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DERLEME /REVIEW

REVEALING THE MULTIFACETED LANDSCAPE OF PROPOLIS RESEARCH (1945-2023): A COMPREHENSIVE ANALYSIS OF DYNAMICITY, SPATIOTEMPORAL TRENDS, AND EMERGING PARADIGMS IN SCHOLARLY DISCOURSE

Propolis Araştırmalarının Çok Yüzlü Görünümünü Açığa Çıkarma (1945-2023): Dinamiklik, Zamansal-Mekansal Eğilimlerin veYeni Paradigmaların Kapsamlı Analizi

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ABSTRACT

Propolis, a natural resinous substance produced by bees, has long been known for its potential health benefits. This study aims to present a comprehensive bibliometric investigation, exploring the dynamicity, spatiotemporal trends, and emerging patterns in the scholarly discourse surrounding propolis research. The study tailed PRISMA guidelines and used MeSH databases and Scopus to retrieve relevant bibliographic data spanning 75 years. R-based Bibliometrix and VOSviewer applications were employed for data analysis. A noticeable increase in scholarly production was observed in the last two decades. Active participation in propolis research was identified from Brazil, China, and Türkiye. The multidimensional nature of propolis research was evident through the diversity of topics covered in highly impactful research and intellectual maps of information sources. Thematic evolution highlighted the dynamic nature of propolis research, with emerging areas of investigation and an enhanced understanding of its therapeutic applications. Five prominent themes emerged: "propolis," "oxidative stress," "honey," "beeswax," and "allergic contact dermatitis." Additionally, emerging themes included chronic kidney disease, COVID-19, and metabolomics. Mapping international cooperation and co-citation of authors demonstrated multiple research activities. The findings of this study hold implications for researchers, healthcare professionals, and policymakers, providing insights into the current landscape of propolis research.

Keywords: Propolis, Bioactive Compounds, Therapeutic Potential, Antimicrobial, Bibliometrics

ÖZ

Arılar tarafından üretilen doğal reçinemsi bir madde olan propolis, sağlık açısından potansiyel faydaları ile uzun zamandır bilinmektedir. Bu çalışma, propolis araştırmalarını çevreleyen bilimsel söylemdeki dinamikliği, mekansal-zamansal eğilimleri ve ortaya çıkan kalıpları keşfederek kapsamlı bir bibliyometrik araştırma sunmayı amaçlamaktadır. Çalışmada PRISMA yönergeleri izlenmiş ve 75 yılı

kapsayan ilgili bibliyografik verileri elde etmek için MeSH veri tabanları ve Scopus kullanılmıştır. Veri analizi için R tabanlı Bibliometrix ve VOSviewer uygulamaları kullanılmıştır. Son yirmi yılda bilimsel üretimde gözle görülür bir artış gözlemlenmiştir. Brezilya, Çin ve Türkiye'den propolis araştırmalarına aktif katılım tespit edilmiştir. Propolis araştırmalarının çok boyutlu doğası, son derece etkili araştırmalarda ele alınan konuların çeşitliliği ve bilgi kaynaklarının entelektüel haritaları ile ortaya çıkmıştır. Tematik evrim, propolis araştırmalarının dinamik doğasını, ortaya çıkan araştırma alanlarını ve terapötik uygulamalarının daha iyi anlaşılmasını vurgulamıştır. Öne çıkan beş tema olarak: "propolis", 'oksidatif stres', 'bal', 'balmumu' ve 'alerjik kontakt dermatit'tir. Ek olarak, ortaya çıkan temalar arasında kronik böbrek hastalığı, COVID-19 ve metabolomikler yer almaktadır. Uluslararası işbirliğinin ve yazarların ortak atıflarının haritalanması, çoklu araştırma faaliyetlerini göstermiştir. Bu çalışmanın bulguları, araştırmacılar, sağlık uzmanları ve politika yapıcılar için çıkarımlar içermekte ve mevcut durum hakkında içgörü sağlamaktadır.

Anahtar Kelimeler: Propolis, Biyoaktif Bileşikler, Terapötik Potansiyel, Antimikrobiyal, Bibliyometri

GENİŞLETİLMİŞ ÖZET

Amaç: Arılar bitkilerden reçine toplayıp kendi salgılarıyla karıştırarak propolis adı verilen harika bir madde üretir ve kovanlarını dışarıdan gelebilecek tehlikelere karşı korumak için kullanırlar. Birçok uygarlık boyunca, geleneksel ilaçlar bu doğal bileşenden geniş ölçüde yararlanmıştır. Propolis son zamanlarda bilimsel açıdan oldukça ilgi çekmiş ve tıbbi olanaklarını ortaya çıkarmaya yönelik çalışmalarda bir patlama yaşanmıştır. Bu araştırma, arılar tarafından üretilen ve sağlık açısından potansiyel faydaları olan doğal bir madde olan propolis dünyasını incelemeyi amaçlamaktadır. Kapsamlı bir bibliyometrik analiz yaparak, propolis araştırmalarını çevreleyen bilimsel tartışmalarda değişen eğilimleri, coğrafi kalıpları ve yeni içgörüleri ortaya çıkarmak amaçlanmıştır.

Gereç ve Yöntemler: PRISMA tarafından özetlenen yönergeleri izleyerek, MeSH veritabanlarını ve Scopus'u titizlikle tarayarak 75 yıllık etkileyici bir süreyi kapsayan zengin bibliyografik veriler toplanmıştır. Verileri analiz etmek için R tabanlı Bibliometrix ve VOSviewer araçları kullanılmıştır.

Bulgular: Araştırmamız, son yirmi yılda bilimsel çıktılarda çarpıcı bir artış olduğunu ortaya koyarak propolis araştırmalarına olan ilginin arttığını göstermektedir. Brezilya, Çin ve Türkiye gibi ülkeler propolisin potansiyelini keşfetme konusundaki aktif katılımlarıyla öne çımaktadır. Propolis araştırmalarının çok yönlü doğası, ele alınan çeşitli konular aracılığıyla canlı bir şekilde tasvir edilmiş, etkili araştırma bulgularına ve aydınlatıcı bilgilere yol açmıştır. Uluslararası işbirliği ve yazar ortak atıflarının incelenmesi, propolis araştırmalarını ileriye götüren küresel erişimi ve işbirlikçi ruhu ortaya koyan, birbirine bağlı araştırma faaliyetleri ağını ortaya çıkarmıştır.

Sonuç: Sonuç olarak, çalışmanın bulguları propolis araştırmaları için akademi, sağlık uygulamaları ve politika oluşturma alanlarında yankı uyandıran geniş kapsamlı çıkarımların altını çizmektedir. Propolis araştırmalarının dinamikliği ve gelişen manzarası, keşif ve yenilik için olgunlaşmış canlı bir alana işaret etmektedir. Sağlam klinik deney kanıtlarından yararlanarak propolis, kanıta dayalı profesyonel onaylarla desteklenen ana akım sağlık hizmetlerinde önemli bir yer edinmeye hazırdır. Propolisin tüm terapötik potansiyelini ortaya çıkarmak için, etki mekanizmalarını aydınlatmaya, disiplinler arası ortaklıkları teşvik etmeye ve titiz klinik deneyler yürütmeye yönelik ortak bir çaba zorunludur. Bu uyumlu yaklaşım sadece propolis anlayışımızı geliştirmekle kalmayıp, aynı zamanda propolisin terapötik müdahalelerin geleceğini şekillendirmede oynayabileceği önemli rolü vurgulayarak daha iyi sağlık sonuçlarının yolunu açmaktadır.

Gelecekte yapılacak çalışmalar, propolisin etki mekanizmalarının kapsamlı bir şekilde araştırılması için stratejiler geliştirmeli, özellikle ikincil metabolitlerinin ve sağlık yanlısı etkileri için konjugatlarının özelliklerini belirlemelidir. Farmakoloji, immünoloji ve doğal ürünlerin kimyası gibi şu anda çok ayrı olan alanların entegrasyonu, sinerjik etkisi de dahil olmak üzere propolis hakkındaki bilgileri ilerletecek ve tıbbi faaliyetlerinin en iyi şekilde kullanılmasıyla yeni formülasyon ve tedavilerle sonuçlanacaktır.

Bununla birlikte, çeşitli popülasyonlar için propolisin güvenliğini, etkinliğini ve etkili dozlarını kanıtlamak için uygun klinik çalışmalar da gereklidir. Böylece bu doğa ürünü, uygulayıcılar için kanıta dayalı önerilerle

geleneksel tıbbın bir parçası olacaktır. Etki mekanizmasını daha derinlemesine inceleyerek, disiplinler arası işbirliklerini teşvik ederek ve iyi klinik çalışmalar yaparak, propolisin gerçek terapötik Değerini takdir edebiliriz ve sağlık hizmetleri gelişecektir.

INTRODUCTION

Propolis (bee glue) is a remarkable material that bees create by collecting resins from plants, combining them with their own secretions, and utilizing them to protect their hives from external threats (Irigoiti *et al.* 2021; Park, Alencar and Aguiar 2002). This natural substance has been widely used in traditional remedies across different cultures. In recent times, propolis has gained significant scientific interest, leading to a surge in research aimed at unravelling its therapeutic potential (Peršurić and Pavelić 2021; Roquetto *et al.* 2015).

The chemical composition of propolis underlies its potential health benefits. Propolis is a multipart mixture of chemicals derived from botanical sources. It contains various compounds, including flavonoids, phenolics, and terpenoids. The occurrence of these bioactive ingredients gives propolis a wide spectrum of properties, including antioxidant, antimicrobial, and anti-inflammatory effects (Ding *et al.* 2015; Jansen-Alves *et al.* 2023; Suleiman *et al.* 2021). Flavonoids contribute to propolis' antioxidant and anti-inflammatory properties, protecting cells from oxidative stress and reducing inflammation. Phenolic compounds in propolis exhibit antimicrobial and antifungal effects, inhibiting the growth of microorganisms (Fonseca *et al.* 2011; Ożarowski and Karpiński 2023; Salami *et al.* 2024). Terpenoids found in propolis contribute to its antimicrobial and antiviral activities. The specific composition of propolis varies based on factors like location and season, influencing its bioactivity. The synergistic effects of its compounds further add to its therapeutic properties (Suleiman 2021; Valverde *et al.* 2023; Zullkiflee, Taha and Usman 2022).

