A Bibliometric Analysis of Postharvest Sprout Inhibition using VOSviewer

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ABSTRACT

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Postharvest sprouting significantly reduces the quality and shelf life of crops. The increasing restrictions on synthetic sprout inhibition, notably chlorpropham (CIPC), have driven global interest in natural bioactive compounds as safer and eco-friendly alternatives. The study aims to provide a comprehensive bibliometric analysis of postharvest sprout inhibition using VOSviewer. Data were retrieved from the Scopus database for the period 1945–2026 using keywords related to postharvest sprouting, sprouting control, sprout inhibition, sprout suppressant, sprout suppression, or sprout suppressive, restricted to English-language articles and conference papers. Bibliometric indicators were analysed using VOSviewer software to identify annual publication trends, prolific authors, countries, and journals, as well as to map keyword networks and scientific collaborations. The analysis highlighted research trajectories, uncovered existing gaps, and provided recommendations for future studies in the field. Analysis of 293 publications reveals a rising annual trend in scientific output and citations that peaked in 2024, identifying Terry, USA, and Status of Food Irradiation in the World journal as the most influential contributors. Furthermore, keyword analysis show that 'sprout inhibition,' 'potato,' and 'storage' form the core research clusters, with 'chlorpropham' serving as a central link between dormancy management and postharvest quality. Future research should explore emerging areas such as organic agriculture, biological control, and plant extracts, particularly essential oils and bioactive compounds such as carvone as sustainable alternatives to synthetic sprout suppressants, addressing current gaps in eco-friendly post-harvest technologies.

1. Introduction

Postharvest sprouting is one of the main obstacles in maintaining the quality and shelf life of agricultural products postharvest. Various agricultural commodities, including potatoes, onions, shallots, garlic, sweet potatoes, and ginger, are highly susceptible to sprouting during postharvest storage. The losses caused by postharvest sprouting of potatoes include water loss, immobilization of carbohydrates and proteins, and tuber shrinkage, resulting in a decline in quality and shelf life [1], [2]. Sprouting is a physiological change that occurs during storage [3]. Sprouting in agricultural commodities occurs after the end of the dormancy period. Dormancy is a period of growth cessation that occurs in agricultural commodities after harvest [1]. Dormancy is characterized by almost no metabolic activity and/or no further development and growth occurring in seeds, tubers, rhizomes, buds, and whole plants [4]. Hormonal and environmental regulation are two factors that greatly influence dormancy in seeds and tubers [5]. Abscisic acid, methyl jasmonate, and ethylene are growth inhibitors, while auxin, gibberellin, cytokinin, salicylic acid, brassinosteroid, and ACC deamylase are growth promoters in plants [6]. Abscisic acid (ABA) is the main hormone responsible for maintaining seed dormancy, inhibiting germination by increasing metabolic inactivity and drought tolerance [7]–[9]. Furthermore, the hormone gibberellin (GA) breaks dormancy and promotes germination by facilitating endosperm degradation and radicle emergence [10].

Various sprout inhibitors have been developed to inhibit sprouting both chemically and naturally in agricultural products. The compound Chlorpropham (isopropyl N-(3-chlorophenyl) carbamate; CIPC) has been the main sprout inhibitor used in potatoes for more than 40 years [11], but its use in the European Union was discontinued after the 2019–2020 storage season due to health and environmental risks. As an alternative, various natural sprout inhibitors have begun to be developed, which are generally applied to potatoes in the form of essential oils. Among the essential oils that have been developed as sprout inhibitors are peppermint, caraway, coriander, eucalyptus (Mentha spicata L.) [12], lemongrass, and clove oils [1]. However, experimental studies discussing sprout inhibition with natural compounds have not been extensively analyzed bibliometrically to systematically map global research trends in this field.

Bibliometric analysis is a systematic research method employed to review literature efficiently [13]. This approach facilitates the identification of data patterns, maps current research trends, and predicts future research directions [13], [14]. By providing a comprehensive overview of a field's structural development, bibliometrics has become an increasingly vital tool for establishing robust research frameworks [13], [15]. This study aims to provide a comprehensive bibliometric review of global research on postharvest sprout inhibition. By systematically assessing publication trends and identifying the most influential authors, countries, and journals, the review maps the scientific structure of the field. Furthermore, the analysis of keyword networks and scientific collaborations serves to clarify research trajectories and identify existing research gaps. Ultimately, these findings offer strategic recommendations for advancing innovation and sustainable practices in postharvest sprout inhibition.

