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# Knowledge Mapping and Global Research Trends of Ginseng Polysaccharides: a Bibliometric Analysis with Visualizations from 1985 to 2023

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**Background:** *Panax ginseng* C. A. Meyer (Ginseng) has a lengthy historical background of utilization and is frequently utilized for the treatment and prevention of various diseases. In recent times, researchers have shown an increasing inclination towards investigating the extraction, purification, structural analysis, and pharmacological properties of polysaccharides present in ginseng. However, there was still a lack of comprehensive and integrated analysis of ginseng polysaccharides.

**Methods:** This study employed the Web of Science Core Collection (WoSCC) as the data source and utilized software tools including Bibliometrix R Package, VOSviewer, and CiteSpace for the purpose of conducting data visualization and analysis of ginseng polysaccharides publications.

**Results:** China emerged as the foremost and most impactful nation in the realm of ginseng polysaccharide research, fostering robust collaborative ties with Republic of Korea and the USA. Yifa Zhou was the most influential author and the International Journal of Biological Macromolecules exerted as the significant influence in this field. The reference DUBOIS M, 1956, ANAL CHEM, V28, P350 received the highest citations. Through a comprehensive examination results of keywords clustering, keywords with the strong burst, and trend topic, the research hot directions of ginseng polysaccharides were focused on structural analysis and pharmacological activities. Specifically, gut microbiota and oxidative stress were active research hotspots of investigating the pharmacological activities of ginseng polysaccharides at present, it also was corroborated in disciplinary category analysis.

**Conclusion:** This study revealed the multidimensional field of research on ginseng polysaccharides. Current hot research directions encompassed structural analysis and pharmacological activities in this field, with research hotspots focused on exploring the pharmacological activities of ginseng polysaccharides in gut microbiota and oxidative stress.

**Keywords:** ginseng polysaccharides, bibliometrics, visualization, gut microbiota, oxidative stress

## Introduction

*Panax ginseng* C. A. Meyer (Ginseng), a perennial herbaceous plant from oriental countries, belongs to the Araliaceae family.[1] It possesses a rich historical background of utilization in the treatment and prevention of various diseases.[2,3] Initially, the effectiveness of ginseng was attributed to Traditional Chinese Medicine Theories. However, with the development of modern scientific technologies, scholars have been extensively investigating the structure of chemical composition and pharmacological mechanism of action of this plant. Ginseng comprises a diverse range of compounds, encompassing ginsenosides, polysaccharides, volatile oils, fatty acids, and phenolic compounds.[2,4,5] Although scholars have predominantly directed their attention towards the low molecular weight constituents, such as ginsenosides, over the past few decades, still cannot satisfactorily explain the mystery of ginseng's medicinal effects.





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At present, polysaccharides as biological response modifiers have been increasingly emphasized by scholars for their multiple biological activities in health food or medicine.[6,7] Extensive studies are being conducted on the purification and structural analysis of ginseng polysaccharides.[8–11] Furthermore, modern research has revealed that ginseng polysaccharides exhibit diverse pharmacological activities.[12–18] As a class of large molecules with abundant pharmacological activities, research on polysaccharide components has become a recent trend in ginseng. However, the existing studies still failed to provide a comprehensive and integrated analysis of ginseng polysaccharides, particularly in terms of identifying research hotspots and future research trends.

Bibliometrics is an emerging research field in information science, providing multidimensional analytical capabilities beyond traditional literature reviews. Bibliometrics utilizes visual analysis of publication and citation counts of countries, institutions, journals, and authors to understand the knowledge structure within specific domains. Additionally, it serves to identify research hotspots and forecast future research trends through the analysis of references and author keywords.[19,20] This discipline has gained extensive utilization within the domains of medicine and pharmacy.[21–23] Given the growing volume of research on ginseng polysaccharides, there is a pressing need to systematically map the existing literature to identify key contributions, emerging trends, and potential areas for future investigation in this field. Bibliometrics establishes a robust framework for the domain of ginseng polysaccharides by generating quantitative visualizations of the research landscape.

Consequently, this study uses bibliometric analysis and visualization techniques to map knowledge, identify current research hotspots, and explore emerging frontiers in ginseng polysaccharides research since 1985. By doing so, it aims to fill the gap in the existing literature and provide a valuable resource for researchers interested in the development and application of ginseng polysaccharides.

# Materials and Methods

## Data Sources and Searching Strategy

For this study, the Web of Science Core Collection (WOSCC) was selected as the data source due to its comprehensive coverage of high-quality peer-reviewed publications in natural sciences and its widespread adoption in bibliometric analyses.[24] Specifically, the literature search was conducted for the period from January 1, 1985, to July 9, 2023, using the "Advanced Search" mode with the following keywords: TS = (Ginseng or Panax ginseng or Renshen) AND TS = (Polysaccharide or Polysaccharides). The search results were then limited to: the type of literature "articles" or "reviews" and the language "English". A dataset was obtained as the final output. To ensure data integrity, the "full record and cited reference" option was selected for download, and the output was provided in text format for subsequent analysis. Figure 1 showed the flowchart of the literature search. Data collection was completed within a single day on 9 July, 2023. Subsequently, to enrich the research scope and explore deeper interdisciplinary connections, datasets for 10 discipline categories were downloaded using the same method. To ensure the accuracy of the research data, two authors (MPL and GBW) independently collected data using established search strategies, systematically recording information such as article titles, publication years, and abstracts. The consistency between the results was 0.90, indicating a high level of agreement in the data collection process.[25] The team would discuss and resolve divergent viewpoints.

## Bibliometrics Analysis and Data Visualization

The analysis of the number of publications and citations per year in the dataset was conducted using Microsoft Excel 2019 (Microsoft, Redmond, Washington, USA),[26] based on the Citation Report of the WOSCC dataset. Among these, pie charts were created based on discipline categorization of publications. For the primary analysis, established bibliometric software were employed, including the Bibliometrix R Package, VOSviewer, and CiteSpace, which have been widely validated for mapping scientific domains. Specifically, the Bibliometrix R Package version 4.3.1[27] was utilized to analyze the number of publications and citations, evaluate core journals, H-indexes, trend topics, and other relevant metrics. Additionally, a world map was created to visually display the geographic distribution of the publications. The analysis of publications for network visualization, overlay visualization, and density visualization in co-authorship networks, journals, and reference co-citation was conducted using VOSviewer version 1.6.19 (Leiden University, Leiden, The

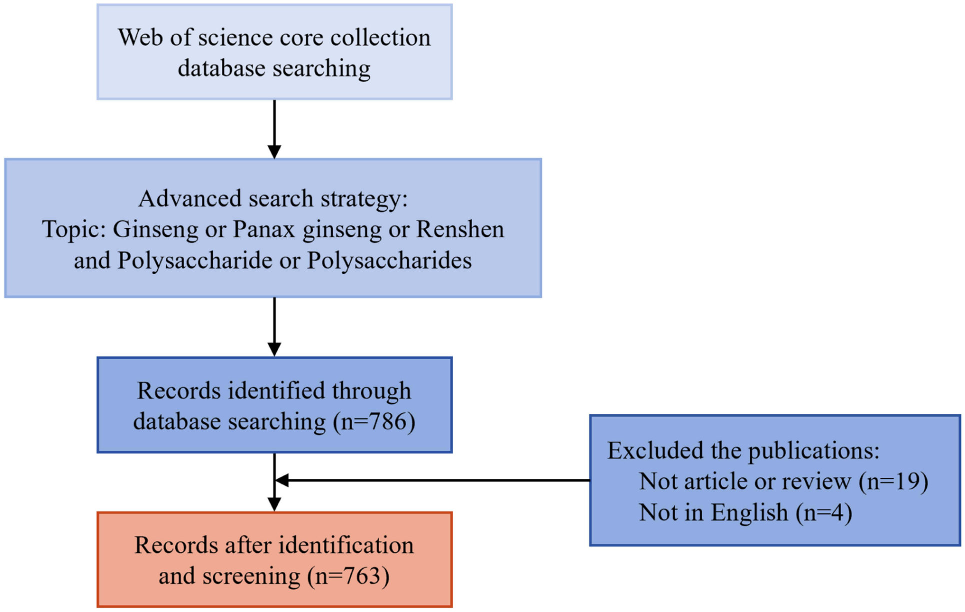


**Figure 1** Flowchart of the literature search process in the study.

Netherlands).[28,29] The analysis of dual-map overlay of journals, reference and author keywords with the strongest bursts and clustering was performed using CiteSpace version 6.2.R3 (Drexel University, Philadelphia, PA, USA).[30,31] Before proceeding with further bibliometric analysis, the thesaurus data were merged.

