Botanical trends in global skin care: a bibliometric analysis

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Research

Abstract

Background: The trend of using botanical-based ingredients in skin care is booming in the global cosmetics industry. A comprehensive and global bibliometric analysis of this field has never been conducted. This study aims to conduct a bibliometric analysis of the current literature from 2000 to 2024 on the use of botanical ingredients in skin care. This analysis aims to identify global and comprehensive research trends and develop future research strategies.

Methods: References were obtained from the Scopus database. The data mining process involved filtering, extraction, export, selection, and validation. A data cleaning process was conducted to standardize the writing. The data were then analyzed and visualized using Bibliometrix-Biblioshiny, VOSviewer, and Microsoft Excel.

Results: The use of botanical ingredients in global skin care is on the rise. Between 2000 and 2024, 1,127 articles were published by 357 publishers, with a 12.3% average annual growth. A total of 4,942 authors from 77 countries contributed to this topic. The United States is the leading contributing country, Tsinghua University is the most productive institution, Science of the Total Environment is the top journal, and Gang Yu is the most prolific author. The U.S. plays a key role in knowledge dissemination on this subject.

Conclusions: The bibliometric analysis reveals growing interest and underscores opportunities for international collaboration, offering a useful reference for academics, researchers, and policymakers to bridge scientific and technological gaps and inform future policies and research.

Keywords: Bibliometric, Botanical, Science mapping, Skin care

Background

The trend of using botanical-based ingredients in skin care is currently growing. Plant-derived natural ingredients are widely applied topically as cosmetic agents to nourish and care for the skin. Scientific advancements have increased consumer awareness of the benefits of using natural, environmentally friendly products with minimal side effects.

Cosmetics enriched with bioactive plant compounds are increasingly used in daily skin care routines to provide various benefits. Certain botanical ingredients have therapeutic applications in the treatment of conditions such as acne, atopic dermatitis, and psoriasis. Others are applied topically as cosmetic agents with functions including antibacterial, antioxidant, brightening, cleansing, moisturizing, regenerating, skin-protective, and softening (Jadoon *et al*. 2015, Michalak 2023).

Interest in the utilization of plant-origin in medicinal and cosmetic formulations has been increasing (Michalak 2023), prompting a significant body of research on plants used for skin care. However, comprehensive bibliometric data and an up-to-date global analysis of this subject remain limited. Such data are essential for researchers and scientists to identify and map the current knowledge landscape and to formulate future research strategies. Therefore, this study is both timely and important.

Advancements in internet technology and computer science have increased the adoption of bibliometric analysis, which enables quantitative evaluation of scholarly output, mapping of citation structures, assessment of contributing authors, institutions, journals, dissemination of research findings, and the diffusion of knowledge across specific topics (Ding *et al.* 2014, Rodríguez-Rojas *et al.* 2019, Elisha & Viljoen 2021, Melo *et al.* 2021). Beyond measuring publication performance, it also provides insights into the structural organization of disciplines and the evolution of research in particular fields (Waaijer & Palmblad 2015).

The study questions addressed in this study can be stated as: What are the growth trends and global averages of publications on the topic of plants for skin care from 2020 to 2024? Which countries contribute the most to this field? What roles do institutions play in advancing this research? Which publishers have produced the greatest number of manuscripts? Who are the most prolific authors? What does the research collaboration network between countries look like? How is knowledge in this field disseminated? What are the emerging trends and directions of scientific development? What is the concept of scientific evolution in this context, and what is the current status of research on plants for skin care?

Materials and Methods

Data sources

Many leading bibliometric studies rely on a single database (Tan *et al.* 2023, Azizan *et al.* 2024) or Scopus (Banerjee *et al.* 2024, Maral 2024, Senthil *et al.* 2024). This approach is intended to mitigate concerns regarding potential data homogenization that may occur when using multiple databases (Mariani & Borghi 2019). Moreover, using a single database can help reduce biases that might arise from integrating data across different sources (Dwivedi *et al.* 2011).

This research is based on data retrieved from the Scopus database, focusing on the topic of plants for skin care. Scopus was selected due to its broad and comprehensive coverage of scientific publications (Bamel *et al.* 2020, Khitous *et al.* 2020). It is the most comprehensive abstract and citation database for peer-reviewed content, including books, scientific journals, and conference proceedings related to science and technology (Nunen *et al.* 2018). Google Scholar was excluded from this analysis, as it lacks the detailed data necessary for a thorough bibliometric study (Bamel *et al.* 2020).

The bibliographic records in Scopus were retrieved using Boolean operators such as OR, AND, quotation marks, and asterisks (Gaviria-Marin *et al.* 2019). The search terms applied in Scopus were: (Plant* OR Herb* OR Botan*) AND (“Skincare” OR Skin care OR "Beauty routine" OR "Skin treatment" OR "Dermatological care" OR "Skin maintenance" OR "“Complexion care” OR “Skin health” OR “Facial care” OR “Cosmetic care” OR “Personal care”). The search targeted scientific literature containing at least one of these keywords, terms, or phrases appearing in the title, abstract, or keywords fields.

References that fulfilled the inclusion and exclusion criteria were analyzed. The inclusion criteria were as follows: publications retrieved from the Scopus database; articles containing relevant information in the title, abstract, keywords, and/or full text; primary (original) research articles; articles written in English; publications from global journals indexed in Scopus; and articles published between 2000 and 2024 to make sure that current and relevant sources are included (Santos *et al.* 2025). The exclusion criteria included articles with insufficient information, evident bias, lack of full-text availability, and secondary or review articles.

Data mining

This stage involved filtering, extraction, metadata export, article selection, data validation, and data analysis. The objective was to identify the thematic coverage of the research articles, which would serve as input for subsequent analysis, including

visualization using VOSviewer and Bibliometrix-Biblioshiny software for advanced bibliometric analysis (van Eck & Waltman 2020). Data were retrieved through a search in the Scopus database on April 15, 2025 (Singh *et al.* 2021, Zhu & Liu 2020). Data mining was conducted in the topic (title) field related to "plants for skin care", as this area was considered representative of the publication content and yielded a substantial number of relevant results. The search strategy was guided by the PICOCTS framework, which includes Population, Intervention, Comparison, Outcome, Context, Time, and Study Characteristics, in which the population was defined as "plants" and the intervention as "skin care" (Mengist *et al.* 2020). All the identified components were utilized to develop a keyword list and formulate a query (Methley *et al*. 2014, Nishikawa 2022)—a structured database request designed to retrieve, insert, update, or delete data efficiently, based on the study's needs. Subsequent steps involved a synonym search to obtain a more comprehensive dataset. Table 1 below presents the search procedure:

Table 1. Stages of data search

Indexer/ Database	Query String	Result	Date of Seach
Scopus	(TITLE ((plant* OR herb* OR botan*) AND (skincare OR "skin care" OR "beauty routine" OR "skin treatment" OR "dermatological care" OR "skin maintenance" OR "complexion care" OR "skin health" OR "facial care" OR "cosmetic care" OR "personal care")) OR KEY ((plant* OR herb* OR botan*) AND (skincare OR "skin care" OR "beauty routine" OR "skin treatment" OR "dermatological care" OR "skin maintenance" OR "complexion care" OR "skin health" OR "facial care" OR "cosmetic care" OR "personal care")))	1,793	April 15, 2025
AND Secondary research	bibliometric* OR scientometric* OR infometric* OR webometric* OR alt?metric* OR "systematic literature review*" OR "systematic review*" OR "scorba" OR "scoping review*" OR "umbrella review*" OR slr OR slna OR balr OR meta-analys?s	37	April 15, 2025
	bibliometric*	4	April 15, 2025
AND NOT Secondary research	bibliometric* OR scientometric* OR infometric* OR webometric* OR alt?metric* OR "systematic literature review*" OR "systematic review*" OR "scorba" OR "scoping review*" OR "umbrella review*" OR slr OR slna OR balr OR meta-analys?s	1,756	April 15, 2025
Limitation	Document type: article = 1,225 Language: English = 1,682 Source type: journal = 1,653	1,163	
Limitation	Year: 2000-2024	1,127	
Final search	(TITLE ((plant* OR herb* OR botan*) AND (skincare OR "skin care" OR "beauty routine" OR "skin treatment" OR "dermatological care" OR "skin maintenance" OR "complexion care" OR "skin health" OR "facial care" OR "cosmetic care" OR "personal care")) OR KEY ((plant* OR herb* OR botan*) AND (skincare OR "skin care" OR "beauty routine" OR "skin treatment" OR "dermatological care" OR "skin maintenance" OR "complexion care" OR "skin health" OR "facial care" OR "cosmetic care" OR "personal care")) AND NOT TITLE-ABS-KEY (bibliometric* OR scientometric* OR infometric* OR webometric* OR alt?metric* OR "systematic literature review*" OR "systematic review*" OR "scorba" OR "scoping review*" OR "umbrella review*" OR slr OR slna OR balr OR meta-analys?s)) AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j"))	1,127	April 15, 2025 Time 12.36 GMT+7

The initial search in the Scopus database on April 15, 2025, yielded a total of 1,793 articles. Among these, 37 were secondary research articles, and four were related to bibliometric studies, leaving 1,756 articles categorized as primary research. Only data from primary research articles were included in the analysis. The search was then refined using the following filters: document type (article) = 1,225; language (English) = 1,682; and source type (journal) = 1,653, which resulted in 1,163 articles. A further filter was applied to restrict the publication years to 2000-2024, resulting in a final total of 1,127 articles.