Bibliometric studies play a vital role in research by providing a quantitative assessment of the scientific literature. They offer valuable insights into publication trends, citation patterns, collaboration networks, and emerging research areas. By analyzing the scientific landscape, bibliometric studies help researchers identify knowledge gaps, influential authors, and top contributing institutions and countries (Fardi, Kodonas and Gogos 2023; Fox *et al.* 2023; Guo *et al.* 2023). These studies aid in understanding the current state of any research, guiding researchers in selecting research directions, fostering collaborations, and promoting advancements. Bibliometric studies are essential for evidence-based decision-making, shaping research strategies, and facilitating the dissemination of knowledge in the field of research (Fardi, Kodonas and Gogos 2023; Guo 2023). Therefore, the present study was intended to conduct a holistic bibliometric analysis of propolis research, mapping the scientific landscape in terms of publication outputs, collaboration networks, citation patterns, and key research topics. The study aims to provide understandings into the current state of propolis research, identify influential authors, institutions, and countries, and highlight emerging research areas. The findings will contribute to a deeper understanding of the field, guide future research directions, foster collaborations, and facilitate evidence-based decision-making in propolis research.

MATERIALS AND METHODS

Data Source, Search Strategy, and Data Collection

The Scopus database was utilized as the main source for this bibliometric study. Scopus provides a comprehensive collection of scholarly publications from various disciplines (Falagas *et al.* 2008). The search strategy involved the use of relevant keywords and MeSH terms (Dhammi and Kumar 2014) to retrieve publications related to propolis research. The keywords used were "Bee Bread," "Bee Glue," and "Propolis." These terms were selected based on their association with propolis in the MeSH Browser (https://meshb-prev.nlm.nih.gov/record/ui?ui=D011429). The search was conducted within Scopus using the identified keywords to retrieve data-driven research. Therefore, the search results were filtered to include only articles, excluding other types of documents such as conference papers, reviews, and editorials. Articles written in languages other than English or those that were still in the press were also not included. The PRISMA guidelines (Şalvarlı and Griffiths 2021) were followed to ensure a systematic and apparent approach to data collection and analysis (Figure 1). PRISMA, or Preferred Reporting Items for Systematic Reviews and Meta-Analyses, is

a framework that was conceived with the intention of using heretofore untapped ideas in a systematic review increasing the quality of reporting and accountability therein. Some of it incorporated a checklist that we followed which contained, inter alia, the title, abstract, background, aims, methodology (eligibility criteria as well as search strategy), outcome (in this setting: selection and characteristics of studies) and conclusion (in this context, interpretation of the evidence and its weaknesses). Also, we oriented the reader with step-wise representation in the form of flow diagram in which the process of selecting the studies was demonstrated along with how many studies were identified, how many more were screened and how many were finally excluded and why were they excluded. Embedded in each of these activities, we incorporated PRISMA with respect to different domains of research enhancing the reproducibility of our work. These guidelines ensured that readers soothe their critics by understanding our clinical methods as well as the evidence we found which will ultimately enhance the knowledge base of clinicians and nurture evidence-based care. We also implemented some changes of PRISMA to keep up with the changing needs of reporting, employing special mechanisms like PRISMA-P for protocol to the extensions for various types of research.

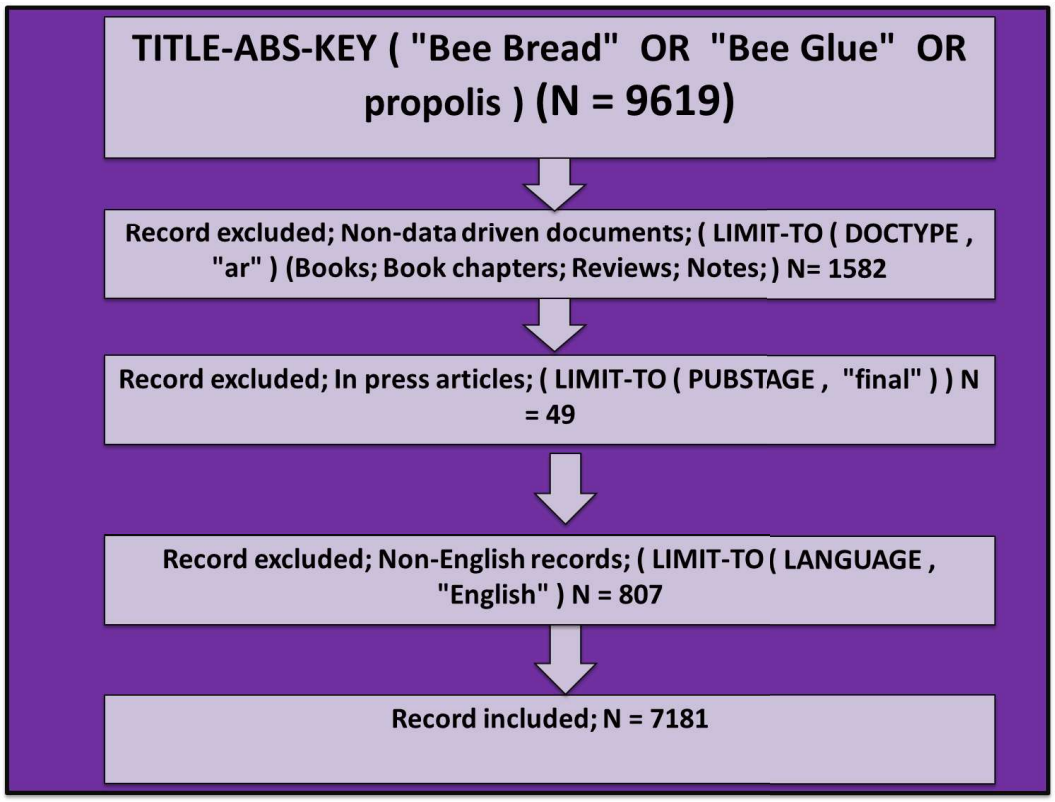

Figure 1. The PRISMA guidelines were diligently followed to ensure a systematic and transparent approach to data collection and analysis. The search and selection criteria were meticulously employed in accordance with the PRISMA guidelines. "ar" denotes the article type, and "DOCTYPE" refers to the type of documents included in the study. The data was extracted on October 2, 2028.

Data Analysis

The collected dataset was analyzed using bibliometric techniques to extract relevant information using VOSviewr (Van Eck and Waltman 2011) and Bibliometrix (Aria and Cuccurullo 2017) applications. The analysis encompassed various aspects, including publication outputs, citation patterns, collaboration networks, and key research topics. The number of publications related to propolis research was recorded and analyzed to identify trends in publication output over time using

regression. This included the total number of publication and annual publication counts. The citation patterns of the identified countries and publications were examined to determine the influence of propolis research. This involved analyzing the number of citations received by each publication, identifying highly cited articles, and exploring the citation networks among the identified publications. Co-authorship analysis was performed to assess the collaboration networks within propolis research. This involved identifying the most prolific countries contributing to propolis research and mapping their collaborative relationships. Keyword co-occurrence analysis was conducted to identify the key research topics within propolis research. This analysis involved identifying the most frequent keywords in the publications and exploring their relationships to uncover emerging research areas and popular themes. The findings from the data analysis were interpreted to provide an understanding of the present state of propolis research. The results were used to identify knowledge gaps, prominent authors and institutions, collaboration opportunities, and emergent research areas.

Ethical Considerations

Ethical considerations regarding data privacy and confidentiality were taken into account during the data collection and analysis process. No ethical approval is required as no human subjects are involved.

RESULTS

Hotspots

The hotspots reveal key contributors in terms of authors, affiliations, and countries. In propolis research, there are a total of 25,004 authors involved, indicating the collaborative nature of the field. Among these authors, 204 have contributed as single authors, implying that they have authored research documents individually without any co-authors. Among the top authors, Bankova, V. (Bulgaria) leads with 106 publications, followed by Bastos, J.K. (Brazil) with 80 publications, and Sforcin, J.M. (Brazil) with 75 publications. The most contributed topics by Bankova, V. include pinobanksin and stingless bees, eutectics and choline, electroplating, geraniin, antioxidants, and tannins. Notable affiliations include the University of São Paulo, with 340 publications; São Paulo State University, with 190 publications; and Public Research University in Campinas (Brazil), with 148 publications. Brazil emerges as the leading country in propolis research with 1,197 publications (Figure 2), followed by Türkiye (627), the United States (532), China (462), and Japan (404). The cumulative production of the top ten countries accounts for 53.70% of the global production in propolis research. These hotspots highlight the noteworthy contributions made by authors, affiliations, and countries in progressing propolis research.