# Results

## Search results and Study Selection Process

Based on our team's previous research into ginseng and polysaccharide components, we observed a growing scientific interest in ginseng polysaccharides. To provide a reference for future research, we conducted a bibliometric analysis of this field. A comprehensive search of the WOSCC database yielded 786 publications related to ginseng polysaccharides. After excluding 19 non-article and non-review publications and 4 non-English language studies, a final set of 763 publications were retained for analysis. The dataset was systematically evaluated through multiple dimensions: trend in publications and citations, country and institutional co-authorship analysis, authors co-authorship analysis, journal contribution, reference co-citation analysis, keywords and trend topic, and disciplinary category.

## Trend in Publications and Citations

A comprehensive search was conducted in the WOSCC database, encompassing a total of 763 publications spanning from 1 January 1985 to 9 July 2023. Among these publications, 671 (87.94%) were articles, while 92 (12.06%) were reviews. The cumulative number of citations amounted to 21,072, resulting in an average of 27.62 citations per publication. Figure 2 illustrated the variation in the number of publications and citations over the years, showing a consistent growth trend for both. Regarding the publications, there was a period of stability from 2010 to 2018, followed by a rapid increase starting from 2019, and reached its peak in 2022 (n = 73). Similarly, it is evident that the citations reached its highest point in 2022 (n = 3135). A model describing the growth trend of publications was established based on the data ($y = 0.0657x^2 + 0.0559x + 3.868$, $R^2 = 0.9093$, x-axis represented the year and y-axis the number of publications per year).

## Country and Institutional Co-Authorship Analysis

A total of 717 institutions from 52 countries contributed to this field. Table 1 provided an overview of the top ten countries that actively participated in this research endeavor.

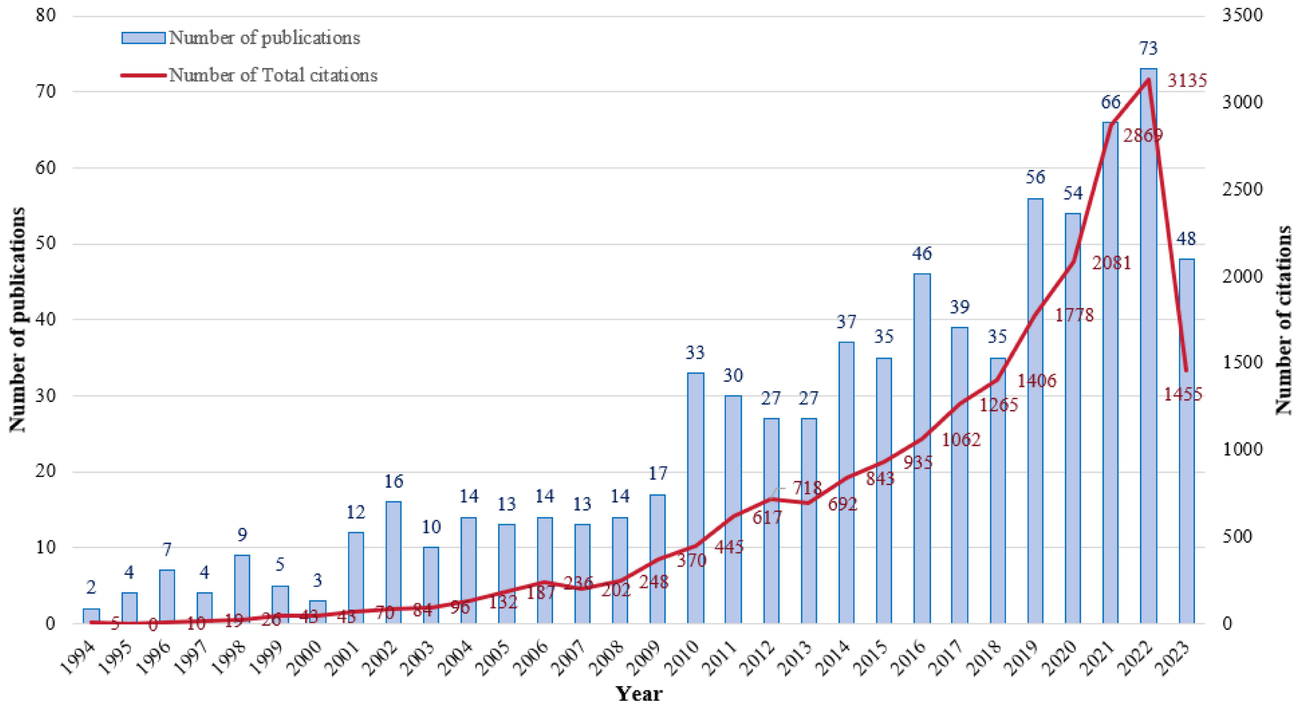


**Figure 2** The annual number of publications and citations.

It was worth highlighting that China emerged as the foremost nation in terms of publications (439 publications, 57.54%), ranked by Republic of Korea (223 publications, 29.23%) and the USA (45 publications, 5.90%). Moreover, China surpassed the combined publication output of the other top 9 countries. The global distribution of research on ginseng polysaccharides, along with the collaboration network among multiple countries was visually represented in Figures 3A and B. These findings suggested that China held the core position in terms of output and influence in this field. Furthermore, China exhibited robust network connections with Republic of Korea and the USA, as substantiated by the substantial width of the connecting lines between nations. Moreover, Figure 3B depicted the collaboration and average publication year overlap among countries, indicating a growing involvement of countries, such as Malaysia and the Netherlands, in ginseng polysaccharide research in recent years.

Similarly, Figure 3C presented an overlay visualization network depicting the level of mutual collaboration and average publication years among various institutions. The figure highlighted a low network density among these institutions, suggesting a limited degree of collaboration between them. Table 2 presented the data concerning the top 10 institutions that demonstrated the highest level of collaboration. Northeast Normal University (Changchun,

**Table 1** The Top 10 Most Productive Countries in the Publications and Citations

| Country | Documents | Citations | Total Link Strength |
|---|---|---|---|
| China | 439 | 11,385 | 66 |
| Republic of Korea | 223 | 6902 | 52 |
| the USA | 45 | 1351 | 38 |
| Canada | 34 | 1032 | 13 |
| India | 19 | 537 | 12 |
| Japan | 16 | 324 | 5 |
| Russia | 9 | 155 | 5 |
| Australia | 7 | 79 | 7 |
| Italy | 7 | 132 | 4 |
| Netherlands | 6 | 180 | 5 |