The data cleaning process standardized the text, which included converting plural forms to singular and aligning keyword usage with the Library of Congress Subject Headings (LCSH). This process was performed using OpenRefine software and was carried out in two phases. The first stage involved cleaning 1,127 articles retrieved from the Scopus database, resulting in 1,123 usable articles; four articles were excluded due to missing titles, abstracts, or keywords. The second stage focused on 6,633 author keywords, which were refined and reduced to 3,432 standardized keywords.

Science mapping and data visualization

Science mapping is a fundamental bibliometric technique that provides a spatial representation of the interconnections among various scientific actors (Small 1999). Its primary goal is to reveal both the structural and dynamic dimensions of scientific research (Börner *et al.* 2003, Cobo *et al.* 2012). Advances in computer technology and software have significantly enhanced this procedure, positioning it as an appealing and effective approach for evaluating the structure and networks within science.

Data collected through data mining are subsequently processed and visualized using Bibliometrix-Biblioshiny, VOSviewer, and Microsoft Excel. Bibliometrix is a tool created using R, developed by the R Core Team and the R Foundation for Statistical Computing (Aria & Cuccurull 2017). It is a software tool that operates within both R and RStudio environments to examine scientific literature and assess the progression of research topics. Bibliometric performance evaluation employs multiple techniques such as word frequency analysis, citation tracking, and the quantification of publications by country, institution, research group, or author (Thelwall 2008).

VOSviewer, an open-source software developed by Leiden University, is designed to construct and visualize scientific publication networks while also offering text mining features that enable the creation of co-occurrence networks of important terms (van Eck & Waltman 2025); when combined with RStudio, it provides a strong and comprehensive framework for bibliometric analysis that facilitates the detection of major trends and significant contributions in the research field over a defined time frame (Santos *et al*. 2025), with VOSviewer further supporting clear and interpretable graphical mapping of bibliometric data (van Eck & Waltman 2010)

VOSviewer identifies and examines terms found within the titles, abstracts, and keywords of selected publications and presents the outcomes in the form of bubble maps that depict specific words or phrases. A manual review is performed to eliminate common or irrelevant terms. The size of each bubble corresponds to how frequently the term appears in the literature. The color indicates the average citation count per publication containing that term, while the distance between bubbles represents how often the terms co-occur (Yeung *et al.* 2018, 2020).

Results and Discussion

The structure of a scientific field can be understood by examining its research activities (Ronda-Pupo 2017). In the context of plant-based science for skin care, the scientific structure was examined using bibliometric analysis to identify ongoing research trends and identify opportunities for future exploration (Li *et al.* 2017, Castriotta *et al.* 2019). The future implications of this research highlight the need for greater attention to emerging challenges, particularly consumer skepticism toward botanical products in skin care, which can be addressed through public awareness initiatives and professional training.

As reported by Kent Baker *et al.* (2020), bibliometric analysis consists of three main types: descriptive analysis, network analysis, and content analysis. Descriptive analysis covers aspects such as yearly publication trends, the most prolific journals, the top contributing countries, prominent authors, and contributing organizations. Network analysis involves citation, keyword, co-word, co-authorship, co-citation analysis, and literature classification. Content analysis includes cluster analysis, gap analysis, and the identification of research trends over time, such as the evolution of plant-based science in skin care applications (Puiu & Bilbiie 2025). Data processing and visualization were conducted using the Bibliometrix-Biblioshiny application and VOSviewer.

Main information

A descriptive analysis of the Scopus database related to plant-based skin care yielded the main information presented in Table 2. The search, conducted for the period 2000-2024, identified 1,127 documents with an annual growth rate of 12.3%. This positive and relatively high growth rate indicates a continuous increase in academic interest in this field (Saputra *et al*. 2025). The analysis identified 4,942 contributing authors, with an average of 5.33 authors per publication. Notably, only 36 authors contributed as sole authors in single-authored documents.

Table 2. Main information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2000:2024
Sources (Journals, Books, etc.)	357
Documents	1,127
Annual growth rate %	12.3
Document average age	8.42
Average citations per doc	65.17
References	48,662
DOCUMENT CONTENTS	
Keywords plus (ID)	13,181
Authors' keywords (DE)	3,432
AUTHORS	
Authors	4,942
Authors of single-authored docs	36
AUTHORS COLLABORATION	
Single-authored docs	42
Co-authors per document	5.33
International co-authorships %	25.11
DOCUMENT TYPES	
Article	1,127

Growth trends in publications and citations

Over the past decades, a large number of impactful articles have been published in a range of academic journals. One approach to identifying these influential works is by classifying publications based on their citation counts (Merigó *et al.* 2015). The citation count reflects the degree of influence, popularity, and recognition a work receives from the scientific community. Figure 1 provides a summary of publication and citation counts from 2000 to 2024 (Gaviria-Marin *et al.* 2019).

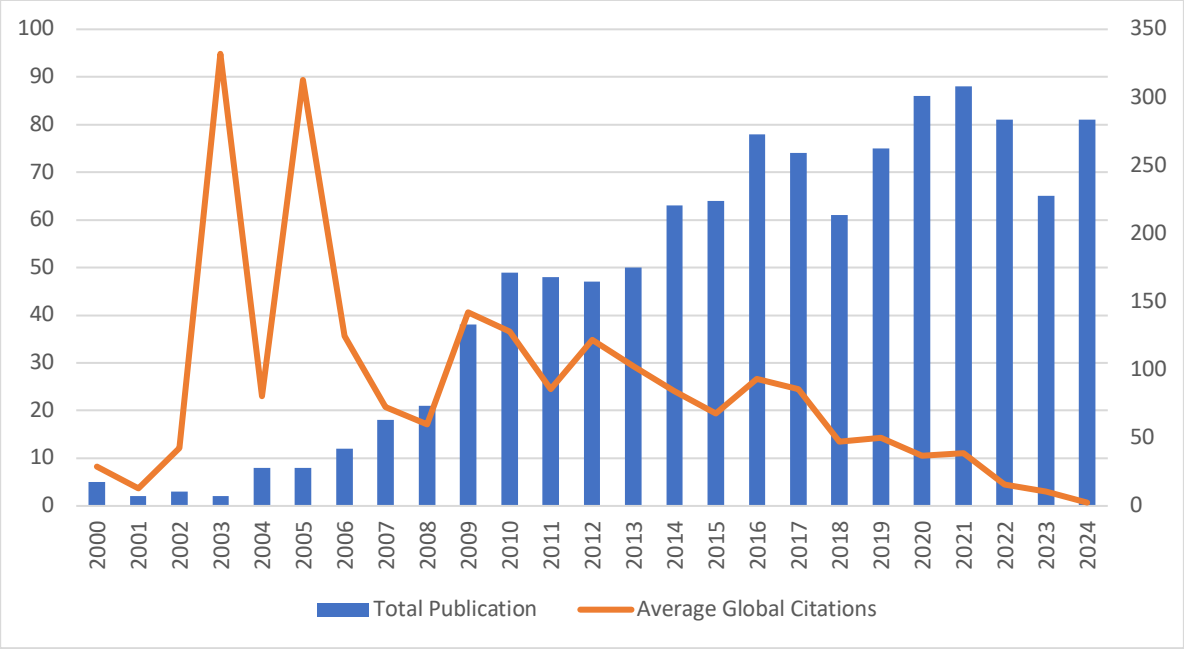

Figure 1. Growth trends in total publications and average global citations

Numerous journals have published research on plant-based skin care. Current publication trends concerning the use of plants in skin care were examined by analyzing the total number of publications and citations per year, along with data categorized by country, journal, contributing author, and affiliated institution. The data used in this analysis were obtained from

bibliographic records retrieved from the Scopus database. Overall, the number of publications on plant-based skin care has shown a steady increase over the years (Figure 1). The progression of publications over time serves as a valuable indicator for assessing the development of a particular research area (Wijaya *et al.* 2023). The rise in publication volume reflects growing academic interest in the topic of plant-based skin care.