2. Method

2.1. Data Collection

The study employs a quantitative bibliometric approach to analyze global advancements in postharvest sprout inhibition research across various agricultural commodities. Bibliometric analysis was conducted to delineate publication trends, scientific collaborations, dominant keywords, and the evolution of research themes. The methodology was selected for its capacity to objectively map the intellectual landscape using data from internationally indexed scientific publications, thereby providing a robust foundation for identifying future research trajectories.

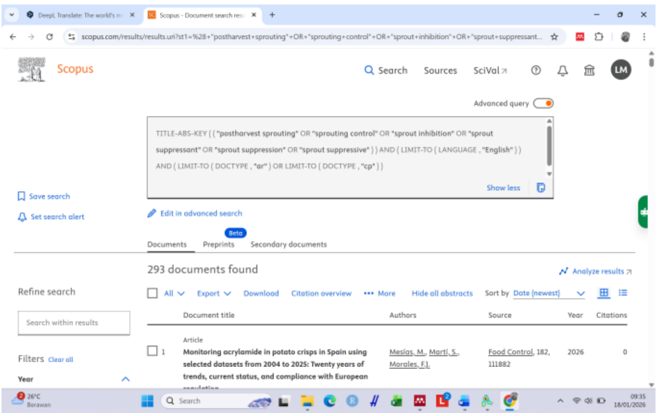

Figure 1. Data retrieval results from the Scopus database, restricted to English language publications and categorized as research articles or conference proceedings.

Bibliographic data was collected through the Scopus database because it has a wide and credible coverage of the scientific literature for quantitative analysis. The data collection process was carried out on Januari 18, 2026, using a combination of keywords: ("postharvest sprouting" OR "sprouting control" OR "sprout inhibition" OR "sprout suppressant" OR "sprout suppressant" OR "sprout suppression" OR "sprout suppressive"). All metadata (title, abstract, author, affiliation, keywords, and citations) was stored in CSV format for further analysis. The results of the data search through the Scopus database were shown in Figure 1. Furthermore, the research data used in this study were limited to journals in English from the results of the research, namely from articles and scientific proceedings, as seen in Figure 1.

2.2. Bibliometric analysis using VOSViewer

Bibliometric analysis was conducted using VOSviewer software (version 1.6.20). VOSviewer was used to construct and visualize maps of collaboration networks between authors, between countries, and keyword co-occurrence. The results of the analysis were visualized in the form of graphs, network maps, and summary tables to illustrate the dynamics of the research. The results were interpreted descriptively by highlighting the growth phase of the research, dominant topics, and open research opportunities. All results were presented to provide a comprehensive understanding of the direction of research development on shoot inhibition in agricultural commodities.

3. Results and Discussion

3.1. Annual Trend of Publication

The **bibliographic extraction** was performed via the Scopus database (https://www.scopus.com/) utilizing the following Boolean search string: (“postharvest sprouting” OR “sprouting control” OR “sprout inhibition” OR “sprout suppression” OR “sprout suppressive”). Regardless of year, language, source, or document type, this search yielded 348 scientific publications, as shown in Table 1. The search results show that scientific publications related to postharvest sprout inhibition have been published from 1945 to 2026 and consist of articles, reviews, conference papers, book chapters and short survey, as shown in Table 1.

Table 1. Bibliographic Extraction in Postharvest Sprout Inhibition

Type of publications	(1945 – 2026)		(2016 – 2026)	
	Number	Percentage	Number	Percentage
Article	294 (275)	84.48 (79,02)	79	76.70
Review	20	5.75	9	8.74
Confrence Paper	18 (18)	5.17 (5,17)	4	3.88
Book Chapter	15	4.31	10	9.71
Short Survey	1	0.29	1	0.97
Total	348 (293)	100 (84,12)	103	100

Of the total Scopus-indexed research output, original publications comprising 294 articles and 18 conference papers account for 89.66% of the total records. For this study, a specific subset of 275 articles and 18 conference papers, published in English between 1945 and 2026, is selected. This selection represents 84.12% of the total output and is chosen to ensure a focus on accessible, peer-reviewed English language data The study deliberately excludes publications from the most recent decade (2016–2026). This exclusion involves 79 articles and 4 conference papers, which together represent approximately 23.85% of the Scopus-indexed research related to postharvest sprout inhibition. This decision is made to focus the analysis on established research trends and foundational data rather than emerging or fragmented recent outputs.