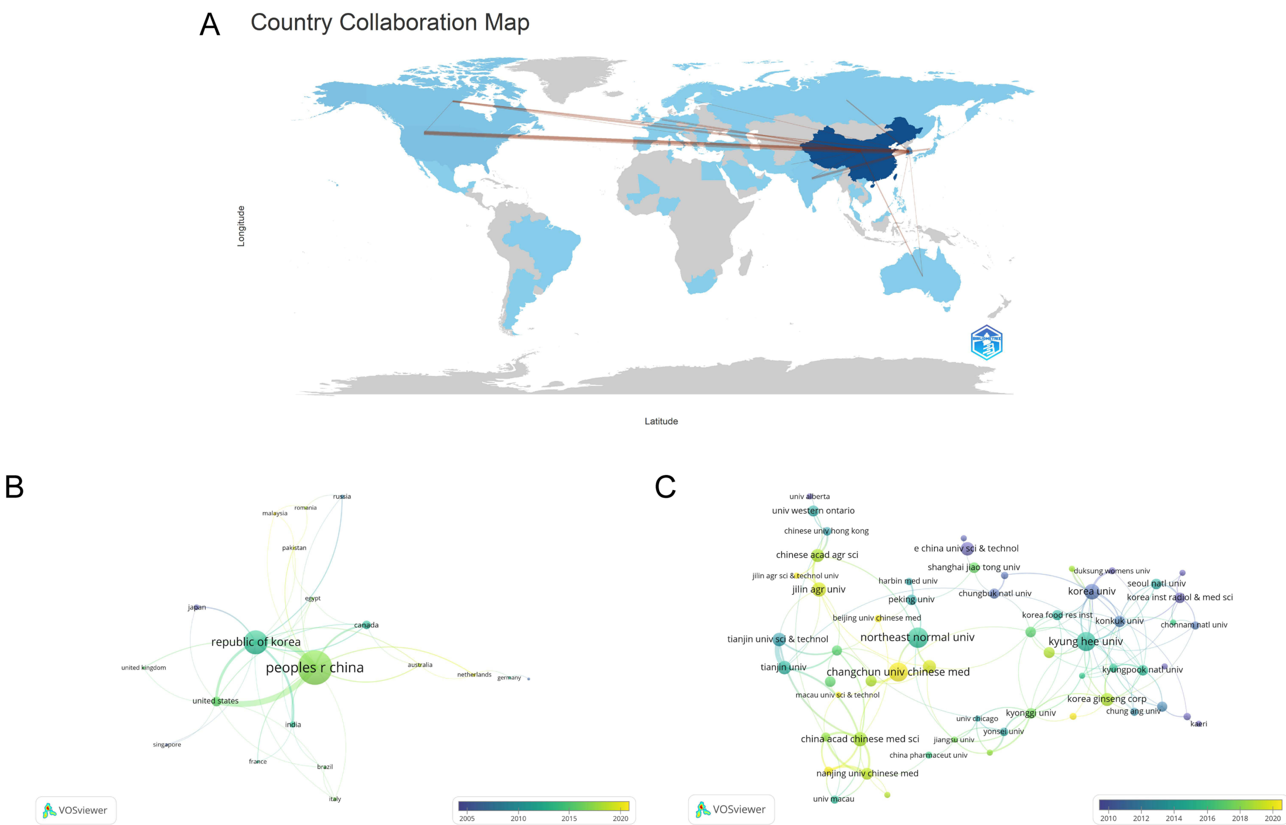


**Figure 3** The bibliometric analysis of countries/institutions output. (**A**) The collaboration map among countries, wherein the intensity of color is proportional to the number of publications in each country and the thickness of the connecting lines indicates the intensity of cooperation. (**B**) The co-authorship network among countries, wherein the circles' size and color denote outputs and the average publication year. (**C**) The co-authorship network among institutions, wherein the circles' size and color represent outputs and the average publication year.

China) led the pack (n = 43), closely followed by Kyung Hee University (Seoul, Republic of Korea) (n = 39). Similarly, Northeast Normal University attained the highest citations totaling 1525 citations, whereas Kyung Hee University (Seoul, Republic of Korea) ranked second with 1151 citations.

**Table 2** The Top 10 Most Collaborative Institutions

| Institution | Documents | Citations | Country | City/Region | Total collaborative strength |
|---|---|---|---|---|---|
| China Academy of Chinese Medical Sciences | 22 | 569 | China | Beijing | 36 |
| Tianjin University | 20 | 231 | China | Tianjin | 29 |
| Tianjin University of Science and Technology | 20 | 254 | China | Tianjin | 28 |
| Kyung Hee University | 39 | 1151 | Republic of Korea | Seoul | 27 |
| Korea University | 26 | 699 | Republic of Korea | Seoul | 25 |
| Nanjing University Of Chinese Medicine | 16 | 382 | China | Nanjing | 23 |
| Kyonggi University | 13 | 317 | Republic of Korea | Suwon | 21 |
| Changchun University of Chinese Medicine | 38 | 634 | China | Changchun | 19 |
| Hong Kong Baptist University | 10 | 318 | China | Hong Kong | 19 |
| Jiangsu Provincial Academy Traditional Chinese Medicine | 9 | 170 | China | Nanjing | 18 |

## Authors Co-Authorship Analysis

A cumulative count of 2835 authors contributed to the publication of articles focusing on ginseng polysaccharides. Figure 4A was utilized to establish a network comprising authors who published more than 3 publications, resulting in the inclusion of 135 authors. Notably, Yifa Zhou from Northeast Normal University (Changchun, China) emerged as the most productive, highly cited, and extensively collaborative author, having published a total of 33 publications and receiving 1450 citations, with a collaboration intensity of 128. Jianjiang Zhong from East China University of Science and Technology (Shanghai, China) hold the second highest publications, amounting to 20 and Guihua Tai from Northeast Normal University (Changchun, China) exhibited the second highest citations and intensity of collaboration. Notably, Guihua Tai and Yifa Zhou originated from the same scientific team. Furthermore, it could be observed that the collaboration groups formed by each author exhibited a relatively stable and limited scope.

Additionally, Figure 4A presented the average publication year of the authors, revealing that authors with a more recent average publication year had a lower level of collaboration. Moreover, Figure 4B provided a density visualization of authors' outputs, further supporting the aforementioned findings.

## Journal Contribution

A total of 763 publications were sourced from 292 distinct journals. Utilizing Bradford's Law, 14 journals were identified as core journals (Figure 5A and Supplementary Table 1). International Journal of Biological Macromolecules exhibited the highest publications (n = 45), and Carbohydrate Polymers emerged as the most frequently cited journal (citations = 1549). Table 3 presented the top 10 journals that garnered the highest citations. In the co-citation network depicted in Figure 5B, it was evident that International Journal of Biological Macromolecules (publications = 45, citations = 1429, H index = 24), Journal of Ginseng Research (publications = 41, citations = 1461, H index = 20), Carbohydrate Polymers (publications = 31, citations = 1549, H index = 23), etc. had great significant in this field. The dual map coverage of journals provided a visual representation of the important citation connections between citing and cited journals. The labels indicated the disciplines covered by the journal, while the colored paths representing cited relationships. Notably, MOLECULAR, BIOLOGY, GENETICS, ENVIRONMENTAL, TOXICOLOGY, and NUTRITION journals were frequently cited by MOLECULAR, BIOLOGY, IMMUNOLOGY, and VETERINARY, ANIMAL, SCIENCE journals (Figure 5C). The dimensions of the circles corresponded to the quantity of publications and authors within a specific field. A greater length along the vertical axis of an ellipse indicated a higher number of published papers, whereas a greater length along the horizontal axis indicated a larger number of contributing authors.

## Reference Co-Citation Analysis

The dataset encompassed a total of 26,401 co-cited references. Figure 6A portrayed the interconnectedness of citations among the 70 most frequently cited references. Table 4 presented a compilation of the top 10 references that received the highest citations, which were mainly categorized into three groups: methods for polysaccharide content determination,

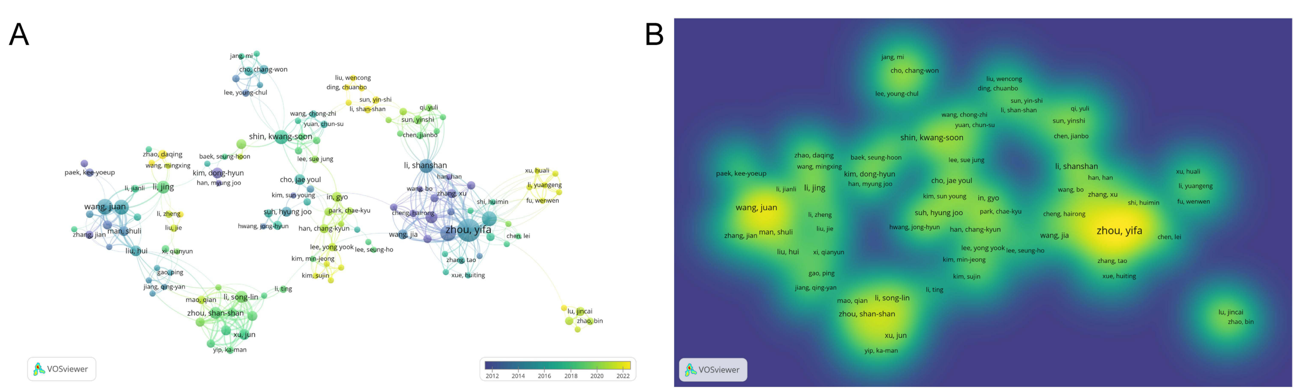


**Figure 4** The bibliometric analysis of authors. (**A**) The co-authorship network among authors in terms of outputs, wherein circle size represents outputs. (**B**) The outputs density visualization of authors, wherein the color depth represents outputs.