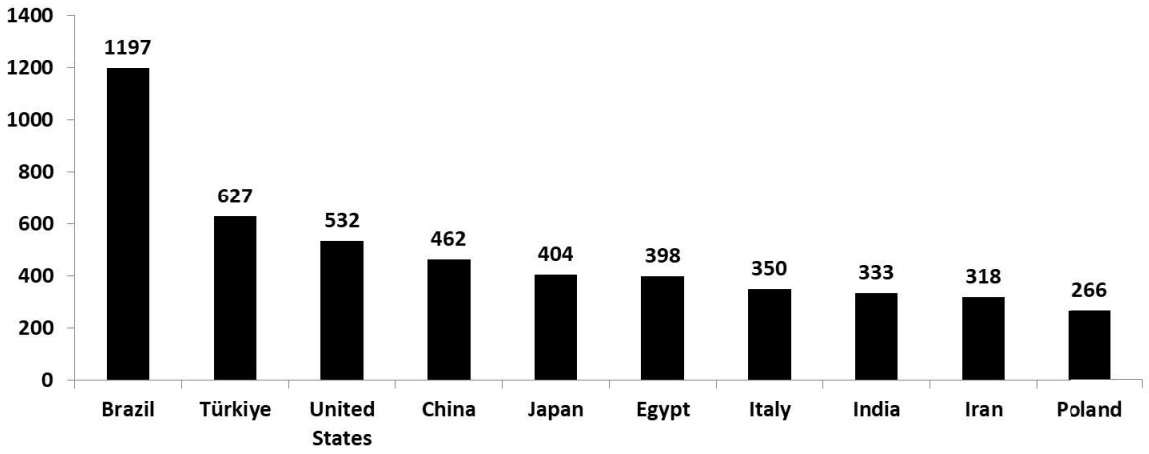

Figure 2. Top-Publishing Countries in Propolis Research. In this figure, the number of articles is represented on the x-axis, while the countries contributing to propolis research are listed on the y-axis. The chart highlights the distribution of research output across different countries in the field of propolis studies.

Sources

With 2110 sources (journals) in propolis research, it demonstrates the extensive and robust body of literature dedicated to studying and exploring the various aspects of this natural substance. Scholars from different disciplines contribute to these journals, further advancing our understanding of propolis and its prospective applications in various fields. The abundance of sources reflects the ongoing interest and significance of propolis as a subject of scientific inquiry and its potential for various therapeutic and agricultural applications. In propolis research, the top sources contributing to the field include "Molecules" with 145 publications, "Evidence-Based Complementary and Alternative Medicine" with 143 publications, "Journal of Apicultural Research" with 102 publications, "Contact Dermatitis" with 97 publications, "Journal of Agricultural and Food Chemistry" with 88 publications, "Food Chemistry" with 86 publications, and "Journal of Ethnopharmacology" with 85 publications. These sources have played a crucial role in disseminating knowledge and advancements in propolis research. Regarding the classification of subjects, the field of propolis research spans various disciplines. The primary subject areas include Agricultural and Biological Sciences with 2064 publications, Medicine with 1988 publications, Biochemistry, Genetics and Molecular Biology with 1914 publications, Pharmacology, Toxicology and Pharmaceutics with 1808 publications, and Chemistry with 1269 publications. Additionally, other subject areas contributing to propolis research include Immunology and Microbiology, Chemical Engineering, Environmental Science, Dentistry, Materials Science, Veterinary, Engineering, Multidisciplinary, Nursing, Physics and Astronomy, Computer Science, Health Professions, Neuroscience, Social Sciences, Energy, Economics, Econometrics and Finance, Earth and Planetary Sciences, Mathematics, Business, Management and Accounting, Psychology, Arts and Humanities, and Decision Sciences. This multidisciplinary nature of propolis research reflects its significance and wide-ranging implications across various scientific domains.

Expansion

From 1945 to 2023, propolis research has demonstrated consistent growth in annual production, as depicted in Figure 3. The average annual growth rate of 1.4% reflects a gradual escalation in the number of research documents over the years. Based on the data, the mean age of the papers in the dataset is 9.46 years. While there have been occasional fluctuations and plateaus in annual production, the overall trajectory showcases an expanding body of research in propolis. The annual growth was analyzed using polynomial regression, and the R-squared value obtained was 0.887. Recent years have witnessed a significant surge in propolis research output, with 434 documents published in 2023, 590 in 2022, and 641 in 2021. This upward trend underscores the growing interest and importance of propolis as a subject of scientific investigation. The early years of propolis research saw relatively few publications, but as the field has advanced, there has been a substantial upsurge in research output. Collectively, these findings reflect the rising attention and research activity in the field of propolis, emphasizing its recognized potential benefits and applications across diverse disciplines.

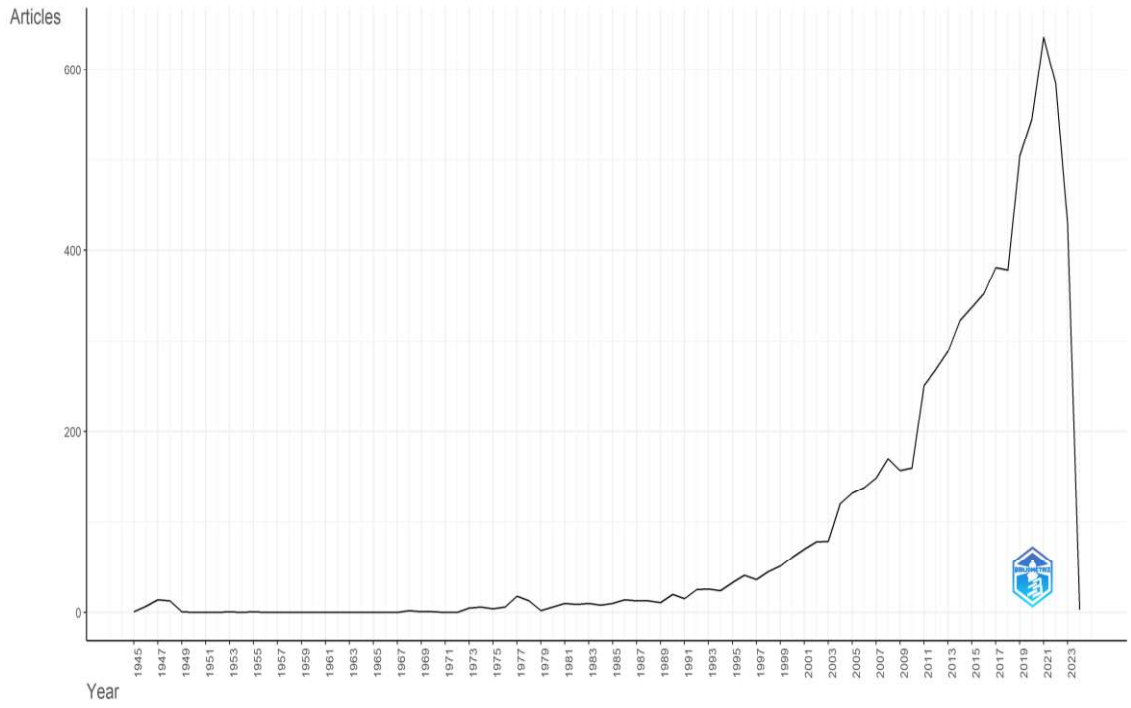

Figure 3. Annual Growth of Propolis Research (1945-2023). The y-axis represents the number of articles published, while the x-axis denotes the years since the first article was published on the topic discussed in this paper. This chart illustrates the progression of propolis research over time, showcasing the increasing trend in scholarly output related to propolis from 1945 to 2023.

Three-field plot

The Sankey diagram, also known as a three-field plot, visually represents the flow of relationships between authors, countries, and sources in a normalized manner. The larger rectangular within each category allow for easy assessment of the relationships among the elements. The color intensity and size of the rectangles indicate strong connections between authors such as "Bastos J.K.," "Berretta, A.A.," and "Rosalen, J.M.," and countries like "Brazil," "China," and "Poland." Similarly, the diagram highlights significant associations with sources such as "Evidence-based Complementary and Alternative Medicine," "Molecules," and "Journal of Ethnopharmacology" (refer to Figure 4). This visualization offers a widespread overview of the interconnectedness and prominence of specific authors, countries, and sources within the analyzed dataset. The examination reveals that Bastos J.K. did not participate in any joint study with countries such as Iran and Indonesia. Moreover, the most productive nations effectively communicated their propolis-related research across all the outlets illustrated in Figure 4. Brazil is the most networked country, followed by China and Poland. Popova, M. and Bankova, V. are the least prolific authors in the domain of propolis research papers, as seen in Figure 4.

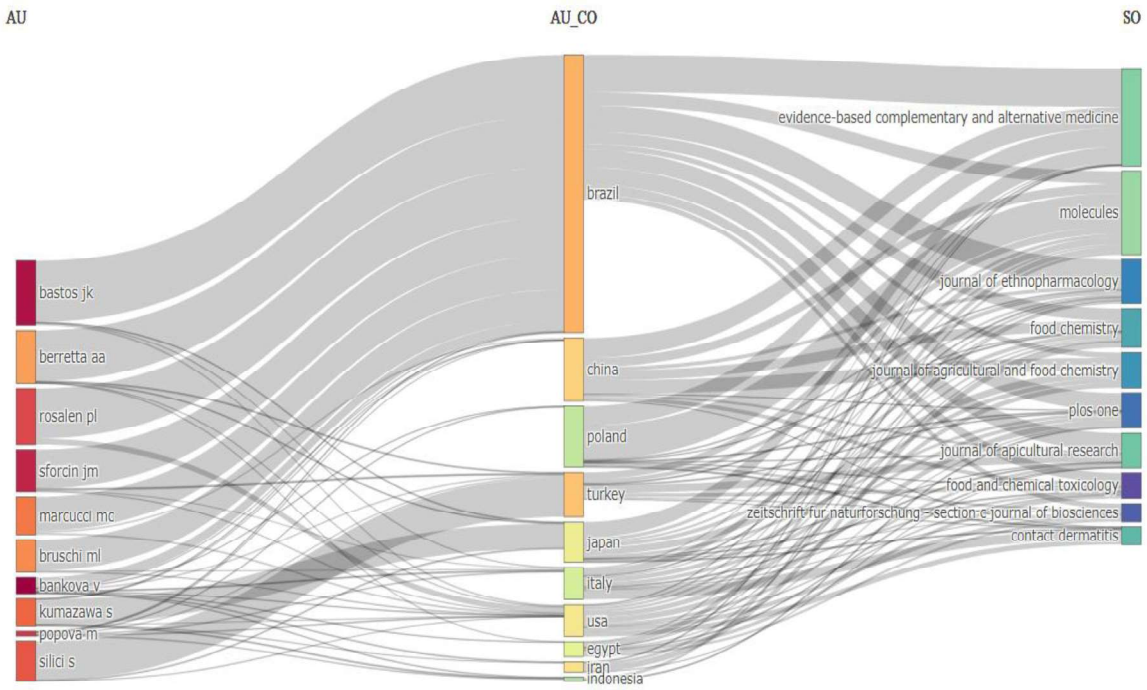

Figure 4. Three-Field Sankey Diagram. This Sankey diagram visualizes the interconnections between authors (AU), authors' countries (AU_CO), and sources (SO). The thickness of the lines represents the number of papers co-authored by authors from different countries and the number of papers published in each source by each country. Each rectangle in the diagram represents a source, a nation, or an author, with the size of the rectangle indicating its significance within the network. The data for this visualization was derived from BibTex files and processed using the Bibliometrix application, providing a comprehensive overview of the relationships within the scholarly network.