Figure 2 illustrates the longitudinal growth in scholarly output and citation impact for 293 scientific publications spanning the period from 1945 to 2026. The data reveals a distinct evolutionary trajectory in sprout inhibition research, which is currently transitioning from a prolonged period of scientific latency to a phase of exponential expansion, particularly regarding citation density.

Figure 2 illustrates the comparative trajectory between the number of publications and citation impact, revealing a pronounced disparity in scale. While the number of articles grows incrementally, reaching a peak of 14 documents, the citation counts surges significantly, reaching 367 in 2024. This pattern indicates that despite the relatively modest volume of literature produced, each publication exerts a substantial intellectual impact and serves as a critical reference for the scientific community, particularly in addressing global post-harvest industry challenges. This phenomenon confirms that the field of shoot inhibition is in a phase of highly active and relevant research, where the dissemination of knowledge and the recognition of new findings outpace the actual rate of article production.

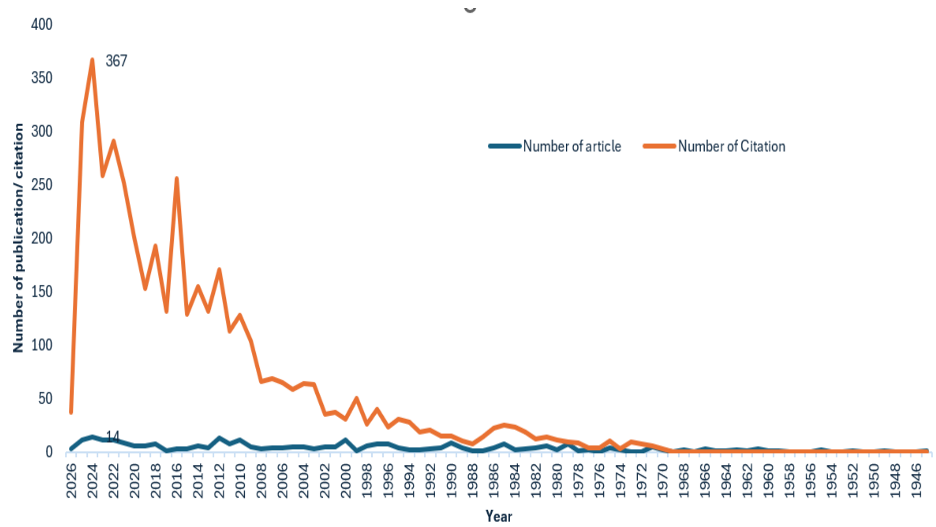

Figure 2. Level of development of research in postharvest sprout inhibition

3.2. Mapping of Author Keywords

In scientific literature, the main focus of an article is represented through the use of keywords that serve as essential instruments to make it easier for readers to map and understand the substance of the research quickly and accurately [16], [17]. A method considered to have a high degree of precision in bibliometric studies is through the visualization of keyword clusters extracted directly from the author's chosen terminology using VOSviewer software [17].

Table 2. Most highly occuring author keywords in postharvest sprout inhibition

	Keywords	Cluster	Occurence	Total Link strength	Link
1.	sprout inhibition	5	40	87	33
2.	potato	29	32	73	29
3.	sprouting	3	26	39	26
4.	storage	2	24	48	30
5.	solanum tuberosum	4	22	30	15
6.	chlorpropham	2	19	41	20
7.	sprout suppression	7	18	38	22
8.	cipc	4	11	30	16
9.	sprout suppressant	3	10	16	13
10.	essential oils	7	9	27	13

Keyword analysis using VOSviewer includes three types of visualizations, each of which provides a different perspective: Network visualization is used to map the interrelationships between keywords in color clusters that indicate the main topic structure; Overlay visualization provides a time dimension by displaying colors based on the average year of publication to identify the latest trends or research novelty; and Density visualization visualizes the level of research saturation through light gradation, where bright areas indicate established topics and dark areas indicate potential research gaps to be explored.

