papers that received 11 or more citations within this dataset. This level of performance highlighted their sustained contributions to and influence in the field. Following closely were Ferreira ICFR, Li Y, Liu Y, Wang Z, and Zhang Y all with an h-index of 10. Rounding out the top 10 was Li J with an h-index of 9, and also among the most prolific authors in terms of publication count. Several other authors such as Singh A, Wang Y, and Zhao L also had a local h-index of 9. However, for the purpose of this analysis, only one representative from this group was included to maintain clarity in identifying the top 10 authors based on the h-index (Table 3).

3.6. Most relevant affiliations

Fig. 4 presents a bibliometric analysis that identified the top 10 affiliations contributing the most to RSM research in postharvest and food technology. The Islamic Azad University was the most productive institution with 115 published papers. Other leading contributors included Universiti Putra Malaysia (95), Punjab Agricultural University (89), Tezpur University (80), and Nanjing Agricultural University (78). The University of Novi Sad (71), National Institute of Technology (63), Northwest A and F University (63), Instituto Politécnico De Bragança (55), and Jiangsu University (54) also played significant roles in advancing research in this field. The substantial publication outputs from these institutions highlighted their active engagement in postharvest and food-related research utilizing RSM, demonstrating the growing importance of optimization techniques in agricultural and food technology research. Interestingly, six of the top 10 institutions were in China and India, indicating that these countries had a strong interest in RSM in postharvest and food technology.

3.7. Country analysis

As shown in Fig. 5, the global landscape of RSM research in postharvest and food studies, based on the corresponding author countries, revealed notable regional disparities. India had the highest number of publications (391) followed by China (348), Iran (152), Turkey (128), and Brazil (100) indicating significant scientific output from Asia and South America. Additional contributors included Malaysia (65), Spain (62), Thailand (61), Nigeria (53), and Mexico (45).

In terms of collaboration patterns, single-country publications (SCP) dominated across all nations, with India exhibiting the highest number (364), followed by China (291) and Iran (130). Multiple-country publications (MCP), indicating international collaboration, were most prominent in China (57) followed by Iran (22), Malaysia and Spain (20 each), and Thailand (19). Notably, India, while having the highest overall output, showed limited international collaboration, with only 27 MCPs out of 391.

3.8. Co-authorship network analysis

The co-authorship analysis involved examining and evaluating collaborative relationships between researchers by analyzing patterns of co-authorship in academic publications (Nazli et al., 2024). The following section presents the strength of collaboration through co-authorship by authors and countries.

3.8.1. Co-authorship by author

The full counting method was applied in VOSviewer to calculate co-authorships. A minimum of 10 documents and 10 citations was set as the threshold, out of 7328 authors. From this, 43 authors met the threshold, and the top 10 authors with the greatest total link strength were selected for visualization. Fig. 6 presents a network map of these co-authorships. Among the selected authors, Wang, X and Zhang, Y showed the highest total link strength of 12, with Wang, X having 15 publications and 347 citations, and Zhang, Y having 19 publications and 346 citations. They were followed by Liu, X, Liu, Y, and Wang, Y each with a total link strength of 11, indicating strong collaborative activity within this author cluster. Notably, Wang, Z had 18 publications and the highest citation count at 435, highlighting the scholarly impact despite an equal total link strength of 11. Li, Y and Zhang, L showed moderate collaboration levels, while Wang, J and Wang, L also contributed significantly with consistent publication and citation records. The visualization revealed three main clusters of co-authorship as the red-cluster, green cluster, and blue cluster suggesting active collaboration networks among leading researchers in the fields of postharvest and food technology related to RSM.

3.8.2. Co-authorship by country

The co-authorship network among countries engaged in publishing research on RSM in postharvest and food technology is illustrated in (Fig. 7A). The analysis involved 102 countries. A minimum threshold was set to include countries with at least one document and at least zero citations. This resulted in the inclusion of all countries, which were further divided into 15 clusters based on their collaboration linkages. As shown in Fig. 7B, a secondary analysis was conducted focusing on the top 10 countries to highlight the most influential contributors based on total link strength. These countries were distributed across three distinct clusters, indicating regional and collaborative groupings. The United States emerged as the most central node in the network, exhibiting the highest total link strength of 45, reflecting its strong and widespread international partnerships. China followed with a total link strength of 36, underscoring its significant role in global collaboration as well as being the top contributor in terms of publications and citations. Spain ranked third with a total link strength of 31, highlighting its active engagement in cross-country research. India, although leading in document count, recorded a total link strength of 27, showing solid but primarily regional collaboration than Brazil. Saudi Arabia and Turkey had total link strengths of 25 and 21, respectively indicating growing research ties within their cluster. Iran and Portugal also had total link strengths of 21, reflecting a moderate but notable presence in the global

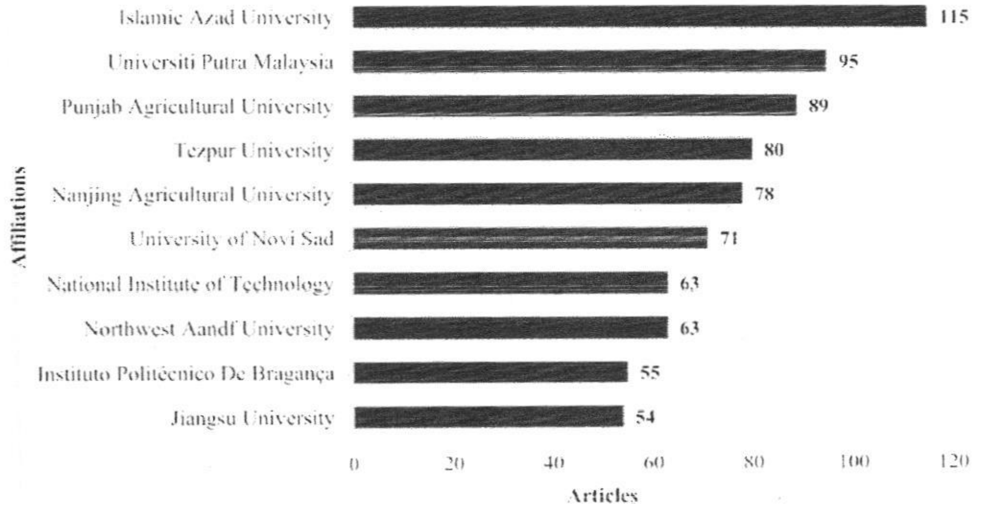

Fig. 4. Top 10 most relevant affiliations in research regarding RSM in postharvest and food technology.