Social structure

Impactful components

The top-cited papers in propolis research along with information on their titles, citation counts, publication years, sources, and citation averages are shown in Table 1. "Estimation of total flavonoid content in propolis by two complementary colorimetric methods," which was published in the Journal of Food and Drug Analysis in 2002, is the most frequently referenced paper (ranked #1). This work has received 3,719 citations in total, with an average citation count of 169.05. The item rated second, "Caffeic acid phenethyl ester is a potent and specific inhibitor of activation of nuclear transcription factor NF-κB," was published in the Proceedings of the National Academy of Sciences of the United States of America in 1996. It has received 1,052 citations, averaging 37.57 citations. Titled "Analysis of propolis: Some parameters and procedures for chemical quality control," the third-place paper was released in 1998 and appeared in the Journal of Apicultural Research. With 914 citations overall, its average citation count is 35.15. The fourth-ranked paper, (Title: Antibacterial, antifungal and antiviral activity of propolis of different geographic origin) which was released in 1999 in the Journal of Ethnopharmacology, examines the antiviral, antibacterial, and antifungal properties of propolis sourced from various regions. It has received 858 citations with a citation average of 34.32. Table 1 highlights the top-cited documents in propolis research, covering a broad range of topics. These include flavonoid content estimation, inhibitory effects of caffeic acid phenethyl ester on NF-κB, quality control procedures, antibacterial and antiviral activities, antioxidant properties, cytotoxicity against tumors, botanical origin of Brazilian propolis, and gut bacteria in honeybee development. These topics showcase the multidimensional nature of propolis

research, encompassing chemistry, biological activities, and interactions with honeybees. The average number of citations per document in the entire dataset of 7,181 documents is 27.23.

Table 1. Top-cited articles in propolis research

Rank	DOI number of the publication	Published journal	Publication year	Citations	Citation average
1st	doi.org/10.38212/2224-6614.2748 (Chang *et al.* 2002)	Journal of Food and Drug Analysis	2002	3719	169.05
2nd	10.1073/pnas.93.17.9090 (Natarajan *et al.* 1996)	Proceedings of the National Academy of Sciences of the United States of America	1996	1052	37.57
3rd	10.1080/00218839.1998.11100961 (Woisky and Salatino 1998)	Journal of Apicultural Research	1998	914	35.15
4th	10.1016/S0378-8741(98)00131-7 (Kujumgiev *et al.* 1999)	Journal of Ethnopharmacology	1999	858	34.32
5th	10.1016/S0378-8741(99)00189-0 (Moreno *et al.* 2000)	Journal of Ethnopharmacology	2000	681	28.38
6th	10.1016/S0308-8146(03)00216-4 (Kumazawa, Hamasaka and Nakayama 2004)	Food Chemistry	2004	678	33.90
7th	10.1016/0014-5793(93)80184-V (Sud'ina *et al.* 1993)	FEBS Letters	1993	486	15.68
8th	10.1007/BF01941717 (Grunberger *et al.* 1988)	Experientia	1988	474	13.17
9th	10.1021/jf011432b (Park, Alencar and Aguiar 2002)	Journal of Agricultural and Food Chemistry	2002	471	21.41
10th	10.1128/AEM.07810-11 (Martinson, Moy and Moran 2012)	Applied and Environmental Microbiology	2012	371	30.92

Impactful scholars

Table 2 presents data on the influence of many scholars' publications on various metrics, including total citations (TC), number of publications (NP), H-Index, G-Index, and M-Index, as well as the year their publishing record began (PY_Start). These indicators provide insights into the researchers' productivity, impact, and citation performance in their respective fields. The H-Index represents the number of papers with a corresponding number of citations, while the G-Index and M-Index offer alternative measures considering the distribution of citations. The TC indicate the overall impact of the researchers' work, and NP showcases their productivity. The PY_Start provides information on the year when their publication record began. Bankova, V. has an H-Index of 43, a G-Index of 78, and an M-Index of 1.162. With a total of 6,319 citations and 104 publications since 1987, their research impact is notable. Rosalen, P.L. has an H-Index of 30, a G-Index of 55, and an M-Index of 1.154. Sforcin, J.M. has an H-Index of 30, a G-Index of 51, and an M-Index of 1.111. They have accumulated 2,846 citations from 75 publications since 1997.

The strength of the H-index is that it assesses the number of citations left at a given pass mark along with the number of articles written. This is the primary authorship index. Based on the number of citations a specific paper has, the G-index first sets itself apart. This finding highlights the importance of publishing in high-impact journals. The M-index was calculated using unique authors per article in relation to the total number of published articles on particular influential factors that foster teamwork. TC: Total citations; NP: number of papers; PY_start: the year of first published article.

Table 2. Author's impact. The influence of many scholars' publications on various metrics, including total citations (TC), number of publications (NP), H-Index, G-Index, and M-Index, as well as the year their publishing record began.

Author	H-Index	G-Index	M-Index	TC	NP	PY_Start
Bankova, V.	43	78	1.162	6319	104	1987
Rosalen, P.L.	30	55	1.154	3501	55	1998
Sforcin, J.M.	30	51	1.111	2846	75	1997
Bastos, J.K.	28	46	1.4	2227	80	2004
Marcucci, M.C.	27	48	0.931	2766	48	1995
Ikegaki, M.	25	38	0.962	2526	38	1998
Popova, M.	25	46	1.087	2197	55	2001
Silici, S.	25	44	1.25	2018	52	2004
Kumazawa, S.	23	48	1.045	2729	48	2002
Park, Y.K.	23	31	0.852	3172	31	1997

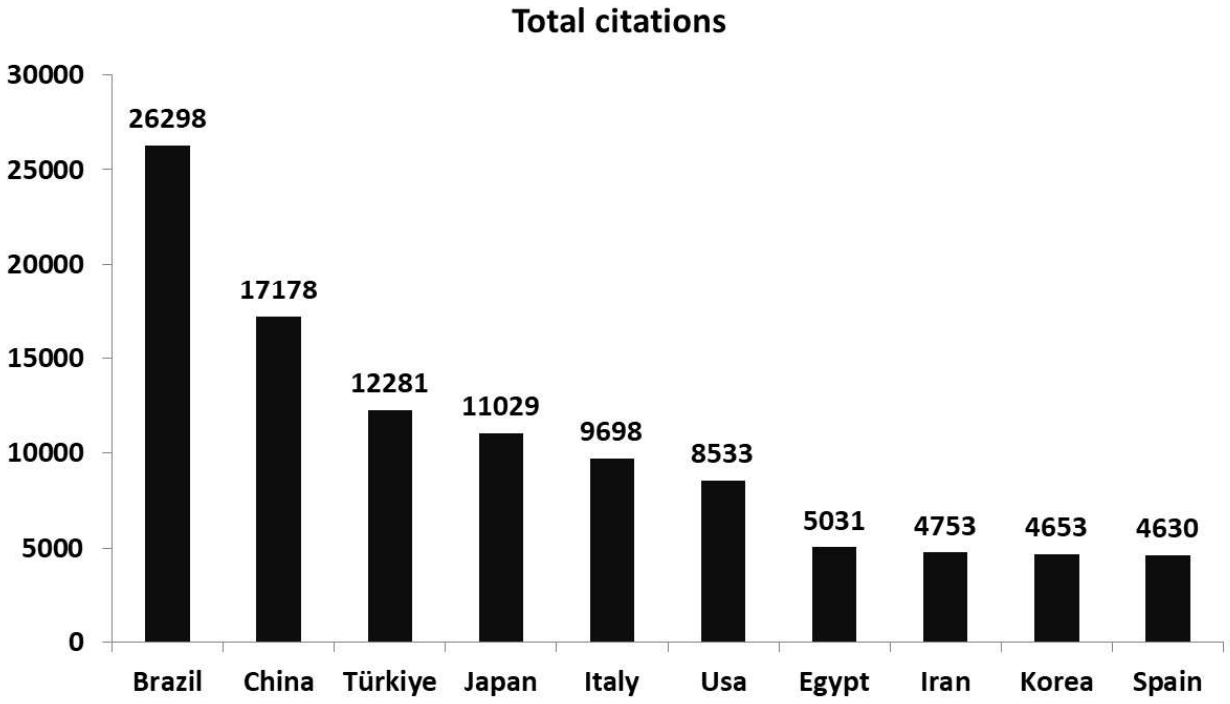

Figure 5. Most-cited countries. This figure showcases the countries that have been most frequently cited in the context of the research presented. The citation frequency serves as a metric for the impact and influence of these countries within the scholarly discourse examined in the study.