The search began in 2000 with five publications, and by 2024, the number had increased to 81. Although the publication trend fluctuated with periods of both decline and growth, it generally showed a gradual upward trajectory. The year 2021 recorded the highest number of publications, totaling 88 research articles published. In contrast, the lowest number of publications occurred in 2001 and 2003, with only two publications each.

The average global citation count of articles has fluctuated over the years, with increases and decreases in certain periods. However, as shown in Figure 1, there has been an overall gradual decline in citations. The highest number of global citations occurred in 2003, with a total of 332 citations, while the lowest was recorded in 2024, with only two citations. This decline is expected, as more recent publications have had less time to accumulate citations and, consequently, have not been cited as frequently, resulting in a lower perceived impact (Santos *et al.* 2025).

Analysis of contributing countries

Based on the premise that research drives development and economic growth, countries around the world are increasingly investing in plant-based research activities (Becker 2015). The topic of plants for skin care has garnered significant global attention, as evidenced by contributions from 77 countries. A data search identified 1,127 selected papers related to this topic published between 2020 and 2024. Countries actively engaged in this area of research are often leaders in innovation, technological applications, and international collaboration. Table 3 presents the ten leading countries in plant-based skin care research with their publication and citation counts. Most studies focus on environmental issues in personal care products, while few address plant-based skin care directly.

Table 3. Top 10 most productive countries in skin care-related publications

Ranking	Country	Total Publication	Total citation
1	United States	177	16,470
2	China	162	9,275
3	Spain	86	7,360
4	India	54	1,391
5	Canada	47	3,457
6	South Korea	41	2,895
7	Germany	34	1,405
8	Japan	34	2,598
9	Australia	31	2,669
10	Italy	30	1,864
.....	.....	.....	.....
21	Indonesia	8	18

Table 3 clearly shows that the United States leads in the number of publications, with China and Spain ranking second and third, respectively. Specifically, the United States leads with 177 documents and 16,470 citations, indicating a potentially greater impact of its publications compared to those from other countries. This prominence underscores the nation's significant dedication to developing plant-based skin care technologies, an effort largely propelled by industry. Several factors contribute to the United States' top position, including its geographical size, widespread use of English, large number of researchers, and substantial investment in research and development (Gaviria-Marin *et al*. 2019).

China ranks as the second-largest contributor globally and the leading contributor from the Asian region, with a total of 162 publications and 9,275 citations. Other notable Asian countries include India and South Korea. India has produced a relatively high number of publications (54 articles), but these have garnered only 1,391 citations. The relatively low citation count suggests that India's publications are less prominent and have a lower impact within the scientific community.

Indonesia also contributed to the field, ranking 21st among countries publishing research on the use of plants for skin care, with a total of eight articles and 18 citations. This relatively low contribution may be attributed to the limited number of

publications from Indonesia in English, as the Scopus database primarily indexes English-language articles. Much of Indonesia's research is conducted in the Indonesian language and tends to focus on national issues. Therefore, it is important to conduct comparative studies between developed and developing countries to better understand global research trends related to botanical ingredients in skin care (Gál *et al*. 2025). Indonesia holds immense untapped potential in utilizing plants for skin care, given its status as a megabiodiversity country. This unique richness provides a strong rationale for fostering international collaboration and enhancing Indonesia's contribution to the global community.

Research on this topic shows that many authors come from high-income countries, such as the United States (Ford *et al.* 2013). Identifying the most contributing countries is valuable for recognizing those with the potential to serve as reference centers for future research and collaboration. Data from bibliometric analyses of top-performing countries provide insights into national research capacity and international competitiveness. This perspective is essential for understanding global research trends and the distribution of scientific publications across regions (King 2004). It also highlights disparities in research funding and output, which can inform international collaborations and policy interventions aimed at promoting more balanced global scientific development (Bornmann & Mutz 2015).

Analysis of contributing institutions

Over the years, researchers have strived to establish a distinct identity for this academic field, gaining recognition from various stakeholders, including universities (Serenko *et al.* 2010). These institutions play a key role in advancing the development of diverse research areas. Between 2000 and 2024, a total of 1,369 institutions were identified as contributors to research on this topic. Table 4 presents the most productive institutions publishing research papers related to skin care, along with their respective countries. This information is useful for identifying potential collaborators in plant-based skin care research. However, publication searches indicate that most existing studies focus on environmental aspects rather than on plant types and their biological activities in skin care.

Table 4. Top 10 institutions contributing to skin care-related research publications

Ranking	Name of Institution	Country	Total Publication
1	Tsinghua University	China	80
2	University of California System	United States	49
3	University of South Bohemia in Ceske Budejovice	Czech Republic	47
4	Beijing Institute of Technology	China	46
5	The University of Queensland	Australia	38
6	Tongji University	China	35
7	Companies-affiliated Research and Development	United States	32
8	University of Santiago De Compostela	Spain	30
9	The Pennsylvania State University	United States	29
10	Universidade Nova De Lisboa	Portugal	28

Institutions from China are the most productive, occupying the first, fourth, and sixth positions—namely Tsinghua University (80 publications), Beijing Institute of Technology (46 publications), and Tongji University (35 publications). Additionally, institutions from the United States show strong contributions, holding the second, seventh, and ninth positions, with the University of California System in second place (49 publications). The third position is held by the University of South Bohemia with a total of 47 publications.

Indonesian institutions also contribute to global research on plants for skin care, although to a lesser extent, with each producing between one and three publications. A total of seven institutions from Indonesia have contributed to this field: the Research Center for Applied Botany (BRIN), University of Indonesia, IPB University, Pancasila University, Research Center for Applied Zoology (BRIN), Research Center for Biosystematics and Evolution (BRIN), and Universitas Pejuang Republik Indonesia Makassar.

Emphasizing top universities and research institutions is essential, as it offers insight into the primary hubs of research activity. This data can assist funding bodies and policymakers in recognizing institutions leading scientific progress (Moed 2006). Universities frequently act as centers of innovation and collaboration efforts, and recognizing key contributors to scientific development can support the formation of stronger academic and industrial partnerships (Leydesdorff & Wagner

2008). This kind of analysis also highlights the institutions and countries at the forefront of collaborative research, as well as those that remain relatively isolated, thus guiding strategies to strengthen research partnerships and promote knowledge sharing (Glänzel & Schubert 2004).

Analysis of contributing publishers

The search results identified a total of 357 publishers that have published articles related to the use of plants for skin care. Table 5 provides details on the 10 leading journals and their respective publishers that have published the highest number of articles and received the most citations concerning the topic related to skin care. It also includes details on each journal's subject scope and quartile ranking. The journal that has published the most articles on this topic is Science of the Total Environment, with 133 documents and a total of 12,475 citations. Published by Elsevier, this journal is classified as a Q1 journal in the field of Environmental Chemistry.