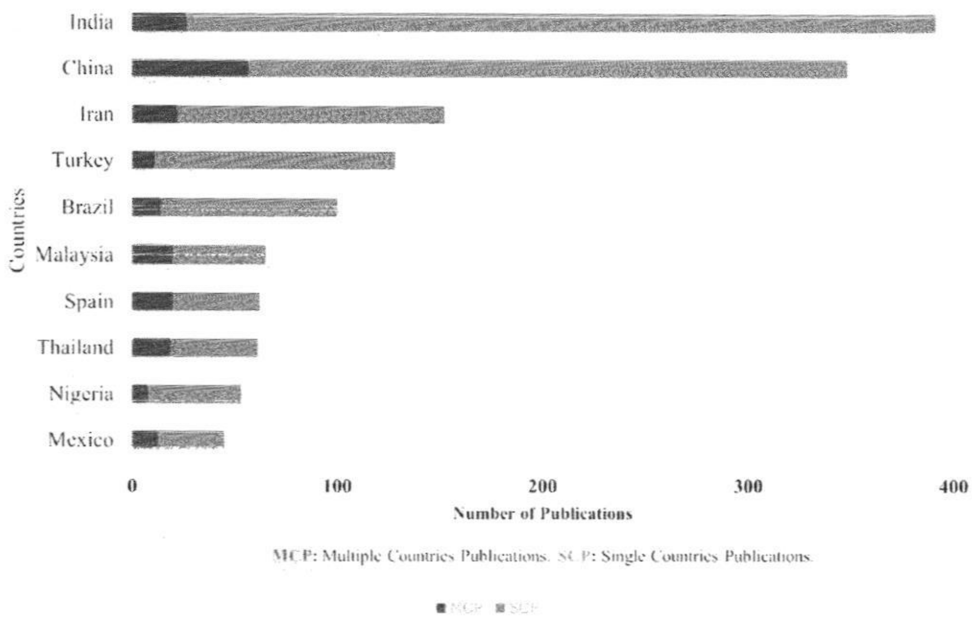

Fig. 5. Top 10 countries based on corresponding authors including single and multiple countries publications related to RSM in postharvest and food technology.

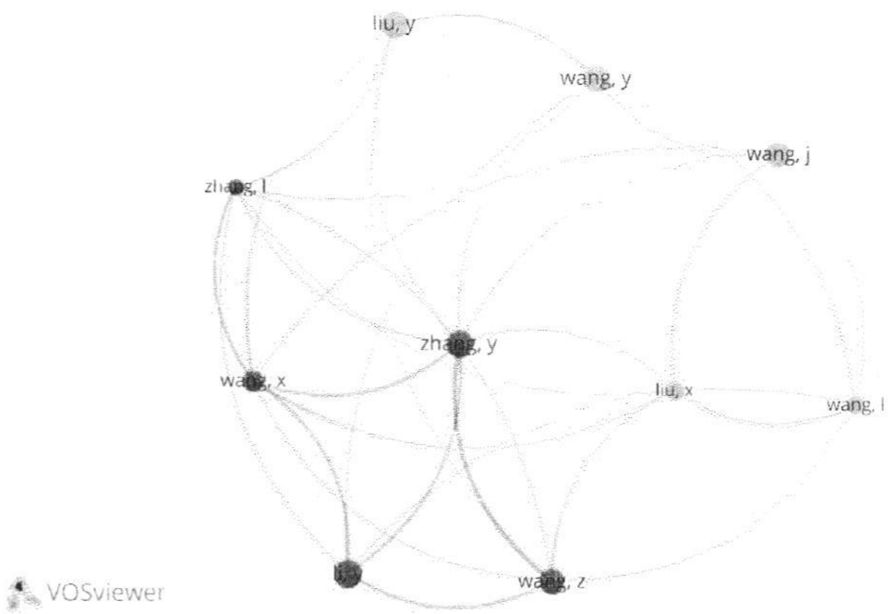

Fig. 6. Author collaboration network visualization in the field of RSM in postharvest and food technology.

network. Brazil, with 19, and Malaysia, with the lowest among the top ten at 14, showed emerging but less dense international co-authorship patterns than the other countries. The total link strength values revealed publication volume and also the depth of international engagement, crucial for knowledge exchange and collaborative innovation in the field of RSM applications in postharvest and food technology.

3.9. *Co-occurrence analysis*

3.9.1. *Keyword analysis*

Keyword analysis is a fundamental process in bibliometric studies because this identifies the most used terms and concepts in a discipline or thematic area. By analyzing the co-occurrence of keywords, the relationships between various topics can be gleaned by tracking trends and shifts in scientific discourse. Keywords express the research priorities and interests of a disciplinary set, while in a scientific study co-occurring keywords reflect how frequently terms appear together or next to each other, indicating the connection between different topics or methodologies (Narong & Hallinger, 2023). In bibliometric studies, keywords are typically selected from the title/abstract of a publication (Donthu et al., 2021). A variety of techniques, approaches, and visualization were applied to the chosen keywords including cluster methods and network visualization to explore the relationships among them and identify patterns, clusters, and themes. The frequency of keyword occurrences and their relationships with other keywords can provide a sense of the major themes in a research field, as well as the most important areas of emphasis or importance, and also provide insight into emerging research fronts (Lu et al., 2021).