Keywords co-occurrence

The conceptual structure and intellectual dynamics of propolis research are characterized by the frequency and co-occurrence of specific keywords. The data contains 28,056 keywords plus (ID) and 12,642 author's keywords. These two keyword categories contain all the terms and phrases used to classify and describe propolis research publications. Bibliographic indexing systems may add keywords to keywords plus (ID) to improve searchability and discoverability. However, the author's keywords (DE) category includes keywords selected by the authors to highlight their research's primary themes, emphasis areas, and findings. These two keyword groups provide a deep overview of propolis study subjects, allowing scholars to examine many pertinent concepts and themes. The dataset

includes a total of 28,056 keywords plus (ID) and 12,642 author's keywords (DE). Among the top author's keywords, "propolis" stands out with a frequency of 2,860 occurrences, indicating its central role in propolis research. Other notable keywords include "flavonoids" (278 occurrences), "antioxidant activity" (234 occurrences), "antioxidant" (215 occurrences), and "antimicrobial activity" (193 occurrences). Additionally, keywords such as "caffeic acid phenethyl ester" (185 occurrences), "honey" (178 occurrences), "beeswax" (173 occurrences), and "Apis mellifera" (170 occurrences) are also frequently mentioned. These numbers provide an insight into the prominence of specific keywords and highlight the areas of focus within propolis research. Propolis research covers its composition, biological activities (such as antioxidant and antimicrobial properties), potential therapeutic applications (such as wound healing and anti-inflammatory effects), and specific compounds (phenolic compounds and polyphenols). The co-occurrence of these keywords reveals propolis' main study fields. The section is regarded as straightforward, and further analyses will be seen in the succeeding portions of this work, which will delve deeper into many aspects such as the conceptual map, thematic development, and emerging trends in propolis research.

Conceptual dynamics

Thematic evolution in propolis research since 1945 was analyzed using Bibliometrix software, providing insights into the progression of research themes over time (Figure 6). From 1945 to 2016, the focus was primarily on topics such as allergic contact dermatitis, antioxidants, artepillin C, bee pollen, beeswax, caffeic acid phenethyl ester, Candida albicans, natural products, and propolis itself. However, a shift in research themes occurred from 2017 to 2024, emphasizing antioxidant activity, oxidative stress, propolis, honey, and the continued exploration of propolis' potential benefits. This analysis highlights the evolving interests and priorities within the propolis research field, reflecting emerging areas of investigation and the changing landscape of scientific inquiry. The year 2016 marks a pivotal point in the conceptual development of the propolis research field. After 2016, there was a noticeable shift in the research landscape, with an expanded focus on antioxidant activity, oxidative stress, propolis, honey, and related bee products. This shift suggests a broader recognition of the importance of propolis as a natural antioxidant and its potential role in addressing oxidative stress-related conditions. This thematic evolution and conceptual development demonstrate the dynamic nature of the propolis research field as new areas of investigation emerge, and the scientific community deepens its understanding of propolis and its therapeutic applications.

Thematic map

The thematic map reveals five distinct themes in propolis research (Figure 7). The first theme, emerging, focuses on allergic contact dermatitis. It has a high Callon density, indicating its development. This theme encompasses research on allergic contact dermatitis and its relationship to propolis. The second theme, classified as motor, represents a significant research focus on propolis itself. It has high Callon centrality and density, indicating its importance. This theme includes topics such as propolis, flavonoids, antioxidant activity, antimicrobial properties, and the phytochemical ingredients of propolis. The third theme, classified as emerging or declining, is centered around beeswax. It has a low Callon density, suggesting a lesser degree of research compared to other themes. This theme focuses explicitly on beeswax and its properties. The fourth theme, classified as motor, revolves around oxidative stress. The values of Callon centrality and density indicate its significance in propolis research. This theme includes studies on oxidative stress, caffeic acid phenethyl ester, apoptosis, inflammation, and their relationships to propolis. The fifth theme, classified as central, is centered around honey. It has moderate Callon centrality and density, indicating its status in the propolis research field. This theme encompasses research on honey, including topics such as *Apis mellifera*, bee pollen, bee products, and the analysis of honey using GC-MS. These five themes represent the key research focus areas within the propolis field. Each theme has its level of relevance, development, and centrality, showcasing the diverse aspects of propolis research that scientists are exploring.

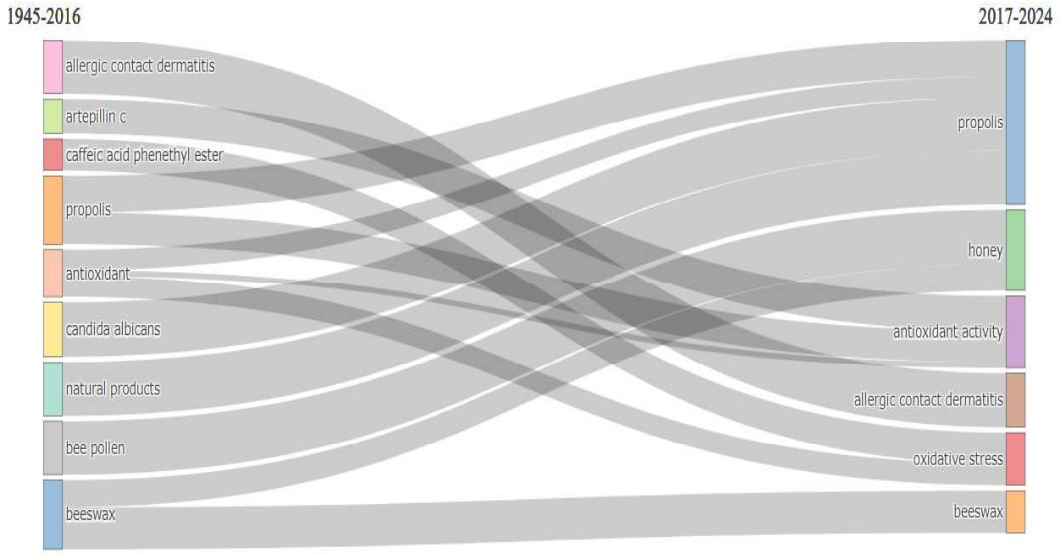

Figure 6. Conceptual Dynamics and Transformation. This figure visualizes the evolution of main topics and the pivotal year of transformation in 2016. The conceptual dynamics within the research field are illustrated, highlighting shifts and trends in the subject matter over time. Generated using the Bibliometrix application and the BibTex data file, this visualization provides insights into the changing landscape of scholarly topics and their development within the specified timeframe.

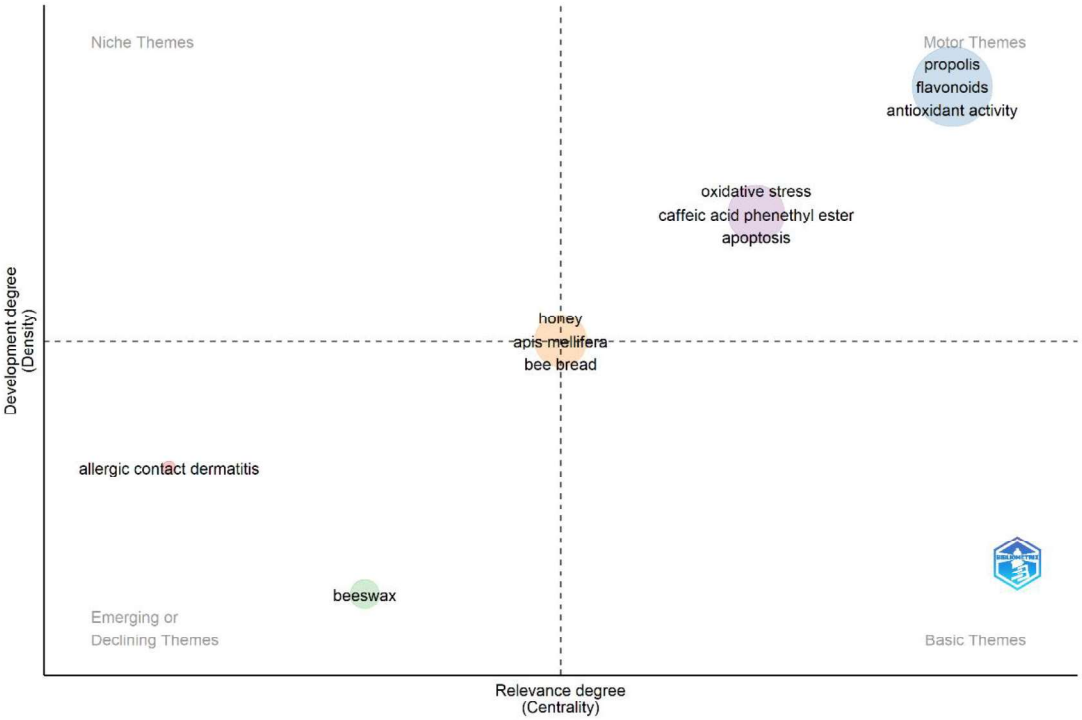

Figure 7. Thematic map. Based on centrality and density, the four quadrants of thematic maps indicate the significance and evolution of the research themes. The BibTex data file and the Bibliometrix application were used to create this figure.