The software (VOSviewer) analyzes the 60 most frequently occurring author keywords from a total of 654 terms, using a minimum threshold of three occurrences per keyword, where each circle represents a keyword and its size indicates its frequency (Salgado-Cruz et al. 2021). The Network Visualization analysis in Figure 3 reveals that postharvest sprout inhibition research is divided into eight distinct thematic clusters. The purple and yellow clusters focus on plant physiology and economic impact, where the connection between the keywords "potato," "sprout inhibition," and "weight loss" indicates that primary research centers on reducing tuber weight loss during storage to maintain "processing quality." Meanwhile, the green cluster, dominated by "chlorpropham" (CIPC) and "storage," highlights a historical dependence on chemical methods that is currently shifting toward the red, orange, and blue clusters which explore more natural solutions such as "essential oil," "carvone," "abscisic acid," "organic agriculture," "ethylene," and "1-MCP." Finally, the emergence of the turquoise cluster linking "food irradiation," "onion," "dormancy," and "antioxidants" signifies the development of alternative technologies to maintain dormancy and antioxidant levels in tubers through irradiation technology.

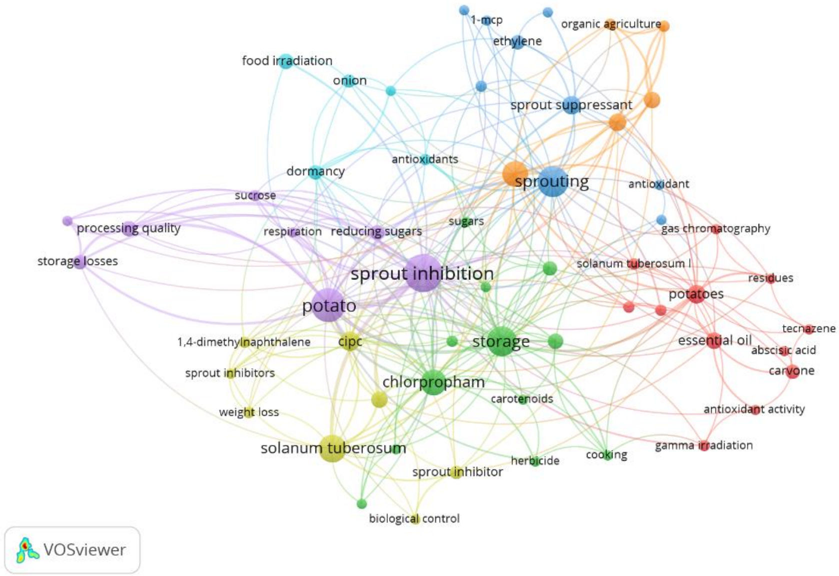

Figure 3. Network visualization of author keywords in postharvest sprout inhibition

The details of the distribution of the strength of relationships between topics are specifically documented in Table 2. The dominance of topics in this research network is clearly reflected in the frequency of author keywords, where "sprout inhibition" ranks highest with 40 occurrences and a total link strength of 87. This is consistent with the large number of nodes in the purple cluster, which confirms the position of sprout inhibition as a central variable connecting various storage techniques. Although research trends are shifting towards natural alternatives, dependence on conventional methods is still represented by the high frequency of the keywords "storage" (24 occurrences) and "chlorpropham" (19 occurrences) in the green cluster. On the other hand, the emergence of "essential oils" and "sprout suppression" with significant total link strength, 27 and 38, respectively, reinforces the growth of research interest in the red and orange clusters as sustainable solutions for the future.

After mapping the strength of relationships between topics through Network Visualization, further analysis is conducted using Overlay Visualization to examine the temporal dimension of this research. Based on the results of the Overlay Visualization analysis in Figure 4, there was a significant shift in research trends from the use of conventional chemical methods such as chlorpropham, which dominated in the early period (blue purple), to the exploration of more modern natural solutions. Keywords such as "essential oil," "organic agriculture," and "ethylene," which appear in shades of yellow, indicate that these topics are the latest research trends (around 2020) focusing on sustainability and food security in the future.