Fig 8. illustrates a keyword co-occurrence network that was analyzed

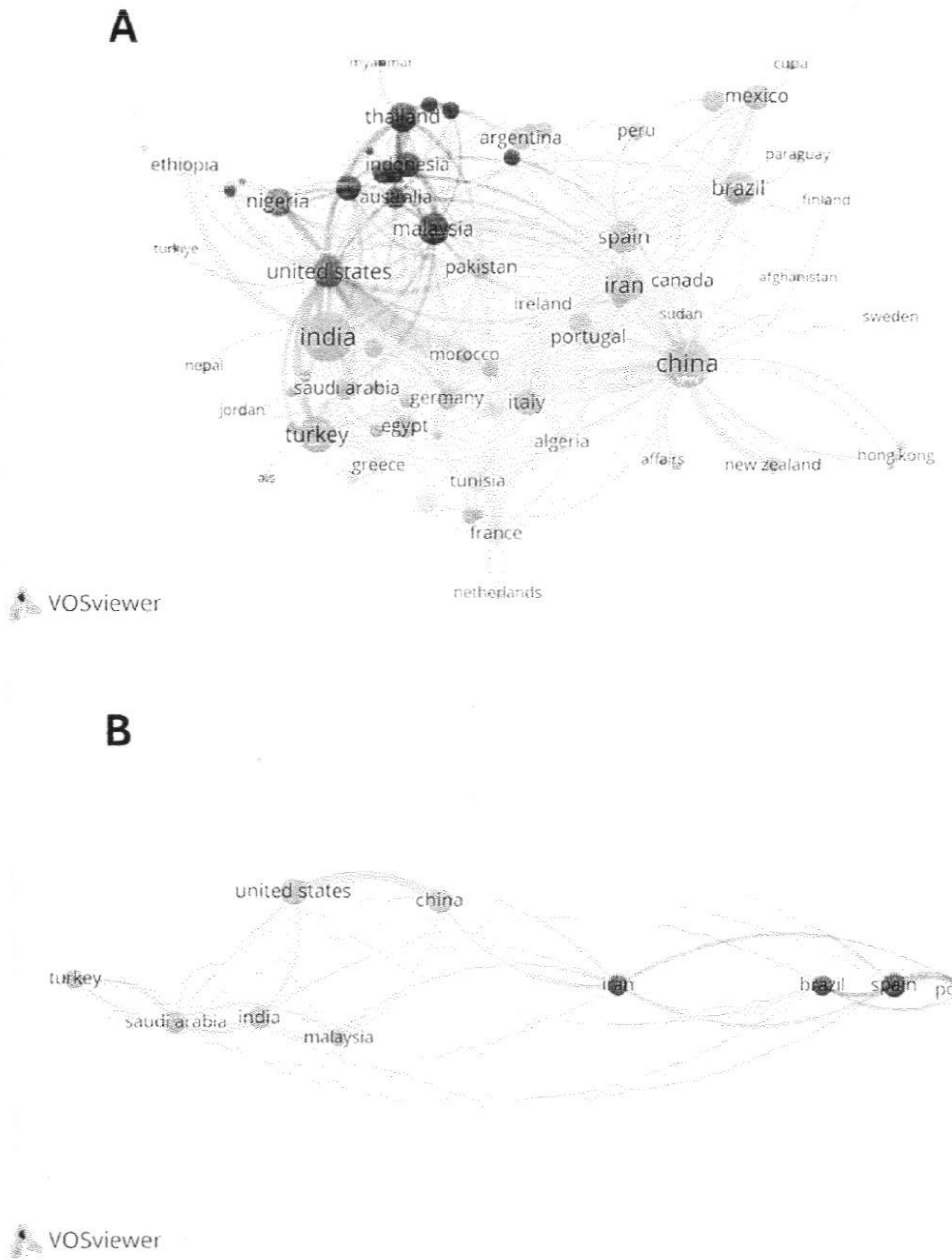

Fig. 7. (A) Co-authorship of all country networks; (B) Co-authorship of the top ten country networks.

for keywords occurring more than 10 times using the full counting method. Out of the 11,476 keywords, 566 met the minimum threshold, with the top 100 most frequently used keywords selected for visualization. These keywords were grouped into four clusters: Cluster 1 (red) contained 38 keywords, Cluster 2 (green) included 37 keywords, Cluster 3 (blue) had 23 keywords, and Cluster 4 (yellow) contained 2 keywords. RSM had the highest number of occurrences (1201) and the strongest total link strength (5943), highlighting its central role in the co-occurrence network, with strong connections across multiple clusters, particularly those involving surface properties, extraction techniques, and antioxidant activity.

The red cluster surrounding RSM and terms such as "chemistry," "antioxidant activity," "plant extracts," and "polyphenols" suggested that the primary focus in the literature was the chemical analysis of food products, mainly plant extracts and compounds with bioactive activity. This suggested that RSM was used to facilitate additional studies to optimize the extraction of bioactive compounds (such as polyphenols) to develop functional foods. Owing to the importance of polyphenols in human health (especially in the prevention of chronic diseases) (Pandey & Rizvi, 2009), future studies using RSM to maximize the extraction and preservation of polyphenols offer great potential for translating the knowledge gained into better quality and safer food products.

The green cluster with articles related to food science containing the terms "food processing," "drying," "physicochemical properties," and "sensory analysis" illustrated the use of RSM to improve food quality while optimizing processing methods. This cluster showed how RSM could be applied to better understand the impact of different processing methods on the physical and chemical composition of foods such as moisture, proteins, and enzymes. This study also explored how aspects of traditional processing methods enhanced the functional properties of food. As society becomes more focused on healthy eating, novel research on food products to enhance nutrition and sensory properties (flavor, texture, and color) is becoming more appealing (Michel et al., 2024).