Table 3. Thematic map terms

Cluster	Classification of the themes	Callon-Centrality	Callon-Density	Rank-Centrality	Rank-Density	Cluster Frequency	Keyworker of the cluster
Propolis	Motor	0.067	2.067	5	5	5897	Propolis, flavonoids, antioxidant activity, antioxidant, antimicrobial activity, antibacterial activity, phenolic compounds, cytotoxicity, antimicrobial, polyphenols, propolis extract, antioxidants, artepillin c, antibacterial, HPLC, flavonoid, natural products, wound healing, chemical composition, antifungal activity, phenolics, anti-inflammatory, *Candida albicans*, red propolis, *Staphylococcus aureus*, brazilian green propolis, green propolis, brazilian propolis, caffeic acid, *Streptococcus mutans*, *Baccharis dracunculifolia*, calcium hydroxide, galangin, biofilm, phenolic acids, chlorhexidine, nitric oxide, stingless bees
Oxidative stress	Motor	0.036	1.993	4	4	1185	Oxidative stress, caffeic acid phenethyl ester, apoptosis, inflammation, chrysin, cape, rat, pinocembrin, lipid peroxidation, rats, caffeic acid phenethyl ester (cape), cytokines, COVID-19, liver, breast cancer
Honey	Central	0.028	1.936	3	3	852	Honey, *Apis mellifera*, bee bread, pollen, bee pollen, chitosan, bee products, GC-MS, royal jelly, honey bee, stingless bee
Beeswax	Emerging or declining	0.004	0.578	2	1	173	Beeswax
Allergic contact dermatitis	Emerging or declining	0.000	1.724	1	2	58	Allergic contact dermatitis

Trending topics

Figure 8 provides an overview of the trending topics in propolis research, highlighting their frequency and the years they gained prominence. Chronic kidney disease emerged as a trending topic in propolis research, with five occurrences between 2022 and 2023 indicating a growing interest in exploring propolis' potential benefits for this condition. Antimicrobial research has been highly prevalent, with 113 instances from 2016 to 2022 demonstrating sustained interest in investigating the antimicrobial properties of propolis. “Propolis extract” has also garnered significant attention, appearing 90 times between 2015 and 2022, suggesting a continued focus on exploring its potential benefits and applications. Bee bread, a bee-made product, has been a trending topic with 100 occurrences from 2018 through 2022, indicating ongoing research into its properties and potential advantages. The broader category of bee products, including propolis, bee bread, and honey, has been a topic of interest, with 51 instances from 2019 to 2022, reflecting exploration into the diverse range of bee products and their potential applications. The global COVID-19 pandemic has influenced propolis research, with 37 occurrences as a trending topic from 2021 to 2022, highlighting efforts to investigate propolis' potential antiviral properties in the context of the epidemic. Metabolomics, a comprehensive examination of metabolites, has gained attention with 17 occurrences from 2020 to 2022, indicating the use of metabolomic approaches to understand propolis' composition and effects. Lastly, antiviral research has been notable, with 15 occurrences from 2016 to 2022, indicating ongoing investigations into propolis' potential antiviral properties. Overall, these trending topics demonstrate the diverse areas of interest and ongoing research within the field of propolis, including its potential applications in various diseases, antimicrobial and antiviral activities, and the exploration of specific propolis components and metabolomic analysis.

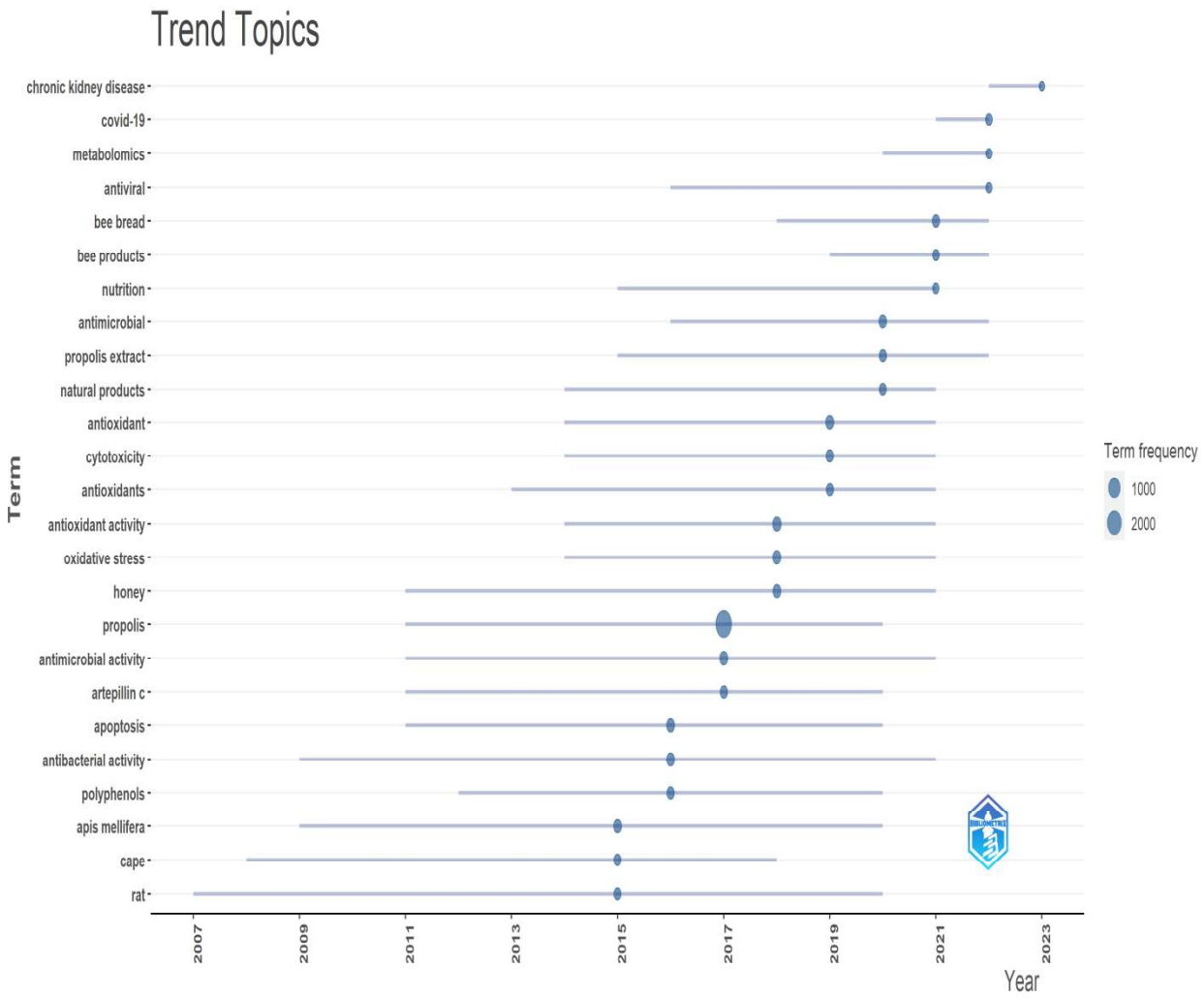

Figure 8. Trending topics. The research topic's temporal span is shown by the graph, where blue circles denote the term's frequency and horizontal lines show the duration. Data files from BibTex and Bibliometrix were used to create this figure.

Social exploration

The data reveals that out of 7181 documents, 20.6% of co-authorships were international collaborations. On average, each document had 5.57 co-authors, indicating a high level of collaboration in the research. These results highlight the significance of teamwork and the exchange of knowledge across borders in the field. Figure 9 presents key findings on research collaboration and publication trends for several countries. Brazil leads in article publications, displaying a significant level of international collaboration and a relatively high MCP (multiple country publications) ratio. Türkiye follows showing moderate collaboration and MCP ratio. China ranks third with 491 articles, indicating a moderate level of collaboration but a higher MCP ratio (Figure 9a). Japan and Egypt demonstrate relatively lower collaboration frequencies but have notable MCP ratios. Other countries, including Iran, India, Italy, Indonesia, and the USA, also show varying levels of collaboration and MCP ratios. These findings highlight the research landscape and international cooperation patterns, shedding light on the countries' scientific productivity and their involvement in multinational publications. Figure 9a gives the number of multi-country documents but does not assess the strength of a country's research cooperation. The single country publications ratio

(SCP) shows the number of published articles with national collaboration. As shown in Figure 9a, the USA has the highest SCP ratio.

Figure 9b represents the strength and progression of global collaboration in propolis research. The United States emerges as the most cooperative nation, closely followed by Brazil. The analysis of collaboration in propolis research goes beyond the leading countries and reveals interesting insights. Figure 9B visually represents the strength and development of collaboration, providing a deeper understanding of the research landscape. Violet-colored rectangles represent leading countries with established networks and partnerships in propolis research. Yellow-colored rectangles indicate countries engaged in recent research collaborations, including Indonesia, Saudi Arabia, Iraq, Iran, and Portugal, suggesting their active efforts to expand research networks. Notably, Egypt and Saudi Arabia have the most significant collaboration, with over 80 joint research initiatives.