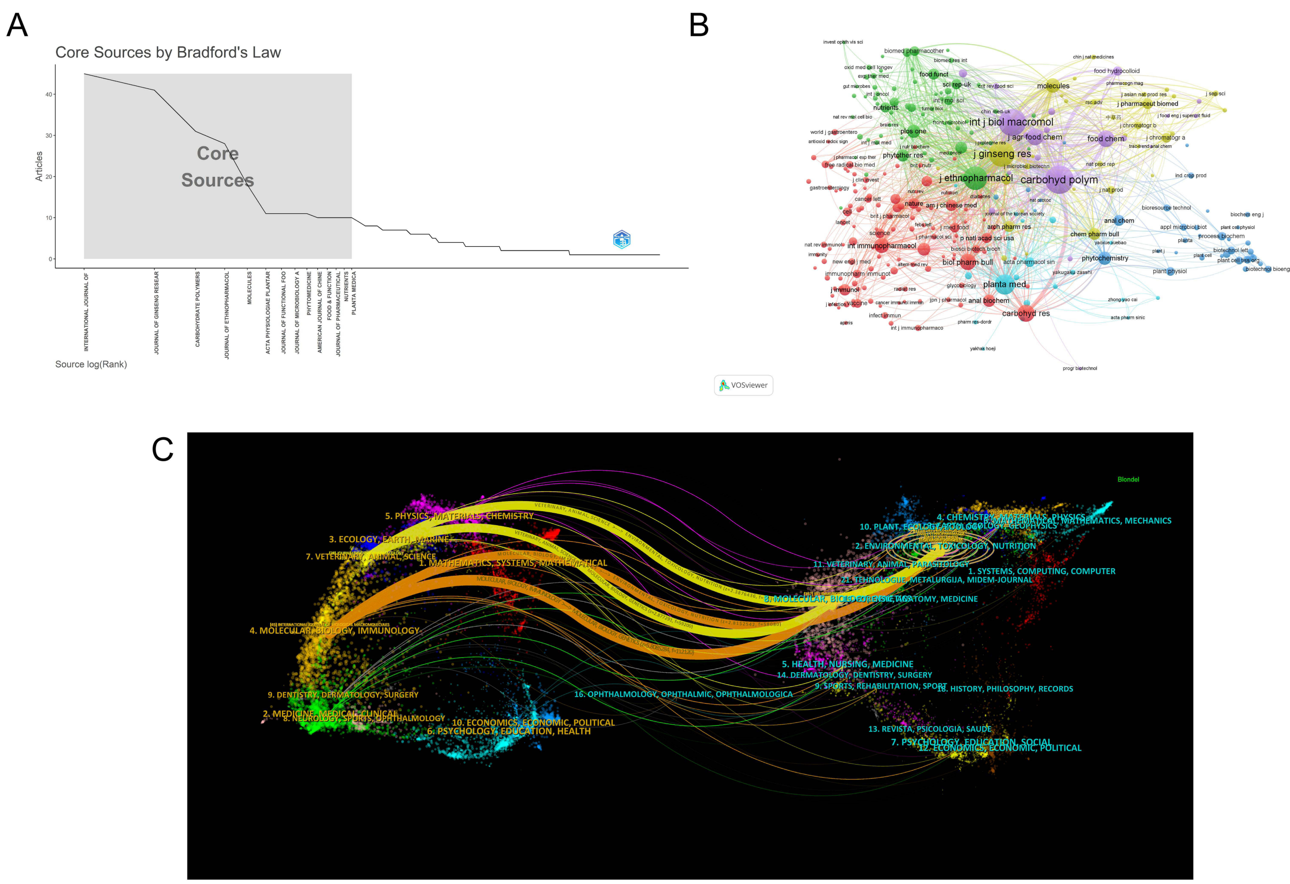


**Figure 5** The bibliometric analysis of journals. (**A**) 14 core journals based on Bradford's Law. (**B**) The co-citation network among journals, wherein the circle size represents citations. (**C**) The dual-map overlay of journals, wherein the colored path represents the cited relationship.

studies on chemical structure and pharmacological activity (particularly in relation to antitumor, immunomodulatory, and antioxidant effects), and reviews on chemical structure and pharmacological activity. DUBOIS M, 1956, ANAL CHEM, V28, P350 garnered the most citations (n = 116).[32] In this research, a phenol-sulfuric acid method was developed, which could be used for the determination of monosaccharides, oligosaccharides, polysaccharides, and their derivatives, including methyl ethers with free or potentially free reducing groups.

Figure 6B visually represented the top 25 references with the strongest citation burst, indicating changes in the citation frequency of these references over time. Six references had strength higher than 9, four of which are also among

**Table 3** The Top 10 Most Influential Journals

| Journals | Country | Documents | Citations | IF (2022) | H-index | ISSN |
|---|---|---|---|---|---|---|
| International Journal of Biological Macromolecules | Netherlands | 45 | 1429 | 8.2 | 24 | 0141–8310 |
| Journal of Ginseng Research | Republic of Korea | 41 | 1461 | 6.3 | 20 | 1226–8453 |
| Carbohydrate Polymers | the UK | 31 | 1549 | 11.2 | 23 | 0144–8617 |
| Journal of Ethnopharmacology | Ireland | 28 | 758 | 5.4 | 15 | 0378–8741 |
| Molecules | Switzerland | 18 | 337 | 4.6 | 10 | 1420–3049 |
| Phytomedicine | Germany | 11 | 249 | 7.9 | 8 | 0944–7113 |
| Journal of Microbiology and Biotechnology | Republic of Korea | 11 | 196 | 2.8 | 7 | 1017–7825 |
| Acta Physiologiae Plantarum | Germany | 11 | 195 | 2.6 | 8 | 0137–5881 |
| Journal of Functional Foods | Netherlands | 11 | 184 | 5.6 | 6 | 1756–4646 |
| Planta Medica | Germany | 10 | 389 | 2.7 | 9 | 0032–0943 |


**Figure 6** The bibliometric analysis of the references. (**A**) The co-citation network among references, wherein the circle size represents citations. (**B**) Top 25 references with the strongest citation bursts.

the top 10 most frequently cited references. ZHANG X, 2009, CARBOHVD POLYM, V77, P544 [33] was found to be the most influential reference with the strongest burst (strength = 12.47) in this field and the second most cited. This article focused on the separation of water-soluble polysaccharides from ginseng roots into two neutral fractions and six acidic fractions. Subsequently, these components underwent characteristic analysis and investigation of biological activities. Specifically, SUN YX, 2011, CARBOHVD POLYM, V85, P490 (strength = 11.52) presented a comprehensive analysis of the chemical composition and biological properties of polysaccharides derived from the leaves, roots, and fruits of Ginseng.[34] GUO MK, 2021, FOOD FUNCT, V12, P494 (strength = 10.46) provided a comprehensive summary of the background, extraction, purification, structural characterization, and bioactivities of polysaccharides derived from various parts and growth conditions of Ginseng, including the root, flower, stem, leaf, and berry.[1] Additionally, result showed that the co-cited references with higher citations predominantly focused on studies and review publications concerning the structure and pharmacological activities of polysaccharides. The reason for this phenomenon was that understanding the structure–function relationship and pharmacological activity of ginseng polysaccharides was crucial for advancing their applications in drug development, functional foods, and traditional medicine.