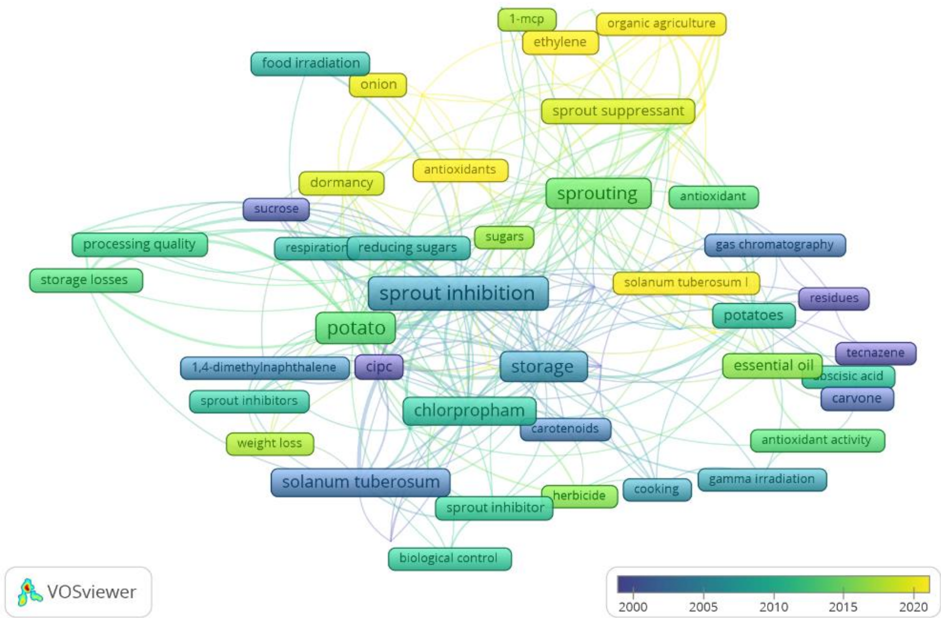

Figure 4. Overlay visualization of author keywords in postharvest sprout inhibition

Complementing this chronological dimension, Density Visualization analysis provides an additional perspective on the level of research saturation through the intensity of color in each keyword area (Figure 5). Areas with very bright and dense yellow light, such as the keywords "sprout inhibition," "potato," and "storage," indicate that these topics are well established and have been the main focus of researchers. Conversely, areas with dimmer or darker colors indicate research gaps or opportunities that are still wide open, particularly in the development of specific technologies such as essential oils, abscisic acid, carvone, organic agriculture, 1-MCP, and ethylene, which have only begun to emerge in recent years.

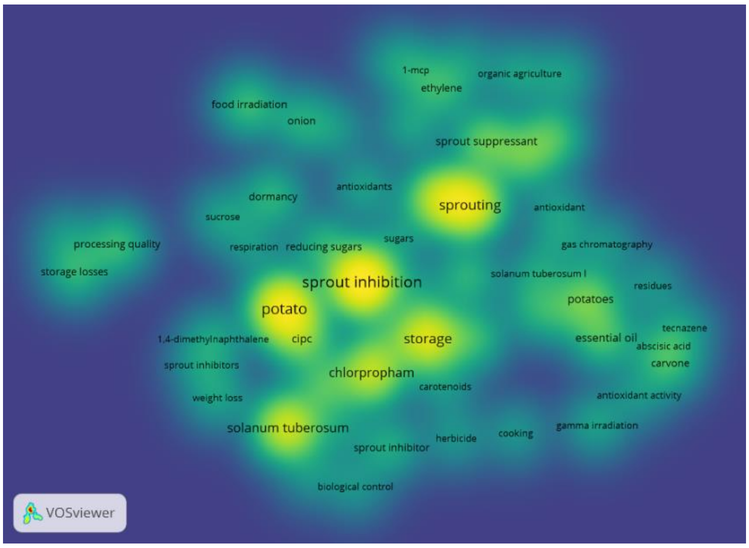

Figure 5. Overlay visualization of author's keywords in postharvest sprout inhibition

3.3. Most Influential Publications

A citation count estimates the influence of a publication or author by measuring the total number of times other publications mention them (Abdelwahab et al. 2023). Table 3 showed 10 influential publications out of 293 publications related to postharvest sprout inhibition. The citation range of the 10 publications was 67 to 205 of the 10 most influential publications.