Table 5. Most productive publishers

Ranking	Journal Name	Total Publications	Total Citation	h-Index	Publisher	Quartile
1	Science of the Total Environment	133	12,475	58	Elsevier	Q1 Environmental Chemistry
2	Chemosphere	74	6,123	39	Elsevier	Q1 Chemistry (miscellaneous)
3	Water Research	45	9,645	37	Elsevier	Q1 Civil and Structural Engineering
4	Environmental Pollution	38	4,286	24	Elsevier	Q1 Health Toxicology and Mutagenesis
5	Journal of Hazardous Materials	36	3,116	28	Elsevier	Q1 Environmental Chemistry
6	Environmental Science and Technology	30	9,270	27	American Chemical Society	Q1 Chemistry (miscellaneous)
7	Environmental Toxicology and Chemistry	30	1,905	18	Oxford University Press	Q1 Environmental Chemistry
8	Journal of Cosmetic Dermatology	26	303	9	John Wiley and Sons Inc.	Q2 Dermatology
9	International Journal of Cosmetic Science	20	489	14	Wiley Blackwell Publishing Ltd.	Q2 Chemistry (miscellaneous)
10	Water Science and Technology	20	726	12	IWA Publishing	Q2 Environmental Engineering
.....	.....	.....	.....	.....	.....	.....
132	Biodiversitas	1	4	33	SMUJO	Q2 Animal Science and Zoology, Plant Science

The five leading journals in terms of skin care-related publications are all published by Elsevier. These journals include Science of the Total Environment, Chemosphere, Water Research, Environmental Pollution, and the Journal of Hazardous Materials. Chemosphere demonstrates high productivity, having published 74 articles and possessing a relatively high h-index of 39; however, it has received only 6,123 citations. In contrast, Environmental Science and Technology has published just 30 articles with an h-index of 30, yet it has been cited 9,270 times. This suggests that journals like Chemosphere may have less influence in this specific field. Possible reasons include the journal's broad research scope, researchers' preference for publishing in journals with higher impact or quality indexes (Norris & Oppenheim 2007), and the availability of free or lower article processing charges.

Journals from Indonesia have also contributed to publications on this topic, with the Biodiversitas Journal from Sebelas Maret University, Surakarta, Indonesia, ranked 132nd. This journal has published one article related to the topic and has received four citations. Information about publishers that produce publications on the use of plants for skin care can be highly valuable

for researchers and academics—both in identifying suitable journals and publishers for submitting their work and in finding relevant references for their studies.

Author productivity

The search identified 4,943 authors publishing on plants in skin care. Table 6 lists the 10 most prolific authors in skin care-related research publications. All regarded as pioneers in this area. Most focused on environmentally oriented personal care, while only a few addressed the narrower topic of plant-based skincare.

Table 6. The most prolific authors in skin care-related research publications

Ranking	Author Name	Affiliation/ Country	Total Publications	Total Citations	h-Index
1	Gang Yu	Tsinghua University, China	13	1,053	13
2	Damia Barcelo	Catalan Institute for Water Research and Institute of Environmental Assessment and Water Research, Spain	11	1,113	10
3	Josep Maria Bayona	Spanish National Research Council, Spain	10	1,467	10
4	Jay Gan	Department of Environmental Sciences at the University of California Riverside, United States	10	1,195	10
5	Jun Huang	University of Sydney, Australia	10	751	10
6	Jochen F. Mueller	The University of Queensland, Australia	10	1,004	9
7	Juan M. Lema	University of Santiago de Compostela, Spain	9	866	9
8	Victor Matamoros	Spanish National Research Council, Spain	9	1,295	9
9	Francisco Omil	University of Santiago de Compostela, Spain	9	784	9
10	Yolanda Pico	University of Valencia, Spain	9	801	7

Gang Yu from Tsinghua University, China, was the most prolific author, with 13 publications and an h-index of 13. Following Gang Yu, Damia Barcelo from the Catalan Institute of Water Research and the Institute for Environmental Assessment and Water Research, Spain, produced 11 publications and had an h-index of 10. Notably, six of the 10 most productive authors on the topic of plants for skin care are from Spain, namely Damia Barcelo, Josep Maria Bayona, Juan M. Lema, Victor Matamoros, Francisco Omil, and Yolanda Pico.

The author with the best combination of productivity and scholarly impact in the literature related to botany and skin care is Gang Yu from Tsinghua University, with 13 publications and an h-index of 13. Gang Yu is widely recognized for his research on emerging contaminants (Wang *et al.* 2024, Zhao *et al.* 2025). Publications by Josep Maria Bayona received the highest number of citations (1,467), followed by Victor Matamoros (1,295), Jay Gan (1,195), Damia Barcelo (1,113), and Gang Yu (1,053). Information on the most prolific authors in the field of plants for skin care, along with their total citation counts, can serve as a valuable reference for identifying influential sources for writing, research, and scholarly publications. Furthermore, this information may also be useful for identifying potential collaborators for future research projects, academic writing, and related scholarly activities.

Analyzing the most productive authors in a given discipline can help identify researchers who have made, and are likely to continue making, significant contributions to the development and advancement of a particular research theme. Recognizing key authors in a specific field also aids in identifying individuals who may provide valuable insights for policy-making and contribute to addressing institutional challenges within that field (Bamel *et al.* 2020).

Among the 4,943 authors who contributed to the writing and publication of articles related to plants for skin care, 13 authors were affiliated with institutions in Indonesia. These include six authors from Mulawarman University, two from the National

Research and Innovation Agency, two from the University of Indonesia, one from IPB University, one from Yapkesbi Polytechnic of Health Sukabumi, and one from the Bandung Institute of Technology. Identifying these influential researchers can help bridge diverse research communities, thereby facilitating interdisciplinary collaboration and innovation (Börner *et al*. 2005).

Research collaboration between countries

Understanding the affiliations and national origins of authors involved in research conducted in a specific country provides insight into the extent of international collaboration, the role of local expertise, and the potential for cross-cultural exchange in addressing scientific challenges (Puiu & Bilbiie 2025). When a research paper involves international collaboration, it is attributed to all the countries represented by its co-authors (K-Synth Slr 2023). Research on plant-based skin care has garnered significant global interest, as evidenced by contributions from 77 countries worldwide. A search of relevant databases identified 1,127 selected papers published between 2020 and 2024.

Figure 2 illustrates the international collaboration network among countries that have published research on plant-based skin care. Among the 77 countries contributing to this field, four countries—namely the United States, China, Spain, and India—have each produced more than 50 publications. Indonesia ranks 21st in terms of publication output, with a total of eight publications related to plants for skin care (see Table 2).

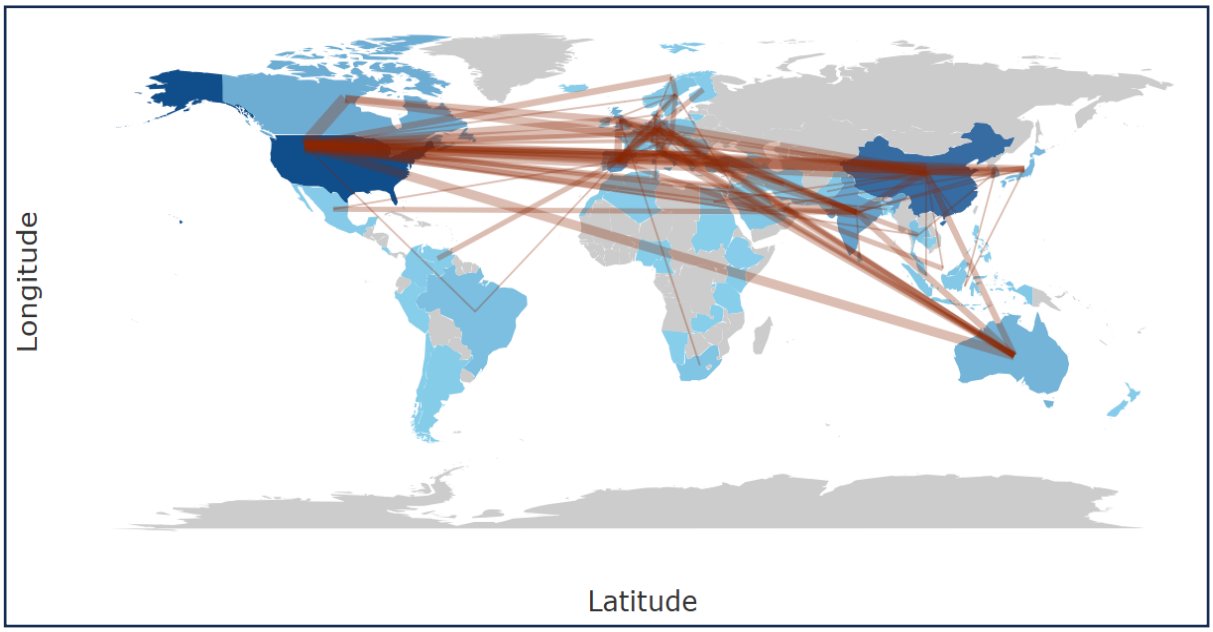

Figure 2. International research collaboration network between countries

Table 7 presents data on the number of collaborative links between countries, as indicated by the weighted connections in Figure 2, in the publication of articles related to plant-based skin care. The analysis of international collaboration reveals that the United States played a central role in fostering research partnerships. Notably, the United States collaborated most frequently with China (26 collaborations), followed by Canada (13 collaborations) and India (11 collaborations).