**Table 4** The Top 10 Co-Cited References

| Cited Reference | Journal | Year | Citations | IF (2022) |
|---|---|---|---|---|
| DUBOIS M, 1956, ANAL CHEM, V28, P350, DOI 10.1021/AC60111a017 | Analytical Chemistry | 1956 | 116 | 7.4 |
| ZHANG X, 2009, CARBOHVD POLYM, V77, P544, DOI 10.1016/J.CARBPOL.2009.01.034 | Carbohydrate Polymers | 2009 | 97 | 11.2 |
| ATTELE AS, 1999, BIOCHEM PHARMACOL, V58, P1685, DOI 10.1016/S0006-2952(99)00212–9 | Biochemical Pharmacology | 1999 | 74 | 5.8 |
| SUN YX, 2011, CARBOHVD POLYM, V85, P490, DOI 10.1016/J.CARBPOL.2011.03.033 | Carbohydrate Polymers | 2011 | 65 | 11.2 |
| BLUMENKR. N, 1973, ANAL BIOCHEM, V54, P484, DOI 10.1016/0003-2697(73)90,377–1 | Analytical Biochemistry | 1973 | 58 | 2.9 |
| LEE YS, 1997, ANTICANCER RES, V17, P323 | Anticancer Research | 1997 | 58 | 2.0 |
| CHOI KT, 2008, ACTA PHARMACOL SIN, V29, P1109, DOI 10.1111/J.1745–7254.2008.00869.X | Acta Pharmacologica Sinica | 2008 | 57 | 8.2 |
| LUO DH, 2008, CARBOHVD POLYM, V72, P36, DOI 10.1016/J.CARBPOL.2007.09.006 | Carbohydrate Polymers | 2008 | 57 | 11.2 |
| WANG J, 2010, J ETHNOPHARMACOL, V130, P421, DOI 10.1016/J.JEP.2010.05.027 | Journal of Ethnopharmacology | 2010 | 55 | 5.4 |
| SHIN JY, 2002, IMMUNOPHARM IMMUNOT, V24, P469, DOI 10.1081/IPH-120014730 | Immunopharmacology and immunotoxicology | 2002 | 53 | 3.3 |

**Table 5** The 10 Most Frequently Used Author Keywords

| Author Keywords | Occurrences | Total Link Strength |
|---|---|---|
| ginseng polysaccharides | 313 | 294 |
| ginsenosides | 80 | 126 |
| pectin | 35 | 35 |
| acidic polysaccharide | 26 | 30 |
| antioxidant activities | 23 | 24 |
| macrophages | 22 | 35 |
| cytokines | 20 | 26 |
| gut microbiota | 20 | 17 |
| immunomodulation | 18 | 26 |
| oxidative stress | 18 | 22 |

## Keywords and Trend Topic

Prior to conducting the keyword analysis, the consolidation of synonymous terms, such as "ginseng saponin" and "ginsenosides", was undertaken. Among the 763 publications, there were a total of 1938 author keywords, with 30 keywords recurring more than 8 times. The findings of Table 5 showcased the foremost 10 author keywords with the utmost frequency. The top 4 keywords pertained to chemical constituents, whereas the remaining 6 keywords were linked to pharmacological activities. The CiteSpace software was utilized to conduct a cluster analysis of keywords.

Figure 7A displayed a total of 12 clusters, which could be categorized into three main research directions: plants and chemical components, structural analysis, and pharmacological activities. Specifically, the clusters labeled as #ginseng saponin, #ginseng pectin, #Korean red ginseng, and #panax ginseng could be classified under the plant and chemical

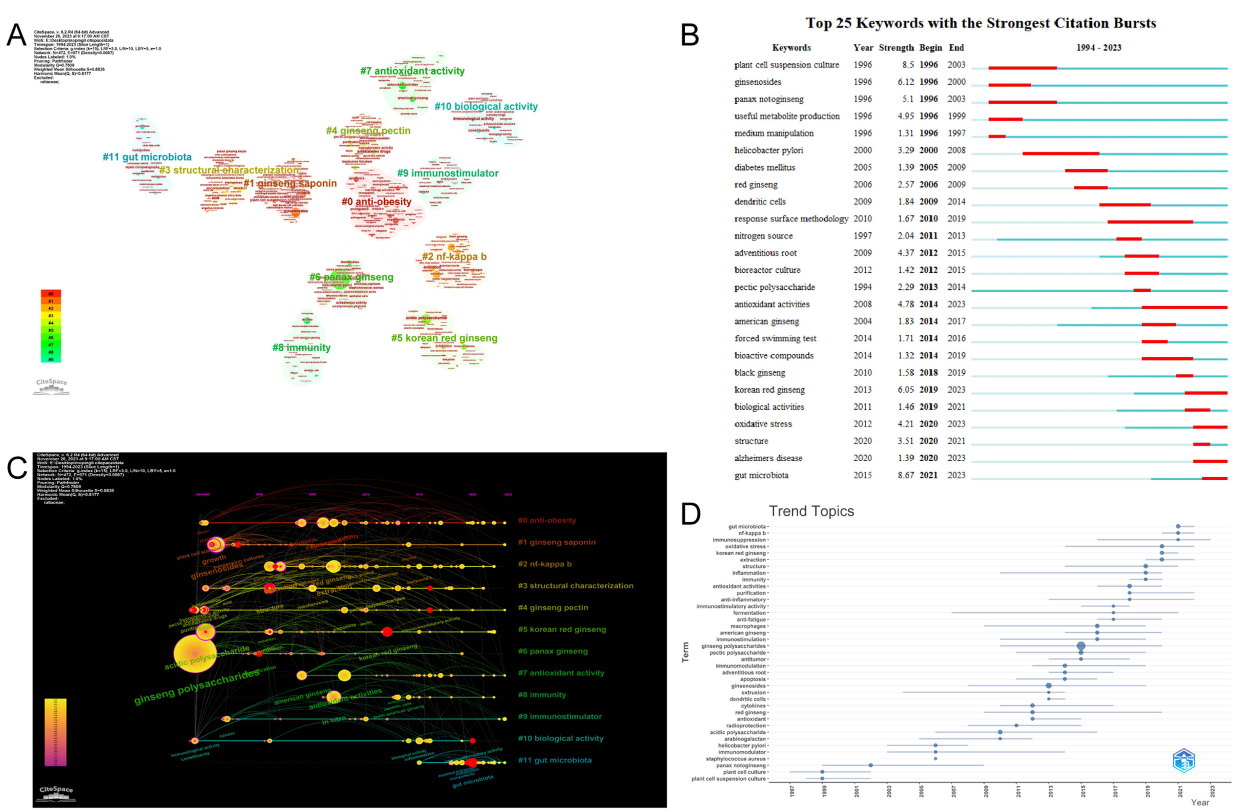


**Figure 7** The bibliometric analysis of the keywords and trend topics. (**A**) The clustering map of keywords. (**B**) Top 25 keywords with the strongest citation bursts. (**C**) The timeline view of keyword clustering in (**B**). (**D**) The trend topics over time.

components category. The cluster denoted as #structural characterization represented the domain of structural analysis. The clusters labeled as #anti-obesity, #NF-κB, #antioxidant activity, #immunity, #immunostimulator, #biological activity, and #gut microbiota could be categorized as pharmacological activities. Additionally, the analysis of research categories based on clustering revealed that investigations encompassed other plants like Panax notoginseng, American ginseng, and red ginseng. All of these plants are members of the Araliaceae family, thereby broadening the scope of research within the same botanical family.