The blue cluster contained terms such as "solvent extraction,"

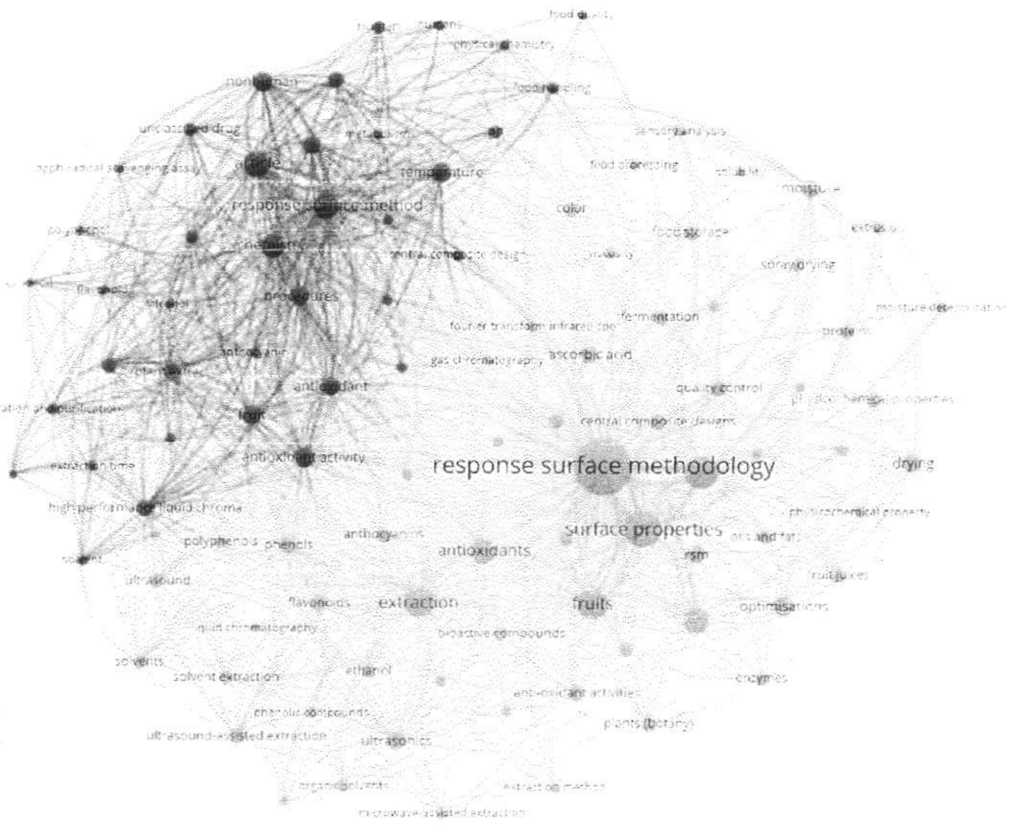

Fig. 8. Thematic clusters of the top 100 author keyword co-occurrence networks related to RSM in postharvest and food technology.

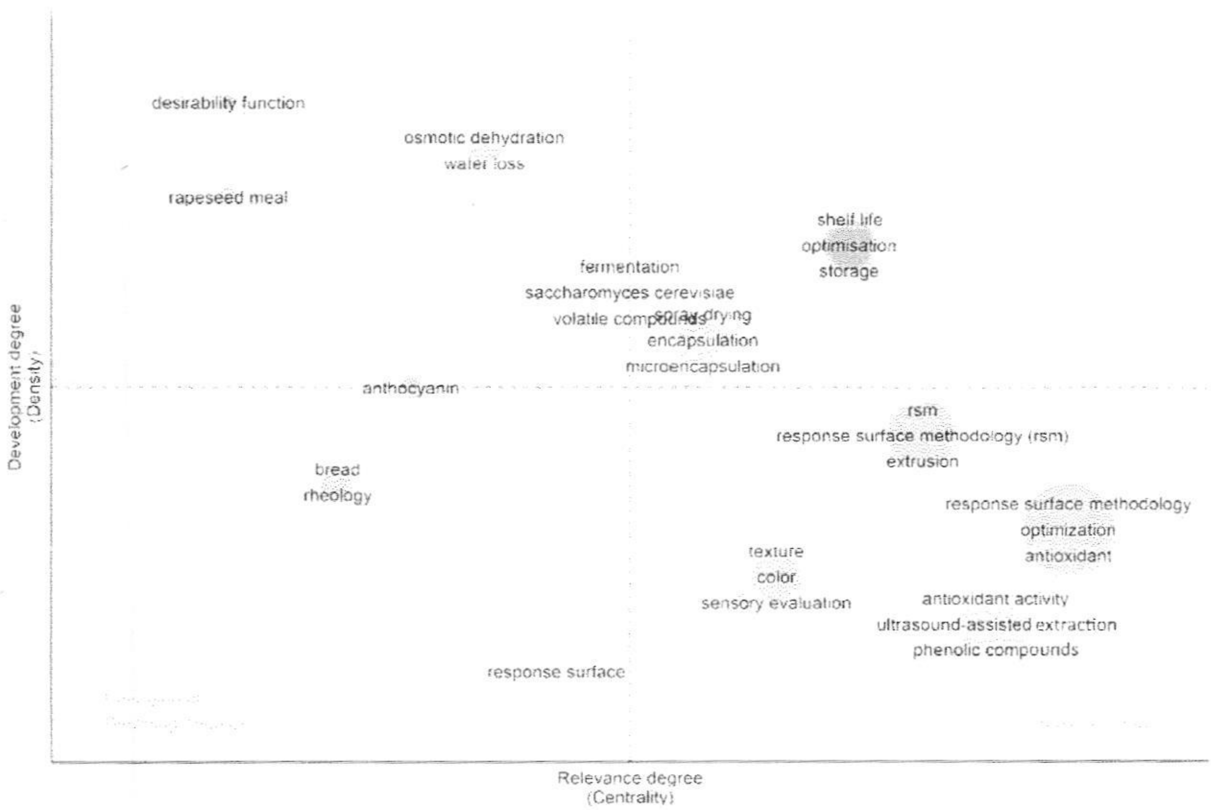

Fig. 9. Thematic map created by the authors' keywords for the use of RSM in postharvest and food technology.

"ultrasound-assisted extraction," and "microwave-assisted extraction" indicating that extraction methods were the main focus of RSM applications. The blue cluster emphasized solvent type, extraction efficiency, and the recovery of bioactives. RSM was more frequently used to optimize extraction methods for bioactive compound yield, especially polyphenols and flavonoids, while conserving energy and limiting solvent use. This cluster indicated that research efforts should be directed toward newer, more sustainable, and energy-efficient extraction methodologies directly related to the tenets of green chemistry and sustainable food production.