Table 3. Most influential publications on postharvest sprout inhibition research

Rank	Title of Articles	Years	Total Citation	Ref.
1.	*Status of food irradiation in the world*	2009	205	Kume (2009)
2.	*The use of carvone in agriculture: sprout suppression of potatoes and antifungal activity against potato tuber and other plant diseases*	1995	153	Hartmans (1995)
3.	*Grain dormancy and light quality effects on germination in the model grass Brachypodium distachyon*	2012	97	Barrero (2012)
4.	*Studies on essential oils, part 42: Chemical, antifungal, antioxidant and sprout suppressant studies on ginger essential oil and its oleoresin*	2005	90	Singh (2005)
5.	*Volatile monoterpenes inhibit potato tuber sprouting*	1991	82	Vaughn (1991)
6.	*Studies on essential oils, Part 41. Chemical composition, antifungal, antioxidant and sprout suppressant activities of coriander (Coriandrum sativum) essential oils and its oleoresin*	2006	81	Singh (2006)
7.	*High-Performance Liquid Chromatography Determination of Phenolic Acids in Potato Tubers (Solanum Tuberosum) During Wound Healing*	1992	81	Ramamurthy (1992)
8.	*Effects of aromatic plants on potato storage: sprout suppression and antimicrobial activity*	1993	75	Vokou (1993)
9.	*Effects of essential oils on sprout suppression and quality of potato cultivars*	2013	68	Gómez (2013)
10.	*Physiological, biochemical and transcriptional analysis of onion bulbs during storage*	2012	67	Chope (2012)

The intellectual strength of the postharvest sprout inhibition research network is dominated by ten influential publications published between 1991 and 2013, with a primary focus on the effectiveness of natural materials and physical technologies. The article by Kume (2009) is the most cited reference with 205 citations, confirming the importance of food irradiation technology on a global scale. In addition, the high influence of research on essential oils and organic compounds such as carvone and monoterpenes (e.g., Hartmans (1995) with 153 citations, Sing (2005) with 90 citations, Sing (2006) with 81 citations, Vaughn (1991) with 82 citations, Vokou (1993) with 75 citations, and Gomez (2013) with 68 citations) proves that the theoretical basis for the transition from synthetic chemistry to natural solutions has been established for a long time and remains relevant today. The integration of these classic publications with the latest trends in 2020 shows the continuity of research focused on the sustainable optimization of tuber storage quality.

3.4. Most Influential Authors

The most influential author in scientific publications can be seen from the number of publications produced. Out of 766 authors, 10 authors encountered the supplies taking at least 6 publications (Table 3). Productivity and academic influence in the literature on post-harvest sprout inhibition are dominated by ten leading authors who have made significant contributions to the development of this field. Terry, Leon Alexander ranks highest as the most influential author with a total of 13 documents and 320 citations, followed by Thomas, Paul R., with 12 documents and 285 citations. The high number of citations obtained by these researchers, such as Cools, Katherine (234 citations) and Chope, Gemma A. (233 citations), shows that their work has become an important reference for other researchers in understanding storage mechanisms and sprout suppression technology. Overall, the identification of the 10 most influential authors out of a total of 766 authors confirms the existence of a core group of experts who consistently steer global research towards more effective post-harvest innovations.

Table 4. Most influential author in postharvest sprout inhibition

No.	Author	Publications	Citations
1	Terry, leon alexander	13	320
2	Thomas, paul r.	12	285
3	Cools, katherine	8	234
4	Chope, gemma a.	9	233
5	Daniels-lake, barbara j.	7	191
6	Prange, robert k.	6	181
7	Thompson, andrew j.	5	156
8	Duncan, henry j.	9	107
9	Dalziel, john	7	99
10	Singh, brajesh p.	9	82

3.5. Most Influential Sources

Based on the data in Table 4, of the 122 journals that published on postharvest sprout inhibition research, there was a very strong concentration of literature on potatoes, with "Potato Research" as the most influential source, with 43 documents and 556 citations. This dominance is reinforced by significant contributions from other specific journals such as "American Potato Journal" (250 citations) and "American Journal of Potato Research" (268 citations), which collectively confirm the scientific community's primary focus on optimizing the post-harvest of this tuber. Although there is diversity in sources from multidisciplinary fields such as "Radiation Physics and Chemistry" (302 citations) and "Postharvest Biology and Technology" (297 citations), the presence of potato-specific journals in the top ten list proves that the theoretical basis of postharvest sprout inhibition research still relies heavily on publications specializing in this commodity to ensure high visibility and impact of the research.