Figure 7B exhibited author keywords of the strongest citation burst. Noteworthy recent burst keywords encompassed *gut microbiota* (strength = 8.67), *oxidative stress* (strength = 4.21), *structure* (strength = 3.51), and *Alzheimer's disease* (strength = 1.39). Figure 7C portrayed a timeline graph, with the clustering and burst keywords offering a clear visual depiction in chronological order. Similarly, "biological activity*"* and "gut microbiota" showed the red rings.The greater width of the chronological circle denoted a higher frequency of the keyword's occurrences, while the red fill indicated an abrupt alteration in the keyword during that specific time period.

Noteworthy, terms, including *gut microbiota, NF-κB, immunosuppression, oxidative stress, extraction*, and *purification*, collectively constituted the current trending topics in the field of ginseng polysaccharide research (Figure 7D). Through a thorough examination of keyword and trend topics, it was observed that structural analysis and pharmacological activity emerged as popular research directions. Further, investigating the pharmacological activity of ginseng polysaccharides in relation to gut microbiota and oxidative stress were current research hotspots.

## Disciplinary Category Analysis

Furthermore, we conducted a disciplinary category analysis and detected author keywords with the strongest bursts to reflect the research directions of ginseng polysaccharides. Figure 8A presented the top 10 disciplinary categories with the highest publications in this field. The discipline that exhibited the highest publications was Pharmacology Pharmacy (n = 150, 13.62%), closely trailed by Biochemistry Molecular Biology (n = 137, 12.44%) and Plant Sciences (n = 137, 12.44%). These findings suggested that the research direction in this field was concentrated in pharmacological activity and biochemistry.

Figure 8B illustrated the output over per five-year intervals for the top 10 disciplines. Most disciplines exhibited an overall upward trend. The publications in nearly all disciplines, especially Pharmacology Pharmacy, Plant Sciences, Chemistry Medicinal, and Integrative Complementary Medicine, saw rapid growth, peaking in the past five years. This trend aligned with the overall publications in the research field. In contrast, Biotechnology Applied Microbiology maintained a steady publication rate. In the past five years, the highest publications were in Biochemistry Molecular Biology (n = 64), followed by Food Science Technology (n = 60), and Plant Sciences (n = 61). Thus, it was evident that the core disciplines in this field shifted from Biotechnology Applied Microbiology to Pharmacology Pharmacy, Biochemistry Molecular Biology, and Plant Sciences.

We examined the keywords with the strongest bursts in the top 10 disciplines (Figure 8C). "Oxidative stress" and "antioxidant activities" emerged as prominent burst keywords across nearly all disciplines, highlighting the therapeutic potential of ginseng polysaccharides in ameliorating oxidative stress. Concurrently, six distinct fields—Biochemistry Molecular Biology, Plant Sciences, Chemistry Medicinal Sciences, Integrative Complementary Medicine, Food Science Technology, and Polymer Science—consistently identified "gut microbiota" as a key research focus in their respective domains. Additionally, "structure" emerged as a burst keyword in both Biochemistry Molecular Biology and Food Science Technology, while "extraction" represented a primary research focus in Biochemistry Molecular Biology, Polymer Science, and Applied Chemistry. These findings collectively underscored the sustained scientific emphasis on polysaccharide structural studies and optimization of extraction protocols. Furthermore, the disciplines of Plant Sciences, Medicinal Chemistry, and Integrative Complementary Medicine identified "absorption" as a prominent research focus, highlighting the need for intensified investigation into the pharmacokinetic properties of ginseng polysaccharides, particularly their absorption efficiency. The results indicated that several research hotspots related to ginseng polysaccharides overlapped with previous results, including pharmacological activities such as gut microbiota, oxidative stress, and antioxidant activities, component analysis such as structure and extraction, as well as sources of polysaccharides like American ginseng and red ginseng. This further explained why these become current research hotspots. Of particular

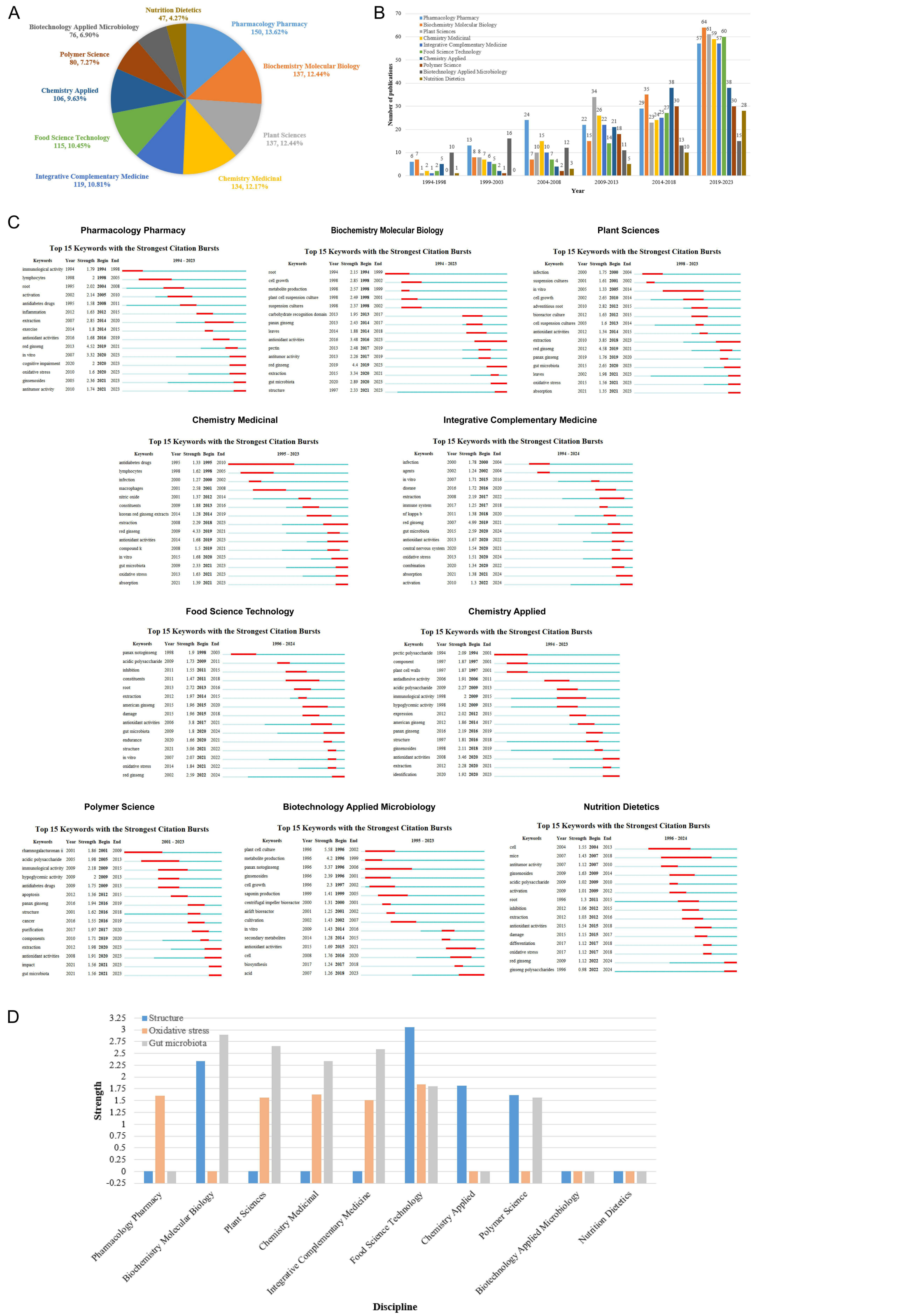


**Figure 8** The bibliometric analysis of the disciplinary category. (**A**) The top 10 most published disciplinary category. (**B**) The publications per 5 years in 10 disciplines category. (**C**) Top 15 keywords with the strongest citation bursts of top 10 discipline category. (**D**) Strength of research hotspots in top 10 discipline category.

significance was also the identification of "antitumor activity" and "cognitive impairment" as research hotspots for ginseng polysaccharides within the Pharmacology Pharmacy discipline. These emerging research foci underscored crucial directions for elucidating the pharmacological mechanisms of ginseng polysaccharides. The field of Biotechnology Applied Microbiology directed attention toward the investigation of acidic ginseng polysaccharide, while Plant Sciences established a distinct research emphasis on polysaccharides extracted from ginseng leaves.