Table 7. International research collaborations between countries

Ranking	From	To	Frequency
1	United States	China	26
2	United States	Canada	13
3	United States	India	11
4	China	United Kingdom	8
5	United States	South Korea	8
6	Italy	Germany	7
7	United States	Australia	7
8	United States	Germany	7

9	China	Canada	6
10	Spain	Italy	6
.....	.....	.....	.....
.....	Indonesia	Japan	2
.....	Indonesia	Malaysia	1
.....	Indonesia	China	1

China is also a key contributor to international research collaboration, engaging in joint publications with several countries, including the United States (26 collaborations), the United Kingdom (eight collaborations), Canada (six collaborations), and Indonesia (one collaboration). Over the past decade, the collaborative relationship between the United States and China in academic publishing has strengthened, driven by China's growing scientific and technological capabilities—such as increased investment in research and development and improvements in global academic rankings (Lee & Haupt 2020, Schneider *et al.* 2014).

Indonesia has contributed to research publications on plant-based skin care through collaborations with Japan (two collaborations), as well as with Malaysia and China (one collaboration each). The limited number of collaborations and the overall scarcity of research in Indonesia—particularly in the field of plant-based skin care—could be due to several factors, including limited research funding, inadequate infrastructure and facilities, limited involvement and cooperation from the industrial sector, restricted access to international journals, and inconsistent research policies. These findings suggest that substantial potential remains for increased collaboration among developing countries in this area of research.

Many articles demonstrate collaboration between researchers from the host country—where the studies were conducted—and researchers from other nations. The significant presence of authors from the host country reflects a strong dependence on local expertise and a profound grasp of the cultural aspects and ecological context of the botanicals used in local skin care. This local engagement likely enhances the significance of the research in addressing the specific needs and challenges of the region. Moreover, these publications highlight the significance of cross-cultural cooperation, in which partnerships among researchers from different countries encourage the exchange of ideas, methodologies, and perspectives.

International cooperation plays a crucial role in improving the quality and expanding the global influence of scientific research. For researchers, engaging in international partnerships is particularly valuable for sharing best practices and advancing methodological rigor. Additionally, researchers are urged to embrace innovative approaches and interdisciplinary approaches to enable more reliable and comprehensive analyses of plant-based ingredients in skin care research (Puiu & Bilbiie 2025).

Bibliometric analysis can identify which institutions and countries are at the forefront of collaborative research and which continue to be more isolated, thus guiding efforts to enhance research collaboration and promote knowledge sharing (Glänzel & Schubert 2004). Such insights are valuable for shaping policy decisions aimed at encouraging global cooperation and improving the worldwide distribution of scientific knowledge (Chinchilla-Rodríguez *et al.* 2010).

Dissemination of science

To enhance and complement the data analysis, science mapping was conducted to highlight the organizational and dynamic dimensions of the research domain (Cancino *et al.* 2017, Merigó *et al.* 2017). The mapping was developed using several techniques, including bibliographic coupling, co-citation analysis (Small 1973), and keyword co-occurrence analysis (Callon *et al.* 1983). Keyword co-occurrence analysis enabled the quantification and visualization of thematic evolution related to the research topic of plants used in skin care. Science mapping also facilitated the identification of key documents and the examination of the most representative structures and interconnections among actors in the field (Blanco-Mesa *et al.* 2017, Martínez-López *et al.* 2018). This analysis is based on data obtained from co-citation and keyword co-occurrence patterns (Valenzuela *et al.* 2017, Wang *et al.* 2018).

The publication of research on plants for skin care in leading scientific journals demonstrates the international scientific community's recognition and appreciation of the potential of plant-based ingredients in dermatological applications. This trend coincides with the growing need for sustainable solutions in the use of biological resources. The study also highlights a growing trend of collaboration among researchers from various countries and disciplines, with the goal of sharing knowledge and promoting innovation to tackle future global challenges related to the depletion of natural biological resources and the loss of traditional local knowledge.

Figure 3 presents a three-field plot, also known as a Sankey diagram, which visualizes the connections between countries, keywords, and authors. This type of diagram provides insights into the research priorities of individual scholars based on their selection of key terms. The United States, China, and Spain emerge as the three leading countries in contributing to the dissemination of scientific knowledge on the topic of plants for skin care. Frequently used keywords include “pharmaceutical and personal care products (PPCPs)”, “wastewater treatment”, and “personal care products”. Among these, “pharmaceutical and personal care products” appear as the most prominent theme in research outputs from both China and the United States and are widely discussed across multiple authors. Leading contributors in this research field include Gang Yu (Tsinghua University, China), Jun Huang (University of Sydney, Australia), and Jay Gan (University of California Riverside, United States).

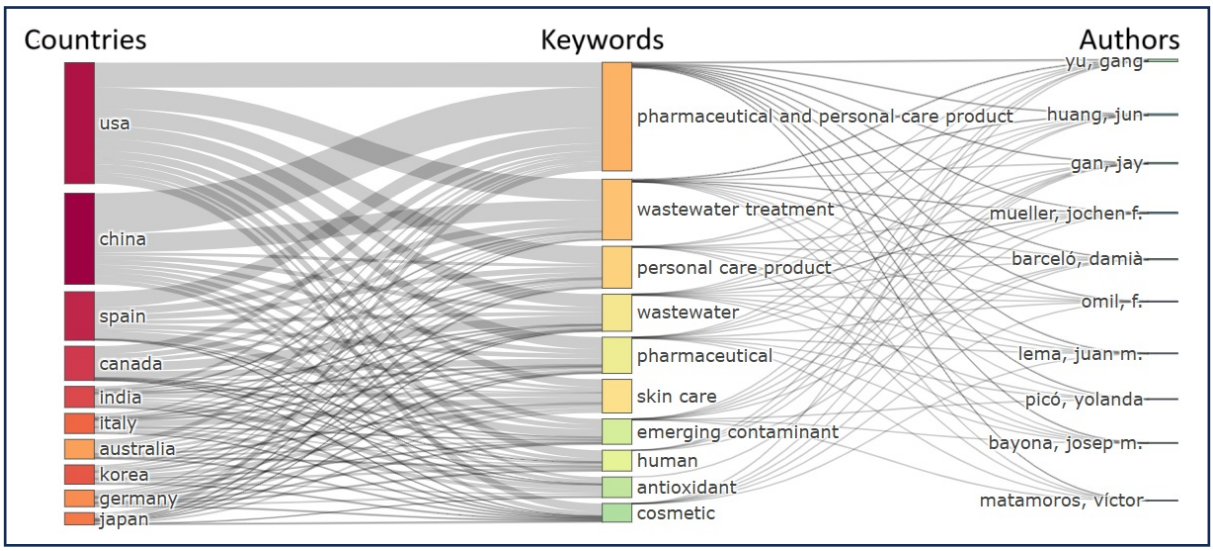

Figure 3. Sankey diagram

The dissemination of knowledge through a range of academic and practical channels is essential for the development of research frameworks that can be implemented across different levels. Scientific publications not only contribute to the advancement of knowledge but also offer practical approaches for utilizing resources more efficiently and sustainably. Science mapping plays a critical role in identifying research trends, fostering technological innovation, and promoting collaborative opportunities among researchers from different countries, thereby supporting the development of effective and applicable solutions.

Trends and directions of scientific research

Research trends related to the use of plants in skin care can be identified through keyword co-occurrence analysis using VOSviewer software. This method enables the visualization of key research topics in a manner that is rapid, unbiased, and replicable (Bamel *et al.* 2020, Grames *et al.* 2019). Furthermore, it facilitates the identification of underexplored or emerging topics by analyzing node dynamics (van Eck & Waltman 2010, Waltman & van Eck 2013).