The yellow cluster, though small, contained the two terms "gas chromatography" and "mass spectroscopy." These terms highlighted the potential of analytical methods using advanced instruments in postharvest and food research. Both methods are frequently utilized alongside RSM to optimize conditions for accurately measuring food components, indicating their important roles in postharvest food safety and quality.

3.10. Thematic map

Fig. 9 presents a thematic map derived from the bibliometric analysis that offers a comprehensive visual representation of research themes within postharvest and food technology, specifically focusing on RSM. Thematic evolution was presented as **supplementary Fig. 1**, providing additional evidence for the thematic map identified in our study. This map categorized themes based on the two key dimensions as centrality, reflecting a theme's relevance or importance to the broader field, and density, indicating the level of development or internal cohesion within the theme. The map was divided into four quadrants as motor themes, niche themes, emerging or declining themes, and basic themes each providing insight into the status and trajectory of different research areas (Alkhammash, 2023).

In the motor themes quadrant, topics such as shelf life, storage, and optimization were identified, indicating their strong development and high relevance in the field. The basic themes quadrant included foundational but underdeveloped topics such as RSM, optimization, extrusion, antioxidant, ultrasound-assisted extraction, phenolic compounds, texture, color, and sensory evaluation. These themes were central to the field and represented its core areas of study. The niche themes quadrant featured topics such as desirability function, osmotic dehydration, water loss, and rapeseed meal. These are well-developed but less central, reflecting specialized and possibly isolated research areas. In the emerging or declining themes quadrant, terms such as bread, rheology, anthocyanin, and response surface appeared. These themes were characterized by low development and relevance in the current literature landscape, signaling either nascent areas of research or declining interest.

3.11. Three-field analysis

The three-field plot displays the relationships between cited references (CR), authors (AU), and keywords (KW) in RSM-related research. The gray lines indicate the connection between these three fields or dimensions, and the rectangles provide a rough indication (based on their relative size) of the number of documents associated with each rectangle. The middle field (AU) is the central field of the plot, showing the most active authors and their connections to references, as well as their thematic keywords. The most active author is Li Y, along with links to themes of response surface methodology, surface properties, and fruits. Second is Wang Y with links to contributions with themes of optimization, antioxidants, and extraction. Other active contributors include Li J, Liu Y, Chakraborty S, Singh A, Wang J, and Chen J. The author field (AU) shows methodological works predominate, but the most frequent keywords show that RSM was central to themes or areas with fruits, antioxidants, and food processing optimization (**Supplementary Fig. 2**).

3.12. Factorial analysis (Topic dendrogram)

The dendrogram displays the hierarchical clustering of keywords in studies using RSM related to postharvest and food research studies. The first hierarchical cluster includes keywords about moisture content, pH, texture, surface properties, and proximate composition. This cluster indicates interest in product quality parameters for RSM optimization. The second hierarchical cluster links keywords regarding antioxidants, phenolic content, extraction, and phytochemicals. This second links to studies aimed at maximizing bioactive compounds and nutritional quality, which fits the theme of the cluster in the dendrogram. A third hierarchical cluster was noted that included keywords related to food science, optimization, RSM, and statistical models. This cluster focused on methodological and process-based applications of RSM. Other hierarchical clusters link keywords to areas of plant extract, essential oils, shelf life, and bioactive compounds. These clusters suggest significant focus on natural sources and functional food development in studies using RSM (**Supplementary Fig. 3**).

4. Discussion

4.1. Bibliometric analysis

The results of this analysis underlined the growing significance of RSM in postharvest and food technology to mitigate global challenges such as food security and sustainability and maximize resource optimization. Over the past decade, RSM has proved an indispensable tool for improving preservation techniques, extending shelf life, enhancing product quality, and minimizing food waste. The bibliometric data reflected these trends.

From a total of 2157 RSM-related publications analyzed, 1271 were focused on food technology, with 886 specifics to postharvest research. This distribution indicated that almost 60 % of the output was food-related, with a significant and growing emphasis on postharvest applications. The strong representation of postharvest studies suggested that researchers are now increasingly leveraging RSM to tackle issues such as storage stability, ripening control, and nutrient retention, which are critical aspects of reducing postharvest losses and ensuring that food reaches consumers in optimal condition. These findings highlighted the widespread adoption of RSM and its evolving role in developing sustainable and efficient food systems.

The number of RSM-related papers increased steadily from 145 in 2015 to 319 in 2024. The most dramatic increase was between 2020 and 2021, resulting from the global focus on food safety and preservation due to the COVID-19 pandemic (Massoud & Zoghi, 2024). The gradual increase over the decade was attributable to the easier and more accessible use of RSM owing to advancements in statistical and computational programs (Asoo et al., 2024). The recent emergence of AI and Machine Learning (ML) offers entirely new directions for predictive modeling and process optimization integrated with RSM (Budi Susilo et al., 2025).

A document analysis of the most salient, high-impact papers included the extraction of bioactive compounds (e.g., phenolics, pectins, flavonoids, and oils) using green practices such as ultrasound and microwave-assisted extraction (Espada-Bellido et al., 2017; Samaram et al., 2015; Wang et al., 2015) as the core research focus areas. Interest in the previously mentioned spray-drying optimization and especially in preserving nutrition indicated the benefits of RSM for food preservation and the development of functional foods. RSM shows versatility for different raw materials and applications including banana peels, papaya seeds, and passion fruit peels (de los Ángeles Fernández et al., 2018; García Castello et al., 2015; Oliveira et al., 2016).

An authorship analysis revealed over 7300 contributors, indicating a highly collaborative research environment. A smaller number of prolific contributing authors such as Li J, Li Y, and Singh A were significant players who shaped the field through the number of studies they published. Ferreira and Xu had a high number of citations (651 and 571, respectively) even though they published fewer papers. The h-index values of Chen J, Pradhan RC, and Wang J indicated the contribution of considerable amounts of academically impactful research over a long period, rather than mere numbers of published articles (Arias-Cardenas et al., 2024).