The burst strength for research hotspots in this field was shown in Figure 8D, and the research hotspots in the three core disciplines all exhibited high burst strength. In particular, Food Science Technology featured three research hotspots with leading burst strengths, making it a trending discipline currently. Additionally, in disciplines with relatively fewer publications, such as Plant Sciences, Integrative Complementary Medicine, and Polymer Science, the keywords with the strongest bursts emerged later (in 2020, 2020, and 2021, respectively), consistent with the output trends. These findings mutually corroborated the emergence of research hotspots and trending disciplines in this field.

# Discussion

## General Information

The objective of our study was to employ bibliometric analysis in order to establish a knowledge map, identify current research hotspots, and explore emerging frontiers in the field of ginseng polysaccharide research from 1 January 1985 to 9 July, 2023. A comprehensive search was conducted on the WOSCC to identify relevant literature on ginseng polysaccharides. A total of 763 publications, published in 292 journals, were included in our analysis. These publications were authored by 2835 authors affiliated with 717 institutions across 52 countries. Furthermore, we obtained a total of 26,401 cited references and 1938 author keywords, which were subsequently analyzed to gain insights into the current research hotspots. The publication titled "Polysaccharides of Panax ginseng"[35] served as a pioneering work in the exploration of ginseng polysaccharides The continuous growth in the publications centered on ginseng polysaccharides is undeniable.

Within this academic field, the nations that held considerable influence were China, Republic of Korea, and the USA. It was worth mentioning that the top three nations displayed a noteworthy level of collaboration, with China leading in terms of publication outputs, citation frequency, and collaborative efforts. This circumstance can potentially be attributed to the primary production regions of medicinal plants belonging to the Panax genus.[36] Notably, among the top 10 institutions, seven were affiliated with China, while the remaining three were come from Republic of Korea. This finding further substantiated the influential roles of China and Republic of Korea in the realm of ginseng polysaccharide research. Moreover, it was worth noting that Northeast Normal University, despite its remarkable achievement of having the highest publications and citations, was not included in Table 2. By examining the collaboration network graph among institutions, it become apparent that Northeast Normal University was only connected to five other institutions, and these connections were relatively limited in scope. This suggested that it lacked extensive communication and collaboration with others. Nevertheless, the significance of its impact should not be underestimated.

Some researchers made outstanding contributions in this field. Ovodov and Solov'eva were the first to report the isolation and structural analysis of ginseng polysaccharides in 1966.[35] Through their research, they were able to confirm the existence of amylopectin-type glucans and pectins in ginseng polysaccharides. Between 1995 and 2004, Jianjiang Zhong and his research team dedicated their efforts to the cultivation of ginsenosides and polysaccharides through plant cell culture techniques involving Panax notoginseng, American ginseng, and Panax ginseng. And their investigations encompassed the evaluation of various factors, including osmotic pressure, nitrogen source, $Cu^{2+}$, and other conditions, with the objective of optimizing yield to meet market demands and minimize costs.[37–41] Subsequently, Yifa Zhou's team made notable advancements in the realm of ginseng polysaccharide isolation, purification, structural analysis, and exploration of biological activities, commencing in 2009. The researchers utilized a variety of techniques including ethanol precipitation, enzymatic hydrolysis with polygalacturonase, ion exchange, and gel permeation chromatography to extract and purify neutral components and acidic components from ginseng roots.[33] Additionally, they successfully obtained various ginseng pectins that contained domains consisting of homogalacturonan and rhamnogalacturonan structures, such as type-I rhamnogalacturonan and homogalacturonan-type pectin, and proceeded to analyze their structures.[42,43] They conducted pharmacological activity research and structure–activity relationship studies on the isolated ginseng polysaccharides.[44–46]

In additional, Bradford's Law was commonly used to identify the core journals for research in bibliometrics analysis. Thereinto, the 14 core journals determined by Bradford's Law encompassed all of the top 10 most frequently cited journals, as indicated in Table 3. This convergence of findings served to validate the significance of these 10 journals within the discipline.

Our study conducted a bibliometric analysis of ginseng polysaccharides from various perspectives, revealing patterns of various countries, institutions, journals, and authors. The multilateral cooperation network established through bibliometric analysis and visualization offers valuable insights into this field.

## Research Hotspots and Trends

Bibliometric analysis has proven to be an important tool for evaluating research trends and hotspots from various perspectives. Regarding the co-cited references, the article DUBOIS M, 1956, ANAL CHEM, V28, P350[32] garnered the highest citations, while the article BLUMENKR. N, 1973, ANAL BIOCHEM, V54, P484 ranked fifth. The establishment of the phenol-sulfuric acid method and the meta-hydroxydiphenyl method in these two publications provided a solid foundation for the investigation of the physicochemical properties of polysaccharides. Furthermore, through analysis top 10 citations and the strongest burst of references, notable examples included the reference of ZHANG X, 2009, CARBOHVD POLYM, V77, P544,[33] SUN YX, 2011, CARBOHVD POLYM, V85, P490,[34] and GUO MK, 2021, FOOD FUNCT, V12, P494.[1] Both the research methodology employed and the findings obtained from these studies serve as valuable guidance for future research endeavors.

Research trends in ginseng polysaccharides indicated a shift in research hotspot from the production of polysaccharides through cell culture to the investigation of their extraction, purification, structure, and pharmacological activities, including gut microbiota and oxidative stress. Through cluster analysis, the identified keywords were categorized into three main categories: plants and chemical composition, structural analysis, and pharmacological activity. Hence, it was apparent that the primary emphasis of research pertaining to ginseng polysaccharides lied in two key areas, namely structural analysis and pharmacological activity. The analysis of burst keywords across ten core disciplines consistently validated our findings, revealing a predominant research focus on the pharmacological activities related to oxidative stress and gut microbiota regulation across most disciplines. This was followed by significant attention to extraction methodologies and structural characterization. These results reaffirmed that the three-tiered research framework encompassing component analysis, structural elucidation, and pharmacological investigation remains the central focus in current ginseng polysaccharide research.

It was widely recognized that polysaccharides possess a substantial molecular weight and intricate molecular composition, devoid of chromophoric and light-absorbing groups. Consequently, researchers have persistently endeavored to investigate improved techniques or instruments for the structural identification of polysaccharides. This was precisely why there was a significant focus on structural analysis in this field. The structure of polysaccharides was intricate and intricately linked to the techniques employed for extraction and purification. Polysaccharides acquired through diverse extraction and purification methods exhibit variations. Previous investigations on ginseng polysaccharides have primarily emphasized the presence of neutral polysaccharides, acidic polysaccharides, and pectins, with particular attention given to the chemical composition of pectins.[47] The composition of ginseng pectin was believed to consist of domains containing high homogalacturonan and rhamnogalacturonan. The rhamnogalacturonan structure could be further subdivided into rhamnogalacturonan I and rhamnogalacturonan II domains.[48] The structure of ginseng polysaccharides has been increasingly studied in greater detail with the advancement of analytical techniques. Furthermore, acid-related components emerged as a significant research focus in Biotechnology Applied Microbiology. A notable example was GSPA-0.3, an acid-soluble ginseng polysaccharide fraction, which demonstrated remarkable therapeutic potential by enhancing H1N1 vaccine efficacy through activation of the TLR4-MyD88 pathway. This activation mechanism not only boosted neutralizing antibody production (surpassing the efficacy of aluminum adjuvants) but also synchronously elevated Th1/Th2 markers, indicating balanced immune polarization[49]. To address the issue of low oral absorption rate of ginseng polysaccharides, researchers employed structural modification techniques, innovative delivery systems, and combination strategies with absorption enhancers, which have significantly improved their bioavailability.[50] Despite these absorption limitations, ginseng polysaccharides can still directly modulate gut microbiota to exert biological activities.[51]