The keywords used in this visualization consist of author keywords (as defined by the researchers) and index keywords (standardized terms for indexing purposes). Every node in the network diagram stands for a possible keyword and its co-occurrence connections with other keywords (Grames *et al.* 2019). To improve the efficiency of this method, a combination of author-defined and related keywords is employed, with duplicate entries removed to ensure accuracy (Vargas-Quesada *et al.* 2017). The size of each circle represents the number of citations, while the distance between any two circles indicates the degree of similarity or frequency of co-occurrence of the corresponding keywords (Bamel *et al.* 2020).

Figure 4 presents a visualization of the scientific trends and directions related to the use of plants in skin care. A total of 3,432 keywords were identified, of which 156 met the minimum occurrence threshold of 11. The analysis of these 156 keywords revealed three distinct scientific clusters. The most prominent cluster is shown in red, followed by those in green and blue. Each cluster corresponds to a group of related terms or concepts, with keywords within the same color cluster indicating a thematic connection within a specific research area. This form of cluster analysis offers meaningful insights into the core themes and emerging trends within the field (Mazov *et al.* 2020).

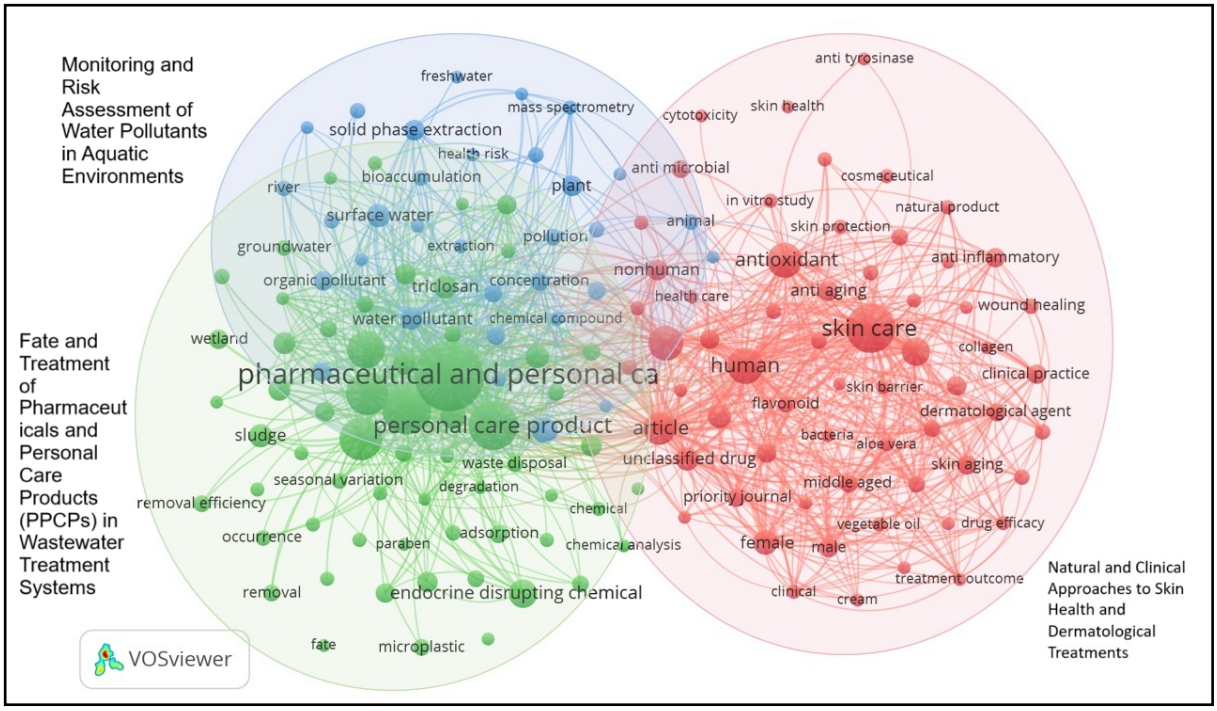

Figure 4. Visualization of scientific trends and directions

In the network visualization, each keyword is represented by a labeled circle. The size of both the label and the circle corresponds to the weight of the keyword; keywords with higher weights—indicating more frequent usage—are displayed with larger labels and circles. The distance between two keywords reflects their relational proximity within the dataset, with closer distances indicating stronger relationships (Franceschet 2009, van Eck & Waltman 2010). The connecting lines (links) represent keyword co-occurrence, and the thickness of each line indicates the strength of that co-occurrence. A more detailed overview of the three scientific clusters related to the topic of plants in skin care is presented in Table 8.

Table 8. Overview of the keyword co-occurrence network analysis using all keywords

Clusters	Thematic Interpretation	Scientific Directions
1 (red)	Main theme: Natural and clinical approaches to skin health and dermatological treatments Subthemes: 1. Skin care and cosmetic products. 2. Natural products and phytotherapy in dermatology. 3. Anti aging and skin protection mechanisms. 4. Clinical and controlled studies on skin diseases. 5. Anti inflammatory and antioxidant effects on skin health.	1. Exploration of natural ingredients, particularly plant extracts and herbal products, as therapeutic agents for skin care, with a focus on anti aging, anti inflammatory, and protection from ultraviolet radiation. 2. Development of cosmetic and cosmeceutical formulations based on natural active ingredients that are supported by clinical evidence of their efficacy. 3. Controlled clinical studies to compare the effectiveness of various dermatological agents in treating frequently occurring skin conditions like acne, psoriasis, and atopic dermatitis. 4. Molecular mechanisms of antioxidants and anti inflammatories in maintaining skin health and slowing down the skin aging process. 5. Evaluation of the role of bioactive components such as flavonoids, polyphenols, and fatty acids in improving skin barrier function and wound healing processes.
2 (green)	Theme: Fate and treatment of pharmaceuticals and personal care products (PPCPs) in wastewater treatment systems.	1. Identification and quantification of emergent contaminants in aquatic environments, especially in domestic and industrial wastewater.

	Subthemes: 1. Pharmaceutical and personal care products that pollute the environment. 2. Wastewater treatment technology in managing PPCPs and other contaminants. 3. Wastewater as the main medium for the presence and movement of emergent contaminants. 4. Quality and composition of liquid waste (effluent) from processing and its impact on the environment. 5. Pharmaceuticals/ pharmaceutical preparations as the main pollutant.	2. Evaluation of the effectiveness of wastewater treatment technologies, like activated sludge, membrane bioreactors, ozonation, and adsorption, in removing PPCPs. 3. Study of the environmental fate and transport of contaminants, including degradation, fate, and plant uptake of PPCPs compounds. 4. Ecological risk assessment and toxicity, including the ecological risk assessment and toxicity of PPCPs compounds to organisms and humans. 5. Exploration of alternative and sustainable waste management strategies, such as waste disposal, sludge management, and water reuse, to reduce water and land pollution.
3 (blue)	Theme: Monitoring and risk assessment of water pollutants in aquatic environments Subthemes: 1. Environmental monitoring of water pollutants. 2. Risk assessment of chemical and organic pollutants. 3. Analytical techniques for pollutant detection. 4. Bioaccumulation and impact on aquatic organisms. 5. Agricultural sources of pollution.	1. Development of multi residue detection methods for water pollutants using chromatography and mass spectrometry. 2. Assessment of human health and ecosystem risks due to water contamination by pesticides, organic compounds, and other anthropogenic pollutants. 3. Study of bioaccumulation and transfer of pollutants from water to the food chain through aquatic organisms. 4. Evaluation of the relationship between agricultural activities and surface water pollution levels. 5. Optimization of environmental monitoring systems based on biophysical and chemical parameters.

The most frequently occurring author keywords in Cluster 1 (red) include skin care, cosmetic, plant extract, and antioxidant. This cluster focuses on the theme of natural and clinical approaches to skin health and dermatological treatments. The publication with the highest number of citations in this cluster is a study by Manela-Azulay and Bagatin (2009), published in the high-impact journal Clinics in Dermatology, which has been cited 110 times. The article highlights that among all cosmetic categories, skin care products demonstrate the fastest-growing sales. These products are available in various formulations, including vitamins, peptides, growth factors, and plant extracts. Topically applied cosmetics containing vitamins are increasingly significant in dermatological care and are becoming essential tools for dermatologists. The rising demand to counteract the signs of aging has notably influenced both society and dermatological practices. Common aesthetic medical procedures include chemical peels, botulinum toxin injections, laser treatments, and soft tissue augmentation.