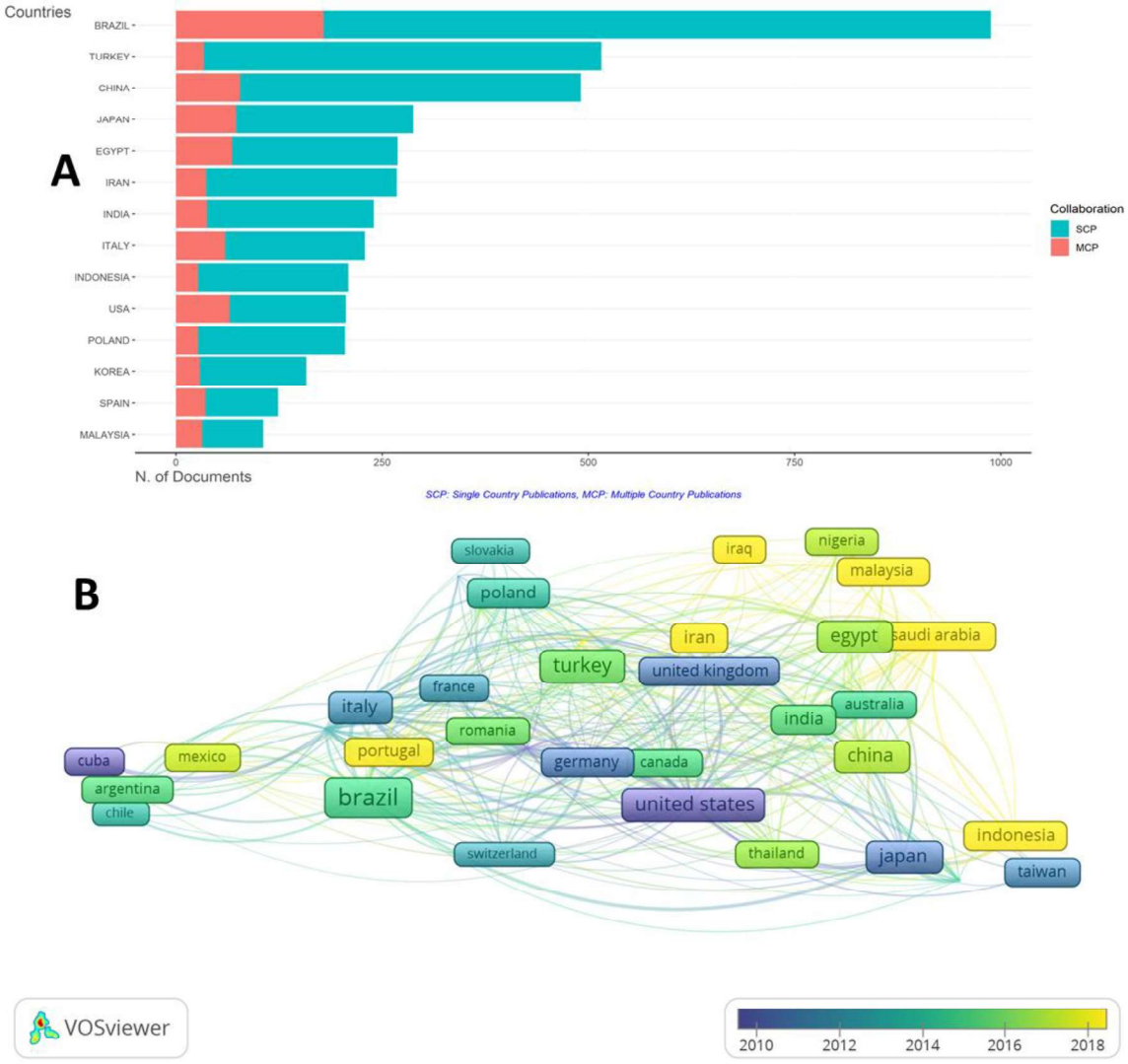

Figure 9. Mapping of international collaboration. A: SCP and MCP analysis of countries' publications. B. the temporal analysis of the global collaboration.

Author's co-citation

Author co-citation is a bibliometric method that examines the co-citation patterns of authors in scholarly publications. It can provide a visual representation of the intellectual map of a field, highlighting the key contributors. Using VOSviewer, this study mapped the author's co-citation with a threshold of 700 as a minimum number of citations of an author (Figure 10). Of the 321838 co-cited authors, 36 meet the threshold. Four clusters were generated (green, red, blue, and yellow) with a total link strength of 421812 and 630 links. Bankova, V. is the leading co-cited author and pioneered the green cluster. Marcucci, M.C. anchored the red cluster. Sforcin J.M. and Park, Y.K. lead the blue and yellow clusters, respectively.

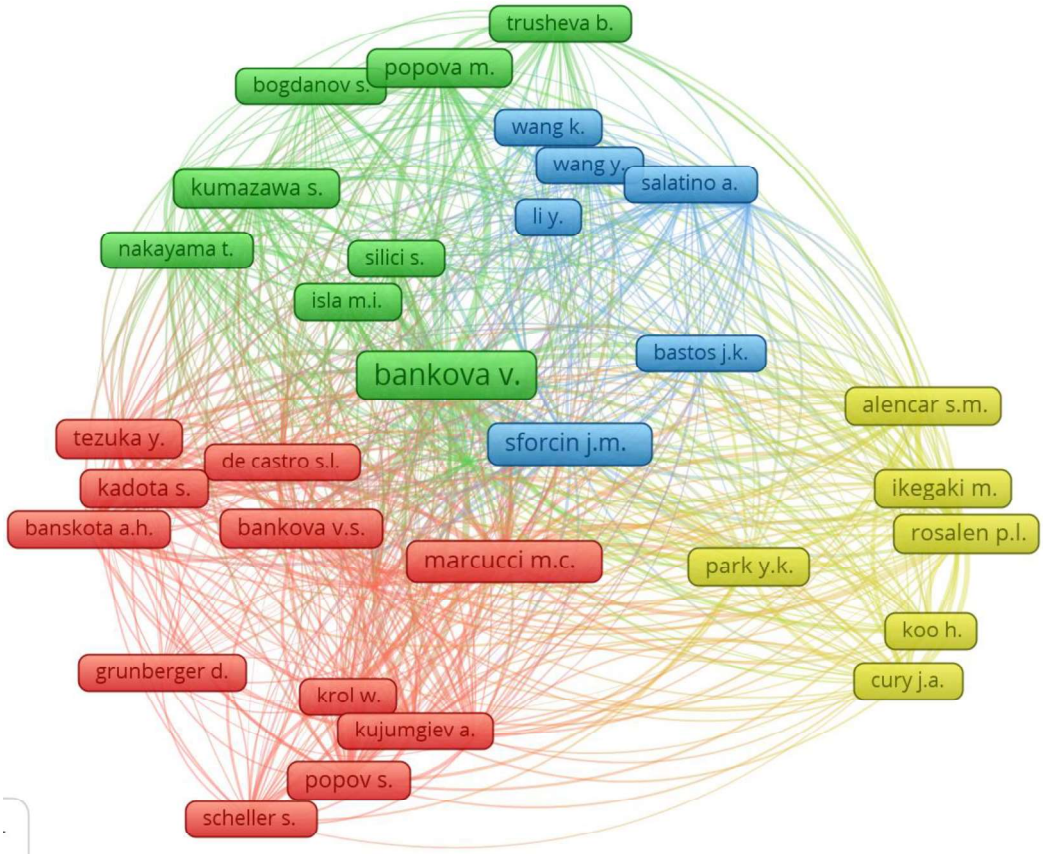

Figure 10. Author's co-citation. Two clusters were detected. A total of 421812 of authors were co-cited. Thirteen of them have been co-cited 630 times.

DISCUSSION

In the area of propolis, recent research uptakes can be explained by some key components. The development of innovative technologies for propolis extraction has increased the efficiency and the cleanliness of this natural product thus making it suitable for research and application purposes (Gupta, Naraniwal and Kothari 2012; Valverde 2023). Besides, notable research in the discipline has caused more interest. Also, the increasing trend of population towards the use of natural products and alternative medicine has created a market increase for researching on propolis and other natural products as there is more demand in health and wellness products that are natural (Glänzel, Leta and Thijs 2006; Salatino, Teixeira and Negri 2005; Zullkiflee, Taha and Usman 2022). All these factors work strongly towards the advancing field of propolis

research and therefore its increased use in scientific research and practical aspects.

Due to its versatility and prospective uses, propolis research spans several fields. Propolis contains many beneficial chemicals, such as polyphenols, terpenoids, and flavonoids. These chemicals have antioxidant, anti-inflammatory, antibacterial, and anticancer effects (Corrêa *et al.* 2017; Gleiznys *et al.* 2019; Hayama *et al.* 2015; Suleiman 2021; Valverde 2023; Zullkiflee, Taha and Usman 2022). Propolis research in biology and ecology examines bee propolis production, hive defense and immunity, and bee health and behavior. These studies advances bee biology and affect pollination and conservation (Shanahan 2023; Simone-Finstrom *et al.* 2017). Pharmacology and medicine study propolis for medicinal uses. Researchers from these fields study its antibacterial, anti-inflammatory, and antioxidant characteristics to produce natural antibiotics, cure inflammatory illnesses, and counteract oxidative stress (Kantrong *et al.* 2023; Omar *et al.* 2023; Valverde 2023; Vilhelmova-Ilieva *et al.* 2023). Propolis may also fight cancer and produce new drugs (Ding 2015; Frión-Herrera *et al.* 2019; Zou *et al.* 2016; Zullkiflee, Taha and Usman 2022). The antibacterial and anti-inflammatory properties were studied in dentistry to prevent and treat oral infections, gum disorders, and tooth caries (Alizadeh Tabari *et al.* 2023; Karaoğlu *et al.* 2023; Kujumgiev 1999; Sales-Peres *et al.* 2023; Shamma *et al.* 2023; Valverde 2023). Natural alternatives to conventional oral care products include propolis-based mouthwashes, toothpaste, and dental materials (Alizadeh Tabari 2023; Karaoğlu 2023; Sales-Peres 2023). Additionally, propolis research connects with food science and agriculture. Propolis's antimicrobial and antioxidant properties are studied for food preservation and functional food additives (Irigoiti 2021). Propolis is studied as a natural pesticide and plant growth enhancer in agriculture (Fuat Gulhan *et al.* 2012). Bioactive substances in propolis and their potential applications make research interdisciplinary. By bridging disciplines, researchers can discover new insights and uses and add to existing knowledge. Recent evaluations concur with this work about the many bioactivities of this natural chemical (Chavda *et al.* 2024; El-Sakhawy, Salama and Tohamy 2023; Salami 2024; Tek, Şentüre Ş and Ersoy 2024).