Fig. 8 presents the keyword co-occurrence network analysis, which sheds light on the thematic research clusters. The red cluster featured terms such as "antioxidant activity," "plant extracts," and "polyphenols," highlighting the focus on optimizing extraction techniques to develop functional foods with relatively "safe" RSM methods to engineer novel bioactive compound extractions (Pandey et al., 2009). The green cluster presented terms such as "food processing," "drying," and "sensory analysis" as improvements to the sensory and physicochemical measures of foods via process optimization. The blue cluster presented advanced extraction methods such as ultrasound and microwave-assisted extraction, featuring a desire for greener technologies and more sustainable approaches. Finally, the yellow cluster contained terms emphasizing analytical approaches via methods such as gas chromatography and mass spectrometry. The combined use of these tools and RSM emphasized the value of postharvest and food quality.

The thematic map further clarified the intellectual structure of this field. Key themes such as "shelf-life," "storage," and "optimization" emphasized the important role of RSM in postharvest quality. Established themes such as "extrusion" and "ultrasound-assisted extraction" provide opportunities for further investigation, while niche themes such as "osmotic dehydration" and "desirability function" demonstrate niche applications with the potential for development in a particular context. The next sections present details on how RSM provides support for optimization across processes such as storage, disinfection, formulation, and sensory evaluation.

4.2. Impact of RSM in postharvest technology

RSM has revolutionized postharvest technology because it can effectively improve, and model complex multivariate systems used in the handling, storage, and preservation of agricultural products. Postharvest loss remains a major global issue, particularly in developing countries, where 30–40 % of produce can be lost by improper storage, inefficient handling, and/or processing under less-than-ideal conditions (Deepak Kumar & Prasanta Kalita, 2017; Rao et al., 2020). RSM is a powerful statistical tool that can systematically study the relationships between several influential variables and their effects on the essential quality attributes of postharvest products to mitigate losses. For scaling industry application, RSM could provide postharvest treatment/condition with the tools to optimize their storage condition parameters, physical chemical treatment, coating formulations, and packaging systems to improve product development, quality, storage and shelf-life for controlling production cost and waste.

One of the most established applications of RSM in the postharvest technology field is the optimization of storage conditions for perishable products, including fruits, vegetables, and flowers. Storage conditions such as temperature, relative humidity, gas composition (including O_2, CO_2, and ethylene levels), and storage time are particularly relevant parameters for maintaining postharvest quality. Singh et al. (2024) used RSM to determine the optimal temperature and relative humidity levels for guava fruit storage to maximize the retention of firmness, color, and vitamin C. Similarly, Cheng et al. (2023) used RSM to investigate the optimal conditions for modified atmosphere packaging (MAP) of strawberries, achieving the desired shelf life and sensory attributes by effectively adjusting the O_2 and CO_2 concentrations. RSM modeling provides a framework for predicting the response of perishable products in several storage environments to enhance decision-making in postharvest management.

RSM enhanced bio-based fungicides, UV-C treatment, ozone fumigation, and cold plasma for postharvest disease control (Guo et al., 2024; Lalpekhlua et al., 2024; Wang et al., 2021). These technologies have many variables including duration of exposure, concentration levels, and environmental conditions that impact their effectiveness and safety. RSM has proven valuable in determining optimal treatment conditions to suppress microbial growth while minimizing chemical or physical damage to the product (Younis et al., 2023). RSM has also been highly useful in the development and application of edible coatings and films used to extend postharvest shelf life as commercially produced coatings, primarily made from polysaccharides, proteins, and lipids which limit moisture loss, gas exchange, and/or microbial contamination (Thakur et al., 2019). The performance of the coating is affected by formulation and application factors including polymer concentration and combinations, solvent ratio, and drying times. RSM optimizes these factors and produces coatings with the desired properties that exhibit elasticity, barrier strength, and bioactive functionality (Pirozzi et al., 2021). Seididamyeh et al. (2024) applied RSM to optimize edible coatings for fresh-cut capsicum. Their model accurately predicted the best coating formulation to reduce microbial growth during the storage phase, resulting in longer shelf life and extended marketability.

RSM also contributes to the development of packaging systems for food preservation. Biodegradable packaging films based on natural polymers have recently attracted interest in postharvest applications (Gupta et al., 2022). It assists in the development of film-forming formulations and processing parameters to obtain film materials with appropriate mechanical characteristics and barrier functions. Researchers have applied RSM to develop starch-based films of appropriate thickness and strength that can carry antimicrobial agents and extend the shelf life of fresh-cut fruits and vegetables, thereby reducing plastic packaging waste (Puri et al., 2023; Thakur et al., 2017). Minimizing vibrations and impacts during the distribution of fresh fruits is also an example of optimizing packaging to minimize loss resulting from external conditions during transportation (temperature, impact energy, acceleration, frequency) (Chaiwong et al., 2021; Wang et al., 2024).

Another potential impact of RSM in postharvest technology is by valorizing postharvest waste and agricultural residues. The circular economy and sustainability aspects have recently encouraged researchers to explore possibilities for the extraction of important phytochemicals (e.g., polyphenols, flavonoids, and pectin) from fruit peels, seeds, and pulp that remain after processing. RSM can assess extraction conditions such as solvent concentration, extraction time, temperature, and pH to achieve optimal yields in the shortest time, using the minimal quantity of solvents to reduce processing costs (Sai-Ut et al., 2023). RSM also efficiently optimized the extraction of antioxidants from pomegranate peels and rotten bananas as waste utilization or valorization to approach zero waste (Ng et al., 2025; Sood & Gupta, 2015).

RSM-based postharvest studies in good-quality journals often include robust analytical components such as ML, artificial neural networks (ANN), and hybrid models as well as statistical optimization to improve predictions and usefulness. Many journals focus strongly on the mechanistic rationale behind the observations using biochemical, physiological, or molecular explanations for observed trends in conjunction with RSM modeling to provide added scientific depth to the study. Conducting validation trials under real-world or industrial conditions can also improve RSM credibility and applicability. Ensuring a rigorous experimental design with adequate replicates, appropriate model diagnostics (e.g., R^2, adjusted R^2, lack of fit, and residual analysis), and clear articulation of limitations and scope can significantly elevate the manuscript's acceptance potential. Finally, framing the research in terms of global issues such as food security, waste reduction, or sustainability appeals to broader journal scopes and editorial interests.