Table 5. Most influential sources on postharvest sprout inhibition

	Souces	Publications	Citations
1.	Potato research	43	556
2.	American potato journal	19	250
3.	Acta horticulturae	16	71
4.	Radiation physics and chemistry	16	302
5.	American journal of potato research	11	268
6.	Postharvest biology and technology	10	297
7.	Journal of agricultural and food chemistry	8	210
8.	Journal of the science of food and agriculture	8	108
9.	Journal of food science and technology	7	87
10.	Potato journal	7	30

3.6. Most Influential Country and International Collaboration

The number of countries participating in postharvest sprout inhibition research reached 49. Table 5 shows the most influetial country in terms of postharvest sprout inhibition related publications and citations. The country that produced the most publications was the United States, followed by the United Kingdom, India, Canada, China, Japan, Brazil, the Netherlands, Italy, and South Africa. The United States is the country whose publications related to postharvest sprout inhibition are most cited, accounting for 26.58% of total citations. Furthermore, the countries that produce the most publications are also led by the United States, followed by India, the United Kingdom, Canada, Japan, the Netherlands, China, Italy, Brazil, and South Africa.

The United States' dominance in the number of publications and citations related to post-harvest sprout inhibition is rooted in its strategic position as the world's potato economic giant, where this commodity is the main raw material for billion-dollar processing industries such as French fries and potato chips. Because these industries demand strict visual quality standards and low sugar content—which is immediately compromised when sprouts appear and convert starch into sugar—research in the US has focused heavily on manipulating the physiological dormancy of tubers. The pressure has increased with the global ban on conventional chemicals (CIPC), forcing American researchers to lead the way in finding natural alternatives such as essential oils and genetic technology, creating a wave of scientific literature that has become a key reference for researchers around the world.

Table 6. Most influential country in postharvest sprout inhibtion

No.	Country	Publications	Citations
1.	United States	66	1054
2.	United Kingdom	54	753
3.	India	47	804
4.	Canada	18	402
5.	China	13	165
6.	Japan	13	325
7.	Brazil	8	56
8.	Netherlands	8	269
9.	Italy	7	94
10	South africa	7	43

Figure 6. Network visualization of reseacrh collaboration in postharvest sprout inhibition

Furthermore, in terms of collaboration, Figure 5 shows that the United States (US) leads the global network in sprout inhibition research. The size of the circle and its central position confirm the US as the main "hub" of world publications and citations, driven by the needs of the massive potato industry. Close collaboration in the blue and red clusters between the US, Canada, and Australia reflects the synergy of countries with similar processing industry standards, while the dominance of the United Kingdom and the Netherlands in the green cluster indicates a highly progressive European research bloc in seeking organic alternatives following the ban on the chemical CIPC. The emergence of India as a separate cluster signifies the rise of a new research powerhouse from a major Asian producer country, which collectively illustrates the global landscape of competition and cooperation in maintaining post-harvest horticultural quality through technological innovation and compliance with international food regulations.

4. Conclusion

The bibliometric analysis of 293 publications reveals a consistent upward trend in scientific output and citation impact, reaching a significant peak in 2024. This research landscape is fundamentally shaped by the United States and the United Kingdom, alongside influential contributors such as Terry, L.A. and the journal *Status of Food Irradiation in the World*. While keyword analysis confirms that "sprout inhibition," "potato," and "storage" remain the core research clusters, "chlorpropham" serves as the critical nexus linking dormancy management to postharvest quality.

Overall, the field is undergoing a transformative shift from a reliance on synthetic chemical suppressants toward more sustainable, bio-based solutions. While foundational topics are well-established, significant research gaps remain. Future inquiries should prioritize emerging areas such as organic agriculture, biological control, and plant extracts—specifically essential oils and bioactive compounds like carvone. Integrating these eco-friendly technologies across a broader range of tuber crops is essential to ensure food safety and support global food security in an increasingly regulated agricultural environment.

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