Brazil's prominence as the most cited country in propolis research can be attributed to various factors. Firstly, Brazil's abundant propolis resources stemming from its diverse ecosystems and geographic regions attract researchers worldwide (Salatino, Teixeira and Negri 2005), leading to more studies conducted on it. Secondly, Brazil has a strong research tradition in natural products and traditional medicine, with experts actively investigating propolis's chemical composition, biological activities, and therapeutic potential (Alves and Rosa 2007). Collaborative efforts and networking with international scientists further enhance visibility and impact. Additionally, the prolific publication output of Brazilian researchers in reputable scientific journals and their significant contributions to propolis research influence the field and garner citations (Glänzel, Leta and Thijs 2006). However, it's essential to acknowledge that other countries and researchers have also made valuable contributions to propolis research. This study concurs with prior research indicating that Brazilian propolis has been extensively examined globally owing to its distinctive chemical makeup and biological attributes, including antioxidant, antibacterial, and anti-inflammatory activities (de Sousa Silveira *et al.* 2024; Franchin *et al.* 2024; Scorza *et al.* 2024).

A positive inclination in the annual production of propolis research during the analyzed period discloses. The number of research documents has steadily increased, indicating a growing interest in propolis and its potential applications. Recent years have seen a distinguished surge in the number of documents, with 2021 recording the uppermost number, followed by 2022 and 2023. Fluctuations and plateaus in annual production reflect variations in research output, potentially influenced by factors such as shifting priorities, funding accessibility, and emergent trends. The data also highlights a significant expansion in research output in recent decades, underscoring the growing recognition of propolis' benefits and applications. Overall, the findings demonstrate the increasing attention and research activity dedicated to propolis, indicating a growing understanding of its potential across various disciplines. The present analysis concurs with prior research indicating a substantial increase in studies about honey and associated products, as documented by earlier bibliometric analyses (Andreo-Martínez *et al.* 2020; Stefanis *et al.* 2023).

The analysis of keywords revealed that wound dressing is a study subject associated with this natural chemical. Propolis has demonstrated significant benefits in wound dressings due to its

superior antiseptic efficiency and antibacterial characteristics. Multiple reports showed the skin wound healing process, related evaluation criteria, and emphasized the improved propolis-based material dressings, including antibacterial properties, adhesion, hemostasis, anti-inflammatory effects, and substance distribution. Moreover, prior reports have documented the use of propolis wound dressing for the treatment of many wound types, including healing wounds, burns, and ulcers (Canales-Alvarez *et al.* 2024; Doodmani *et al.* 2024; El-Sakhawy, Salama and Tohamy 2023; Manginstar *et al.* 2024; Necip *et al.* 2024; Zayed *et al.* 2024). Future directions for propolis-based wound dressings in wound healing are offered. The observed findings align with previous studies (El-Sakhawy, Salama and Tohamy 2023; Manginstar 2024) indicating that propolis-based materials may serve as a potential novel dressing for wound occlusion and tissue restoration.

The evolution in propolis research themes after 2016 can be linked to developments in scientific knowledge, the appreciation of propolis' potential benefits, the broader interest in natural remedies, and the changing priorities of the scientific community (Sandberg and Corrigan 2001). Improved analytical methods and technology (Gupta, Naraniwal and Kothari 2012) allowed researchers to explore new aspects of propolis, particularly its antioxidant activity and potential for addressing oxidative stress (Fonseca 2011). The growing understanding of propolis's bioactive compounds and its status as a valuable natural product also contributed to increased research. Additionally, the expanded focus on honey and related bee products reflected an interest in alternative remedies (Peršurić and Pavelić 2021). Overall, evolving interests and advancements in scientific understanding drove the shift in research themes, shaping the progression of propolis research since 2016.

The trending topic of COVID-19 in propolis research can be attributed to several factors. Propolis is being explored for its potential antiviral activity against coronaviruses, including COVID-19. Its antimicrobial properties and immunomodulatory effects have sparked interest in understanding how propolis may support the immune system and mitigate the impact of the virus. The COVID-19 epidemic has also heightened attention in natural products and traditional medicine, leading researchers to investigate propolis as a potential treatment or supportive therapy (Silveira *et al.* 2021). Additionally, the public's curiosity and concern regarding COVID-19 have contributed to increased attention on propolis research. As a natural substance with potential health benefits, propolis has garnered interest as a possible solution for combatting the virus (Karaoğlu 2023; Omar 2023; Ożarowski and Karpiński 2023; Sales-Peres 2023; Taysi *et al.* 2023; Vilhelmova-Ilieva 2023). The combination of propolis' bioactive compounds and the urgent need for effective COVID-19 treatments has driven research in this area. The trending topic of COVID-19 in propolis research reflects the ongoing efforts to find solutions and explore the potential of natural compounds in addressing the global pandemic.

Author co-citation is a bibliometric analysis that examines the co-citation patterns of authors in scholarly publications (Zhang *et al.* 2023). It involves identifying and analyzing the occurrence with which two or more authors are cited together in the reference lists of articles. Author co-citation analysis helps identify influential authors and research themes within a field and the relationships and networks among researchers. It can provide a visual representation of the thematic structure of a field, highlighting the key contributors and the extent of their interactions. It can also assist researchers in determining areas that require more study and gaps in the body of knowledge. All things considered, author co-citation analysis is a useful method for comprehending the academic environment and recognizing important individuals and their contributions (Carollo *et al.* 2023; Tan *et al.* 2023; Zhang 2023). The most contributed topics by Bankova, V. include pinobanksin and stingless bees, eutectics and choline, electroplating, geraniin, antioxidants, and tannins. Marcucci, M.C., the top-cited author in the red cluster, is a researcher with a diverse range of interests spanning multiple fields. Researchers in this cluster are interested in various topics, including dental materials and bonding agents in restorative dentistry, female reproductive health, nonvital tooth treatments, honey and stingless bees, and regenerative dentistry focusing on tooth pulp and stem cells. This demonstrates their multidisciplinary approach and contributions to different areas of study (Adiningrat *et al.* 2023; Alizadeh Tabari 2023; Jauhar *et al.* 2023; Kantrong 2023; Mandil *et al.* 2023; Rasool *et al.* 2023; Saleh *et al.* 2023; Shamma 2023). Researchers in the blue clusters are interested in apoptosis, 8-bromo-7-methoxychrysin, and flavones (Ding 2015; Frión-

Herrera 2019; Zou 2016). Dietary carbohydrates, allicin, garlic, diallyl trisulfide, biogenic amines, antimicrobial, histamines, and tyramine are the primary research for the scholars in the yellow cluster (de Figueiredo *et al.* 2017; Lee *et al.* 2019; Park *et al.* 2020; Park, Lee and Mah 2019; Roquetto 2015; Takeshita *et al.* 2013).

Many clinical applications of propolis research have been reported. But at the same time, certain critical limitations need to be addressed. There are issues such as geographical composition variations where one region may produce propolis that may be very different from that produced in another, thus impacting its safety and effectiveness (Zullkiflee, Taha and Usman 2022). Moreover, unformulated variations and indefinite formulations of the compound also make it impractical for clinic or hospital use, which raises concerns about uniformity in doses and results (Valverde 2023). In addition, propolis cannot be applied or used in a larger scope due to regulatory requirements since there is always limited data to support the claims (Ding 2015; Valverde 2023). Understanding these challenges is important in order to broaden the clinical uses of propolis and protect its safety when used in medicine.

This bibliometric research has certain major limitations. Firstly, all these studies have reported in published scientific literature only, making it impossible for unpublished or non-indexed research, therefore biasing the outcomes either way. The selection criteria used to look for such papers in this case has been criticized for inducing selection bias therefore making it less generalizable. At any case, the better the study, the more the data there will be, and in most cases, the data may be insufficient or inaccurate, thereby influencing the study's findings. Owing to its time cutoff knowledge, this July 2023 study has not been able to identify new developments or research directions. Different bibliometricians employ bibliometric data analysis to make classification as well as analysis that tends to deviate from one researcher to another researcher. Also, citation analysis can outline patterns and relationships, but not determinants and processes. Finally, the use of numbers perhaps may hide useful information affecting the way one would assess the value of all the studies such as the clinical relevance and even outcomes measured in humans, which are in real life more logically observable than in laboratory settings as the progression of many diseases does not fit the clinical trials. Overcoming these drawbacks is important in increasing the quality and relevance of bibliometric approaches to the analysis of scientific activity.

Conclusion: At the end of the study, a comprehensive bibliometric review of propolis research was carried out, showing its growth, new trends, and the spatiotemporal distribution of studies conducted in various spheres. The interesting fact that emerged from analysis of the research literature includes the strong growing tendencies of interest towards the use of propolis in medicine which makes this topic of scientific research quite pressing and important in the world today. The research output development throughout the countries and regions demonstrates the wider growing awareness of the health benefits and healthcare relevance of propolis. Recognizing patterns and trends in propolis research has significant implications, such as the ability to identify hotspots and research gaps for future work. These temporal and geographical patterns must be clearly understood in order to foster connectivity and cross-pollination among researchers in order to advance the issues at hand. In the future studies should develop strategies for thorough exploration of the action mechanisms of propolis, especially determining the properties of its secondary metabolites and their conjugates for pro-health effects. Integration of currently very separate fields including pharmacology, immunology, and chemistry of natural products will advance the knowledge of propolis including its synergistic effect resulting in new formulation and treatments with the best use of its medicinal activities. Along with this, proper clinical studies are required also to prove the safety, efficacy, as well as effective doses of propolis for various populations so that this product of nature would be part of conventional medicine with evidence-based recommendation for practitioners. By delving deeper into its mechanism of action, promoting cross-disciplinary collaborations, and performing good clinical studies, we can appreciate the true therapeutic Value of propolis and health care will improve.

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Authors' contributions: All authors agreed to be accountable for all aspects of the work and made a significant contribution to the work reported,

regardless of whether their contributions were in the areas of conception, study design, execution, data acquisition, analysis, and interpretation, or all of these. They also took part in the article's drafting, revision, or critical review and gave their final approval for the version to be published.

Availability of data and material: The current study's datasets are accessible from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no conflicting interests.

Consent for publication: Not applicable.

Data availability status: The authors confirm that the data supporting the findings of this study are available within the article.

Ethics approval: No human subjects were used in this paper, thus ethical approval is not required.

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