RSM can provide food manufacturers and post-harvest managers with the tools to optimize their processing parameters, coating formulations, and packaging systems to enhance product development, shelf life, and food waste. RSM helps post-harvest managers use data to identify important processes and their interactions to support a more efficient and cost-effective post-harvest processes; in this case, RSM supports the scientific research and industrial applications. Although there are exciting prospects of RSM in both edible coatings, biodegradable packaging, and extraction processes from food waste (vegetables, fruits, cereal grains), and their application can be examined, there are practical challenges before widespread use. First, scaling laboratory-optimized formulations to commercial production can be problematic due to variability in raw material quality, environmental influences, and operational limitations. For instance, costs, such as bio-based polymers, solvents, or specialized processes, as well as the regulatory oversight of biologically active coatings (including engineered nanoparticles), antimicrobial agents, or extracted phytochemicals could be a barrier to implementation. Furthermore, real storage and transportation situations are more complicated than laboratory-controlled situations, thereby not aligning with the optimized conditions set in the laboratory.

4.3. *Impact of RSM on food technology*

In the broader area of food technology, RSM has emerged as a fundamental statistical tool for the optimization of formulation, processing, preservation, and/or quality control. The complexity associated with food systems, the dynamics of ingredients, and the processing influencing sensory, nutritional, and functional properties necessitates a model that can adequately analyze the variables associated with combinations of ingredients (Fanzo et al., 2022). RSM statistically models variables that significantly impact food formulation and quality, as a powerful experimental design tool that evaluates the effect of several independent variables on one or more response variables (Kim et al., 2023).

RSM is extensively applied in food product formulation, primarily to optimize ingredient combinations and achieve the desired sensory, functional, and nutritive properties. Many researchers have applied RSM in the formulation of functional beverages, where balancing the concentrations of different fruit juices, sweeteners, and functional additives (probiotics, antioxidants) is vital to optimize important parameters (pH, viscosity, taste) determined by consumer preference (M'hir et al., 2021; Srivastava et al., 2024).

In thermal food processing, RSM is used in time-temperature combinations to inactivate pathogens while maintaining desirable characteristics (texture and nutrients) which are particularly useful in treating dairy, juices, and ready-to-eat meals. RSM is utilized in non-thermal technologies including high-pressure processing (HPP), pulsed electric fields (PEF), and ultrasound-assisted processing (Melios et al., 2025). RSM has also been used to enhance ultrasound conditions for juice processing to enhance nutritional gain, juice recovery, and microbial safety (Lieu et al., 2010; Yıkmış et al., 2025), and is instrumental in drying technology, an essential processing operation to preserve the shelf-life of dried products derived from spices, herbs, fruits, and vegetables. The parameters used for drying (temperature, air velocity, time, and slice thickness) are complicated and can interact with system parameters affecting drying efficiency and quality (Joudi-Sarighayeh et al., 2023). Researchers have applied RSM to improve time, temperature, and other parameters to minimize drying time, energy, and environmental impact while retaining acceptable color, aroma, and bioactive compounds in the dried product (Nanjoo et al., 2024). RSM has also been used to identify the optimal conditions for spray drying and improve the quality of orange-fleshed sweet potato powder (Arebo et al., 2023). Similarly, RSM was used to evaluate microwave drying conditions for turmeric to enhance product quality, increase shelf life, and decrease drying time (Parmar et al., 2025).

RSM supports the best use of bio-actives such as polyphenols, omega-3 fatty acids, and dietetic fiber in functional and fortified foods to develop snacks and bakery products. These bioactives often compromise taste and stability, and RSM strikes a balance between the value of any nutritional changes and product taste (Nilova et al., 2020). RSM has been used in the development of ice cream to modulate sweetness and creaminess and improve hedonic ratings and consumer acceptance, with a reduced number of experimental trials (Głuchowski et al., 2021). For example, del Pilar et al. (2022) demonstrated that green marketing approaches within an organic food company in Peru influenced the commercialization of healthy products. This suggests consumers exhibited a preference for brands that endorse ecological, healthy, and non-harmful practices, particularly during the COVID-19 pandemic.

In food safety and microbiological research, RSM is used in antimicrobial treatments by modeling the inactivation of pathogens with pH, temperature, and duration of exposure to determine Hazard Analysis and Critical Control Point (HACCP) for product regulatory compliance (Awuchi, 2023). RSM has also been used in fermented food systems to maximize variables such as inoculum size, pH, and temperature to enhance healthy beneficial metabolites in food products such as yogurt and kombucha and overcome inconsistencies to develop stable products with positive health benefits (Bansal et al., 2015; Dong et al., 2024).

The ability of RSM to adapt to multi-objective optimization is valuable for researchers and industry professionals to standardize processes, reduce costs, and improve product development while meeting multiple quality parameters, including shelf life, sensory characteristics, and nutrient density. When utilizing advanced approaches such as ML and ANN with a sound mechanistic rationale, whether biochemical, physiological, or molecular, RSM studies present better opportunities for high-impact publications. For example, a recent case study by Amarasinghe et al. (2024) demonstrated the use of ML models to illustrate the use of advanced computational tools for sustainable food production and decision-making. RSM can become timelier and more relevant for high-impact journals as an effective response to global issues such as food security, food waste reduction, and sustainability.

In conclusion, RSM has significantly impacted the postharvest and food technology sectors, allowing researchers to develop predictive models and reduce the number of experiments by effectively evaluating multi-factor systems and, most importantly, designing safer, more nutritious, and sustainable food products and postharvest processes. Thus, RSM plays a critical role in responding to the demands of the evolving global food space.

5. Implications for future research

The results of this bibliometric analysis provide crucial directions for further research on the use of RSM in postharvest and food technology. The most important future direction is the development of sustainable and green extraction technologies. RSM efforts should therefore integrate parameters related to environmental sustainability, especially carbon footprint calculations, to maximize the ecological footprint of optimized processes, leading to more sustainable food processing systems. Environmental sustainability is a worldwide concern, and the need for more eco-friendly and energy-efficient methods of extracting bioactive compounds from plant sources has never been more urgent. Researchers can further explore the optimization of green solvents, microwave-assisted extraction, ultrasound-assisted extraction, and other non-toxic methods using RSM to improve extraction yields while minimizing energy consumption and environmental impacts.