Gut microbiota was emerged the hotspots of pharmacological activity in this field. In previous research, it was ascertained that ginseng polysaccharides possess the potential to mitigate and manage an array of ailments, including enteritis, diarrhea, tumors, aging, obesity, lipid metabolism, and other maladies, through the modulation of the gut microbiota. Such as, ginseng polysaccharide (WGP) was observed to modulate the composition of the gut microbiota in the context of regulating antibiotic or sodium polystyrene sulfonate-induced diarrhea.[52] The potential of crude polysaccharide (GP-c) and its fractions neutral polysaccharide (GP-n)[53] in tumor prevention and treatment was demonstrated through the restoration of short-chain fatty acid levels, the increase in microbial metabolite valeric acid, and the upregulation of Akkermansia and Bifidobacterium to enhance the gut microbiota ecosystem. Likewise, the polysaccharide extracted from ginsenoside residues (GRP) using ultrasound[54] was observed to enhance the abundance of beneficial bacteria in anti-aging treatment. Additionally, the pectin isolated from ginseng berry (GBPA) has demonstrated significant improvements in lipid disorders among obese rats, while also leading to an increased presence of Akkermansia, Bifidobacterium, Bacteroides, Prevotella, and elevated levels of acetic acid, propionic acid, butyric acid, and valeric acid.[55] In other words, it demonstrated the triangular interaction between ginseng polysaccharides, gut microbiota, and the host in combating various diseases. Particularly noteworthy maybe was the significant pharmacological potential of ginseng polysaccharides in both antitumor activity and cognitive improvement. Mechanistic studies demonstrated that ginseng polysaccharides modulated the gut microbiota composition and regulated the kynurenine/tryptophan ratio, thereby enhancing the antitumor efficacy of anti-PD-1/PD-L1 immunotherapy. It suggested ginseng polysaccharides combined with alpha PD-1 mAb may be a new strategy to sensitise non-small cell lung cancer patients to anti-PD-l immunotherapy. This groundbreaking discovery emerged as one of the most valuable research directions in the field of cancer immunotherapy.[56] Additionally, polysaccharides from ginseng leaves inhibited tumor metastasis via macrophage and NK cell activation.[57] Similarly, recent years in this field witnessed significant advancements in research on cognitive impairment, with high-quality studies emerging in this field. Notably, a 4.7-kDa polysaccharide derived from Panax ginseng demonstrated remarkable therapeutic potential by suppressing amyloid-β (Aβ) pathology via mitophagy activation in cross-species Alzheimer's disease.[58] And another research demonstrated that RG-l pectin promoted longevity via TOR pathway in Caenorhabditis elegans.[59] Collectively, these studies suggested that the bioactive components of ginseng polysaccharides may serve as promising neuroprotective agents, while simultaneously providing a modern scientific interpretation of Traditional Chinese Medicine applications.

Similarly, in terms of oxidative stress, it was ascertained that crude polysaccharides acquired through hot water extraction and purification possess the capability to mitigate and manage a range of ailments, including liver damage, kidney damage, and fatigue syndrome, by regulating oxidative stress. Specifically, ginsan demonstrated efficacy in the prevention of liver damage by suppressing oxidative stress and inflammatory reactions.[60] Additionally, ginseng polysaccharides exhibited the ability to diminish oxidative harm in the kidneys of ischemia/reperfusion rabbits by elevating lipid peroxidation levels and diminishing antioxidant enzyme activity.[61] *Panax ginseng* polysaccharides (GPS) effectively inhibited gastric inflammation and oxidative stress by suppressing NF-κB and STAT.[60,62] GPS demonstrated the ability to promote red blood cell glycolysis and hepatic gluconeogenesis pathways, thereby protecting red blood cells from oxidative stress damage.[63] Moreover, ginseng acidic polysaccharides (WGPA) and its acidic polysaccharide fraction (WGPA-A), exhibited potential in treating chronic fatigue syndrome by reducing the activities of superoxide dismutase and glutathione peroxidase.[44] In fact, in the past two years, there has been an explosion of research on the involvement of ginseng polysaccharides in regulating gut microbiota and oxidative stress, making it a research hotspot in the field of pharmacological activity.

Additionally, it was evident that research hotspots across various disciplines were intertwined and not independent. Identified research hotspots such as structure, gut microbiota, and oxidative stress frequently appeared in both core and trending disciplines, thus enabling mutual validation between research hotspots and trending disciplines. On one hand, the frequent occurrence of keywords related to research hotspots highlighted the significance of a discipline. On the other hand, the across various disciplinaries appearance of keywords made them research hotspots. However, there was also the possibility of overlap in the publications indexed by different disciplines, despite each discipline having its own research tendencies. Nevertheless, it is undeniable that the analysis results of disciplinary classification reflected the rich layers of research in this field. Assignment of research content to particular disciplines allowed for the identification of Pharmacy and Plant Chemistry as the domains responsible for the isolation, purification, and structural analysis of polysaccharides. Conversely, the investigation of pharmacological activity aligned with disciplines such as Pharmacology, Biochemistry, Molecular Biology, etc. These outcomes aligned with the outcomes of the disciplinary category analysis and keywords burst, and furnish compelling evidence to substantiate the conclusions derived in this study.

In summary, based on our systematic investigation of current research hotspots and top 10 disciplinary validation in ginseng polysaccharides, we can reasonably anticipate that future research trends will center on a three-tier paradigm of composition-structure, functional mechanisms, and application development. On the one hand, advanced methodologies will be employed to achieve precise structural characterization, including structural modification and functionalization of polysaccharides, alongside the establishment of standardized quality control measures such as fingerprint profiling. On the other hand, efforts will focus on elucidating structure–activity relationships and deepening the understanding of biological mechanisms, particularly in oxidative stress modulation and gut microbiota regulation. Additionally, the pharmacological activities of ginseng polysaccharides, especially their antitumor activity and improving cognitive impairment, are expected to emerge as major research hotspots in the coming years. Furthermore, the application of emerging technologies, such as multi-omics approaches for systematic decoding of multi-target mechanisms and the development of advanced drug delivery systems (eg, nanoparticles and liposomes), will likely become critical research directions. These advancements will collectively provide a robust scientific foundation for the clinical application of ginseng polysaccharides and their development into functional food products.

## Strengths and Limitations

Our study offered an insightful, objective, and accurate analysis of publications on ginseng polysaccharides through the exploration of knowledge map, trends, and research hotspots. It represents the first comprehensive research in this field to utilize bibliometric software for multidimensional visualization of data. As such, it has the potential to become a valuable resource for scholars in this field. But there were still some limitations. Firstly, this study was based solely on the WoSCC, excluding literature from other databases such as PubMed and Scopus. However, researchers generally consider WoSCC to be the best database for bibliometric studies, providing most of the information on a specific topic.[24,64] Secondly, our analysis was restricted to English-language publications. While this approach aligned with common bibliometric practices as English, it might inadvertently exclude relevant studies published in other languages. Additionally, the data retrieved with our chosen keywords might not encompass all research in this field. Furthermore, some recently published high-quality research might be excluded from this analysis because they had not enough time to accumulate citations, thus not yet demonstrating their impact. We intend to update the study in the future and attempt to address these limitations.

# Conclusion

This study conducted a bibliometric analysis and data visualization of the field of ginseng polysaccharide research, based on publications since 1985. The analysis revealed the knowledge map, current research hotspots, and emerging frontiers within this domain. The findings indicated a notable increase in publications and citations, suggesting the growing significance of this research topic to the academic community. This study has revealed the multidimensional field of research on ginseng polysaccharides, specifically in the fields of pharmacology and pharmacy. The current hot research directions in this field encompassed structural analysis and pharmacological activities, with research hotspots focused on exploring the pharmacological activities of ginseng polysaccharides in gut microbiota and oxidative stress.

Future research trends in this field will center on a three-tier paradigm of composition-structure, functional mechanisms, and application development, providing a robust scientific foundation for clinical applications and functional food development.

# Data Sharing Statement

Data included in article/supplementary material/referenced in article.

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## Disclosure

The authors report no conflicts of interest in this work.

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