Another influential article within Cluster 1 is a study by Singh and Agarwal (2009), published in the high-impact journal Clinics in Dermatology, which has been cited 78 times. The study explains that cosmetics are not only applied to nourish and improve the skin's appearance but also serve as effective agents in the treatment of various dermatological conditions. Herbal-based cosmetic formulations are particularly popular due to their generally low toxicity and potent antioxidant properties. One such compound is silibinin, a flavonolignan derived from *Silybum marianum* (milk thistle), which exhibits strong antioxidant activity and modulates numerous molecular changes induced by xenobiotics and ultraviolet radiation, thereby protecting the skin. Silibinin has shown promise in managing various dermatological conditions and in mitigating skin aging. Additionally, a study by Ehrlich *et al.* (2006), cited 63 times and published in the highly reputable journal Dermatologic Surgery, introduces a novel anti aging treatment approach that utilizes growth factors and cytokines.

The most prominent author keywords in Cluster 2 (green) include PPCPs, wastewater treatment, personal care products, wastewater, and effluent. This cluster primarily focuses on the fate and treatment of PPCPs within wastewater treatment systems. Among the most frequently cited publications in this cluster is a study by Loos *et al.* (2010), published in Water Research—a highly reputable journal—which has received 980 citations. This publication presents the development of a model for integrating Geographic Information System (GIS), interactive systems, user applications, and dynamic visualizations of water pollution incidents.

Another influential study is by Wu *et al.* (2010), published in Environmental Science and Technology (also a highly regarded journal), which has been cited 358 times. The authors highlight the existence of various PPCPs in solid waste and wastewater treatment plant residues, emphasizing their potential to accumulate in plants. Similarly, Sui *et al.* (2011), in a publication also appearing in Environmental Science and Technology and cited 333 times, examine the occurrence and removal of PPCPs in wastewater treatment plants. This research evaluates three biological treatment methods: conventional activated sludge, biological nutrient removal, and membrane bioreactors. It concludes that membrane bioreactors are moderately effective at removing compounds such as diclofenac, trimethoprim, metoprolol, and gemfibrozil, whereas the other methods show lower removal efficiency.

The most prominent author keywords in Cluster 3 (blue) include water pollutant, environmental monitoring, and concentration. This cluster focuses on monitoring and assessing the risks of water pollutants in aquatic environments. The study by Halden and Paull (2005) is the most cited publication in this cluster, published in Environmental Science and Technology—a highly reputable journal—which has been cited 544 times. The article investigates triclocarban (TCC), an antimicrobial agent commonly used in personal care products, and highlights the limited understanding of its environmental impact. The study reveals that TCC tends to persist in various environmental compartments, underscoring the need for thorough evaluation of its ecological and human health risks.

Another notable publication is by Kuroda *et al.* (2012), published in Environmental Science and Technology—a highly reputable journal—and cited 128 times. This study investigated groundwater contamination in urban areas of Tokyo by selected PPCPs (including diethyltoluamide, crotamitone, ethenzamide, propyphenazone, carbamazepine, and caffeine), as well as *Escherichia coli*, across 50 groundwater sources. The contamination was attributed to a compromised sewage infrastructure. Another important contribution within Cluster 3 is the study by Matamoros *et al.* (2010), published in Analytical Chemistry—also a highly respected journal—which has been cited 112 times. The researchers designed a method to identify target analytes in four rivers experiencing different levels of human-induced impact. Their analytical technique utilized comprehensive two-dimensional gas chromatography (GC×GC) combined with time-of-flight mass spectrometry (TOF-MS).

Thematic evolution of knowledge

To examine how conceptual structures evolve over time, a temporal analysis should be incorporated (Laengle *et al.* 2017). This approach enables the identification of shifts in research interest across different periods (Merigó *et al.* 2018, Tur-Porcar *et al.* 2018). Thematic evolution of knowledge can be explored by utilizing databases such as Scopus, Web of Science (WoS), or Dimensions to identify and analyze relevant empirical studies on the use of plants in skin care (Cortez-Clavo *et al.* 2015).

The concept of thematic evolution related to this research was analyzed using the Bibliometrix-Biblioshiny tool based on author keywords. Figure 5 illustrates the evolution of publications on skin care research, highlighting the most frequently studied topics (Gaviria-Marín *et al.* 2019). The width of the connecting lines between research themes represents the strength of thematic linkage and the volume of publications associated with each topic.

Over the 24-year research period, the thematic evolution of studies on skin care can be categorized into four distinct phases: 2000-2013, 2014-2017, 2018-2021, and 2022-2024 (Figure 5). From 2000 to 2024, a consistent thematic trend persisted, centered around core topics linked to pharmaceutical and personal care products. From this foundational theme, broader research areas related to general skin care emerged and remained prominent until 2021. Starting in the 2022-2024 period, the thematic landscape began to diversify, with the emergence of more specific topics such as *Acne vulgaris*, anti aging, atopic dermatitis, inflammation, and ultraviolet protection. This thematic evolution reflects a critical step in scientific development, promoting the enhancement and adjustment of technologies that are becoming more embedded in daily life, thus boosting efficiency and generating economic value (Almeman 2024).

Figure 5 presents the emerging trends in research topics related to skin care during the 2022-2024 period. While these topics have already received some scholarly attention, they remain promising and warrant further investigation, making them viable areas for future research. Notably, themes such as *Acne vulgaris*, anti aging, and ultraviolet protection continue to show significant potential for exploration. This indicates sustained academic and practical interest in the field, largely due to its relevance and applicability in everyday personal care practices.

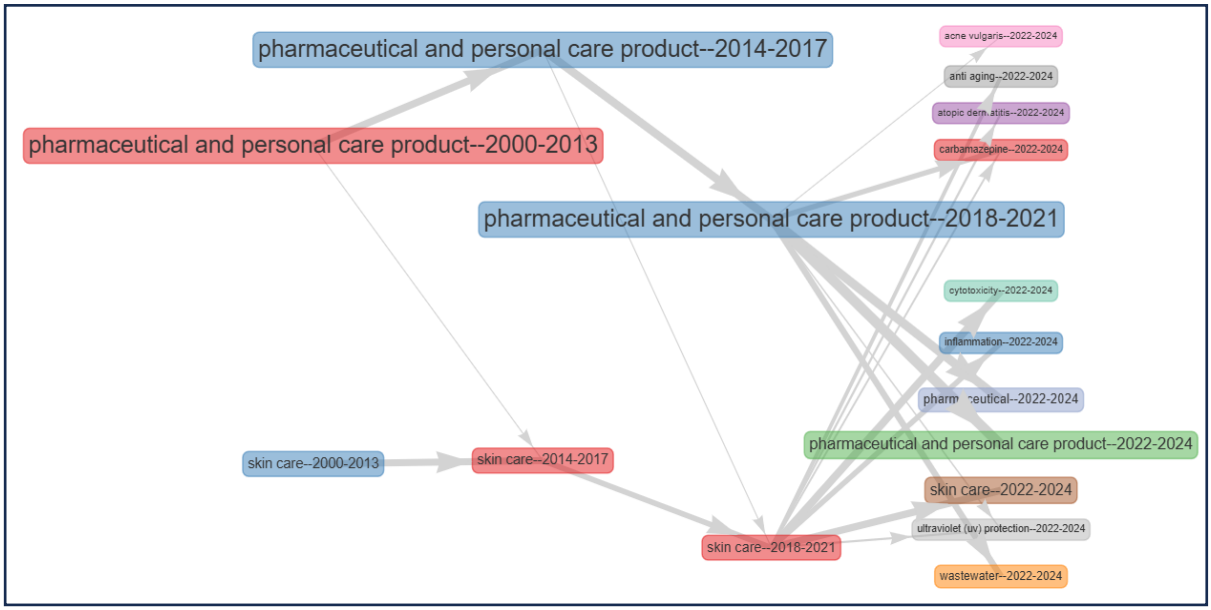

Figure 5. Thematic evolution in skin care-related research

There is a substantial number of publications in high-impact journals addressing topics such as *Acne vulgaris*, anti aging, and ultraviolet protection. As an example, research conducted by Zhang *et al.* (2024), published in the Journal of Cosmetic Dermatology, examined the synergistic anti-inflammatory effects of *Guaiacum officinale* and *Rhodomyrtus tomentosa* extracts, demonstrating their efficacy in improving *Acne vulgaris* and reducing skin redness. Similarly, Nema *et al.* (2013), in a publication in Pharmaceutical Biology, reported that *Centella asiatica* extract containing asiaticoside exhibits promising skin care potential due to its anti elastase and anti hyaluronidase activities, with IC_{50} values of 19.27 ± 0.37 and 14.54 ± 0.39 µg/mL, respectively, when compared to ursolic acid. Additionally, research by Antognoni *et al.* (2017) highlighted that the red berries of *Hypericum androsaemum* contain phytochemicals that promote skin regeneration, making them a promising ingredient for use in skin care formulations.