The rise of niche research areas in thematic maps, including osmotic dehydration, water loss, rapeseed meal, and desirability functions, provides promising opportunities for future innovative studies with significant practical applications in specific food sectors. Future studies should consider how RSM can optimize niche processes to improve their performance and extend the scope of these processes to wider sectors of the food industry. Osmotic dehydration has been traditionally limited to fruits and vegetables but could be advanced with RSM-optimized processing outcomes to broaden the preservation of different food products, thereby increasing shelf life and reducing waste.

More research on consumer acceptance of the sensory attributes of RSM-optimized food products is needed. As food technology develops, it is important to understand how consumers react to the taste, texture, and sensory experience of RSM-optimized foods. Future work should employ a framework of RSM, using the methods of either a sensory panel, preference mapping, or conjoint analysis, to systematically acquire consumer preferences, understanding consumer interaction with the product, in order to improve and develop product performance. Once there is improved understanding between the consumer and the product, this conceptual framework will have important implications on the acceptance of RSM and the successful commercialization of RSM within food science.

These advancements will lead to reduced agro-waste and improved food production sustainability. Interdisciplinary partnerships will also be increasingly important for advancing research and development of RSM applications. AI and machine learning can now develop optimization models, allowing RSM to deliver more accurate predictions and enhance process control in food production. AI and ML are now able to create optimization models for RSM, which will allow it to give better predictions and control of processes in food production. For example, RSM frameworks supported by AI and ML have been used to generatively model and predict a fermentation process and optimize for the quality of dairy products. AI also has the potential to improve the process effectiveness and product quality by integrating food processing parameters from big data analytics into RSM framework. This capability will improve the monitoring and processing of food, with new technologies such as Internet of Things (IoT) sensors, robotics, and digital twins presenting many opportunities to incorporate RSM in new ways. Blockchain technologies now offer interesting possibilities when combined with RSM to minimize the supply chain and improve traceability to the source, thereby enhancing food safety and quality. RSM can be a valuable tool in 3D food printing to optimize the creation of healthy, dietary-appropriate customized food products by shaping textures, flavor combinations, and dietary contents.

National and international collaborations are also important areas to explore in future research. Co-authorship featured the influence of countries such as the United States and China in RSM research and highlighted the potential for countries like India, Brazil, and Saudi Arabia to improve their international collaboration. Interestingly, India was the top country in terms of the number of published articles but the low international collaboration suggests an opportunity to expand its research networks. Increasing international collaboration among emerging and leading countries will foster the exchange of wisdom, resources, and innovative approaches to tackle complex global food challenges. This collaboration between leading countries may also lead to the evolution of standardized global protocols for RSM in postharvest and food technology. Institutional enablers can also be an important way to support and sustain long-term global partnerships, and to ensure equitable knowledge sharing with institutional enablers such as international research consortia, open-access datasets, and joint funding calls.

6. Conclusions

This bibliometric analysis of RSM in postharvest and food technology emphasizes the growth and increased variety of research using RSM. The number of publications and citations has steadily increased over the years, indicating that RSM is gaining considerable attention as a valuable approach for solving important problems in food processing, preservation, and quality management. India, China, and Iran have been leading contributors to RSM research, likely due to their active agri-food sectors, supportive government investments, and strong educational infrastructures. However, wider international participation in RSM research is needed, which could be facilitated by international collaborative networks, open-access tools and datasets, and interdisciplinary consortia. Facilitation of such activities would increase geographic diversity and researcher engagement, improve the potential for research output exchange, and facilitate global applicability of RSM research outcomes across food systems. Co-authorship and keyword cooccurrence demonstrate research is interconnected and used across a wide range of topics, including food, functional foods, and green technologies, which can benefit sustainable food systems. The thematic map showed that RSM research has changed to more developed and central topics, such as shelf life and storage optimization. Topics that are foundational to these are highly underdeveloped (e.g., antioxidant analysis, texture, and sensory evaluation), making them points of potential future research. The bibliometric analysis highlighted the significant role of RSM in developing postharvest and food technology, particularly in optimizing fruit and vegetable preservation, shelf life, quality control, and food processing. Interestingly, further research should connect RSM with real-time AI-based monitoring, blockchain-based traceability, and interdisciplinary approaches to tackle global issues in food security, sustainability, and public health.

Statement of human and animal rights

Title: Response Surface Methodology in Postharvest and Food Technology Research: A Bibliometric Assessment

The author(s) state(s) that this research was conducted in accordance with the Helsinki Declaration as revised in 2008.

In all studies involving animals, the author(s) followed the guidelines for the use and care of laboratory animals of the author's institution or the National Research Council or any national law pertaining to care of animals in research.

Name of researcher: Assoc. Prof. Dr. Saowapa Chaiwong (Corresponding author)

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When reporting experiments on human subjects, authors should indicate whether the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. If doubt exists whether the research was conducted in accordance with the Helsinki Declaration, the authors must explain the rationale for their approach and demonstrate that the institutional review body explicitly approved the doubtful aspects of the study. When reporting experiments on animals, authors should indicate whether the institutional and national guidelines for the care and use of laboratory animals were followed.

CRediT authorship contribution statement

Sathiyaraj Sivaji: Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Suriyakala Gunasekaran:** Writing – review & editing, Validation, Supervision, Software, Methodology. **Rattapon Saengrayap:** Writing – review & editing, Validation, Supervision. **Pramod Mahajan:** Writing – review & editing. **Tatiya Trongsatitkul:** Visualization. **Di Wu:** Visualization. **Kayeen Vadakkan:** Writing – review & editing. **Suchada Sukrong:** Visualization. **Saowapa Chaiwong:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Saowapa Chaiwong reports financial support was provided by Mae Fah Luang University. Saowapa Chaiwong reports a relationship with Mae Fah Luang University that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afres.2025.101461.

Data availability

Data will be made available on request.

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