Positioning of skin care research

A bibliometric analysis highlights significant potential for advancement and innovation through the integration of keyword network mapping. This approach provides a thorough summary of existing research and highlights possible directions for future investigation and advancement. Figure 6 presents the positioning of skin care research in relation to other associated topics. In Figure 6, the size of each node (circle) indicates how frequently a keyword appears, while the color of the nodes reflects the average publication year linked to each keyword. The closeness of the nodes illustrates the level of association between keywords, whereas overlapping nodes signify how often the keywords appear together within the network (Bamel *et al.* 2020).

The evolution of prominent research topics over time can be observed through the co-occurrence of keywords in the density visualization presented in Figure 6. The color gradient in the visualization represents the distribution of keywords over time, ranging from purple (2010), blue (2012), blue to green (2014), green (2016), green to yellow (2018), and yellow (2020).

For instance, the keyword “dermatitis contact” emerged around 2010, “skin aging” around 2012, “cosmetic” around 2014, “skin care” around 2016, “antioxidant” around 2018, and “anti aging” around 2020. This timeline suggests that research on plant-based skin care initially focused on treating skin conditions (e.g., contact dermatitis) and has progressively shifted toward cosmetic applications, particularly those focusing on particular issues like anti aging.

Notable and promising research topics that continue to attract attention include the use of plants and anti aging strategies. Plants remain a compelling area of study due to the growing public interest in body care and treatments utilizing natural ingredients derived from botanical sources. Research in this area may involve exploring the properties of the plants themselves or their application in skin care products. Anti aging research focuses on understanding the biological processes of aging, its impact on health, and strategies for prevention or intervention. Additionally, antioxidants remain a valuable subject of investigation due to their significant role in promoting health, preserving beauty, and preventing various diseases.

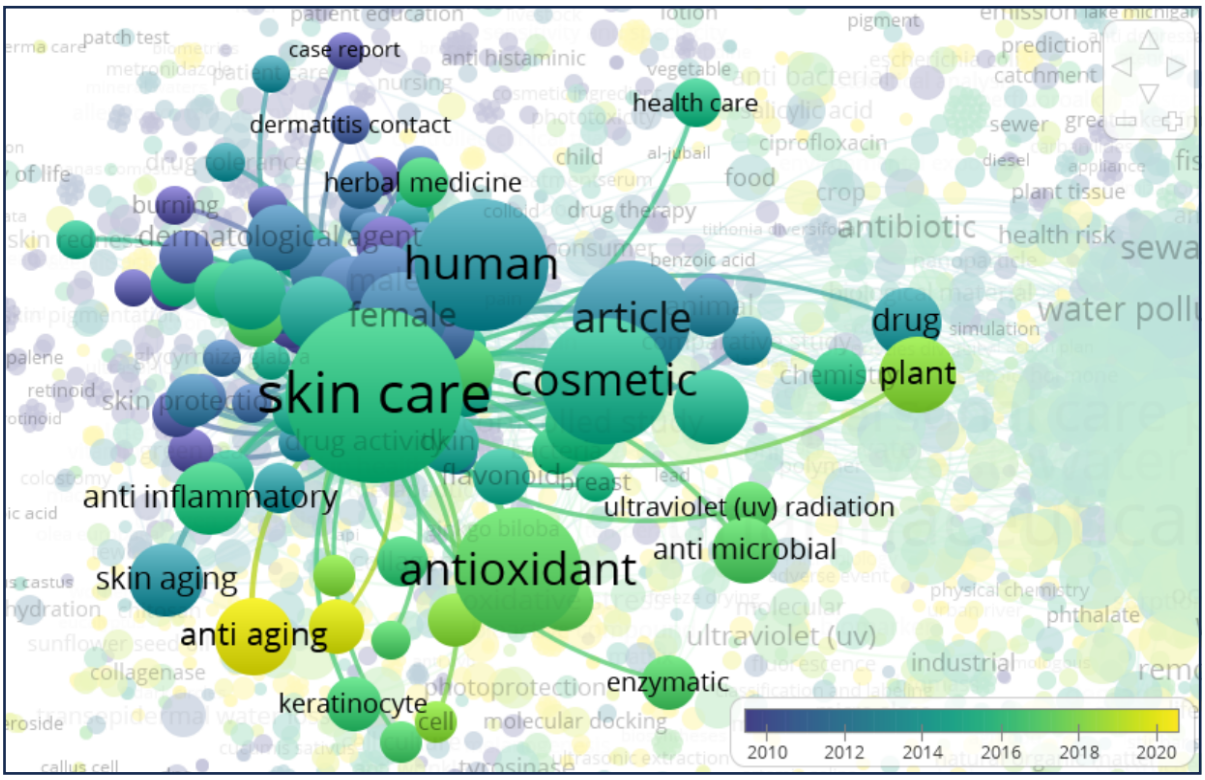

Figure 6. Timeline and research positioning

Study Limitations

Although this bibliometric analysis is comprehensive, several limitations remain. The first arises from the query design (TITLE: ((plant* OR herb* OR botan*) AND (skincare OR “skin care” OR “beauty routine” OR “skin treatment” OR “dermatological care” OR “skin maintenance” (Table 1). While we aimed to construct and map the query to capture the full scope of research on the development and application of botanical ingredients in global skin care products, the results were dominated by environmental science literature. The leading contributing journals (e.g., Science of the Total Environment, Chemosphere), the most productive authors (e.g., Gang Yu, Damià Barceló), and the identified research clusters largely focused on the fate, occurrence, and management of pharmaceuticals and personal care products (PPCPs) as pollutants in wastewater and aquatic systems.

This bibliometric analysis primarily maps scientific discourse on the environmental impacts of synthetic chemicals in PPCPs, rather than on the formulation, efficacy, or mechanisms of plant-derived ingredients in skin care. This indicates that research on botanical-based cosmetics remains a smaller subset compared to the broader environmental studies of PPCPs. The terminology used in titles, abstracts, and keywords is biased toward environmental contexts. Future bibliometric studies aiming to explore plant-based cosmetic applications should employ more precise search strategies and focus on journals dedicated to botany, herbal studies, biology, and cosmetic science.

Data analysis in bibliometric studies is inherently constrained by the coverage and indexing accuracy of the selected database, in this case Scopus. Although Scopus is widely recognized, it does not capture all relevant publications, particularly those in local journals or non-indexed books. Finally, bibliometric approaches are quantitative in nature, effectively identifying trends, volumes, and relationships, but not assessing qualitative aspects of research, such as methodological rigor or the efficacy of botanical ingredients.

Conclusion

This bibliometric analysis highlights the accelerating global interest in botanical-based ingredients for skin care, driven by consumer demand for natural and sustainable solutions. The United States remains the leading contributor in terms of research output, collaborations, and influence, followed by China, Spain, Canada, and India. Thematic mapping reveals three core research domains: dermatological applications of botanicals, the environmental fate of pharmaceuticals and personal care products, and the monitoring of aquatic pollutants. Although the field is still dominated by environmental perspectives,

recent years demonstrate a clear shift toward clinical and cosmetic applications, including acne, anti-aging, inflammation, and ultraviolet protection. Future progress will depend on overcoming consumer skepticism and expanding dermatology-focused investigations through targeted awareness, professional training, and interdisciplinary collaboration. Strengthened partnerships among academia, industry, and government, particularly in developing countries will be essential to bridge knowledge gaps and advance the sustainable integration of botanicals into modern skin care.

Declarations

List of abbreviations: Not applicable

Ethics approval and consent to participate: The study was conducted following ISE Code of Ethics Guidelines (ISE 2008).

Consent for publication: Not applicable

Availability of data and materials: All supporting data are summarized in the main and supplementary tables within the article**.**

Competing interests: The authors declare that they have no conflict of interest.

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