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Research Article

A Decade of Research about Honey as an Antioxidant in Scopus Database: Bibliometric Analysis

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ABSTRACT

Honeybees transform flowers' delicious, aromatic, and viscous nectar into the naturally occurring, antioxidant-rich honey. A growing scientific study increasingly supports honey's use in complementary and alternative medicine. No bibliometric analysis of published data on honey antioxidants has been conducted to ascertain the state of the research. Using VOSviewer and RStudio, we conducted a bibliometric analysis of the scholarly articles about honey's antioxidants in the Scopus database. Honey's antioxidant properties were covered in 765 papers between 2013 and 2023. Most publications (309 articles) are attributed to Malaysian researchers, with Universiti Sains Malaysia being the most productive, with 53 articles produced. Food Chemistry is the most productive source, with an average of 64.8 citations per article and 24 documents. Having the highest H-index of 10, Battino M significantly influenced the studies of honey's antioxidant properties. "Honey" and "antioxidant activity" were the most frequent keywords. We can learn about the novelty of honey as antioxidant research from these data.

INTRODUCTION

Honeybees undergo a process of converting the sugary, aromatic, and thickened nectar derived from flowers. Due to its geographical and botanical provenance, honey exhibits a multifaceted amalgamation characterized by diverse compositional elements and distinctive attributes. The basic properties of honey are contingent upon the floral source from which bees collect nectar (Tafere, 2021). The two primary classifications of honey are monofloral and multi-floral (Bayram and Demir, 2018). Monofloral honey, such as Manuka, sourwood, tupelo, orange blossom, acacia, and palmetto honey, is derived exclusively from the nectar of a single species of flower (Mărgăoan *et al.*, 2021). The multi- and poly-floral honey category encompasses several types, such as Georgia wildflower honey, Savannah honey, and Charleston honey (Azman and Zakaria, 2019). Honey is a natural material that presents a promising alternative for mitigating the growing incidence of diseases and ameliorating the inevitable detrimental consequences connected with pharmacological treatments (Ahmed *et al.*, 2018).

Honey has historically been employed for domestic and medical applications; nevertheless, its antioxidant effects have recently garnered significant attention (Tafere, 2021). Oxidative stress refers to the imbalance in antioxidant enzymes inside the human body resulting from free radicals and their corresponding stabilizing agents (Manisha *et al.*, 2017; Pizzino *et al.*, 2017). The human body contains both enzymatic and non-enzymatic antioxidants. These enzymes and natural compounds can effectively neutralize excessive reactive oxygen species (ROS), hence mitigating potential cellular structural damage. Both non-enzymatic and enzymatic antioxidants play a crucial role as inherent protective mechanisms against prooxidant environmental conditions (Kurutas, 2016). Honey comprises enzyme antioxidants, including glucose oxidase, catalase, and peroxidase. Ascorbic acid, carotenoids, proteins, phenolic acids, tocopherol,

flavonoids, and amino acids are only some of the non-enzymatic antioxidants found in honey (Azman and Zakaria, 2019).

In recent decades, honey has garnered significant attention in scientific research, leading to a substantial expansion of empirical evidence that bolsters its application within the field of complementary and alternative medicine (Zakaria *et al*., 2021). However, to evaluate the development and progress of this field of study, a thorough bibliometric review of the available literature on the antioxidant properties of honey has yet to be done. This article conducted a bibliometric analysis to evaluate research performance, identify influential papers and researchers, and track the development of a research field that provides a more comprehensive evaluation of research and supports informed decision-making in research evaluation and planning. To conduct a bibliometric analysis, this study looks at scholarly publications published between 2013 and 2023 using the VOSviewer and RStudio programs. This study analyzed the scientific literature on honey's antioxidant capabilities published in the Scopus database using the VOSviewer and RStudio programs. Analysis of bibliometric data is known as bibliometrics, and it is used to assess and keep tabs on the state of the published literature. Authors, books, universities, periodicals, and countries are all represented in this dataset's citation references (Dede and Ozdemir, 2022). As a result, proficiently conducted bibliometric studies can provide a robust basis for expanding a subject in novel avenues and enhancing the quality of research for subsequent investigations (Donthu *et al*., 2021; Setyawan *et al*., 2024).

METHODS

Study technique and search strategy

The articles employed in this study were retrieved from the Scopus database on April 23, 2023 (https://www.scopus.com). The research findings have been disseminated through internationally recognized health journals. The primary emphasis of the study was on the time spanning from 2013 to 2023 in the English language, with particular attention given to the phrase "honey antioxidant." The data underwent a comprehensive cleansing process, including detailed checks for duplication and verification of articles that addressed the topics of honey and antioxidants. The articles retrieved from Scopus were imported into Microsoft Excel software and stored in the format of comma-separated values (CSV) files.

Data analysis

The CSV export data were analyzed using VOSviewer version 1.6.19, a software tool developed by the Center for Science and Technology at Leiden University in the Netherlands. The present study investigates various components, including institutions, sources, writers, publications, and the co-occurrence of keywords. The process of data cleansing involves utilizing Excel's thesaurus function as a means of preventing duplication. The data analysis was done with Bibliometric, a tool developed by the Department of Economics and Statistics at the University of Naples Federico II in Italy. The study was done using the RStudio program (version 2023.03.0-386) integrated with the R (version 4.3.1), using the bibliometrix package, then directed to the Biblioshiny app. The present program analyzes publication patterns, sources, nations, and authors who make contributions.

RESULTS AND DISCUSSION

Data searches

A total of 765 articles were identified by the Scopus search engine using the keywords "honey antioxidant". To analyze and delineate the knowledge concepts about the advancement of research on honey as an antioxidant, the Scopus database was employed to conduct a bibliometric analysis of honey and antioxidants. The bibliometric study was conducted in a three-step process, which involved selecting an analytical approach and identifying research criteria (Šūmakaris *et al*., 2020). The bibliometric analysis encompasses two primary methodological approaches: performance analysis and science mapping (Dede and Ozdemir, 2022). The performance analysis considers the contributions of academics from diverse nations, institutions, sources, and authors, which enhance the productivity of the papers generated (Donthu *et al*., 2021). Meanwhile, scientific cartography visually represents the cognitive framework and progress of scholarly inquiry (Dede and Ozdemir, 2022). Scientific mapping was employed to conduct accurate article analysis, considering factors such as the publication year, topic, document type, institutional affiliation, keyword research (co-occurrence), and the country's research contribution (Ferrari *et al*., 2020).

Publication trend

It is anticipated that there will be a rise in the number of scholarly works examining

honey's antioxidant properties in the forthcoming years. Table 1 presents an overview of publishing data trends and the average number of citations per piece. The years 2022, 2021, and 2020 have been identified as the periods during which the highest number of articles were generated, with 115, 114, and 93 articles, respectively. The mean number of publications generated between 2013 and 2023 was 69.5, with an average of 2.7 citations per year and 18.3 for each document. In terms of citation frequency, the year 2016 has exhibited the most significant average of 4.13 citations per year among the articles examined. It was followed by 2018, which had an average of 3.81 citations per year, and 2013, which had an average of 3.3 citations per year. Using citations in research strategy and the research system has witnessed a notable rise in performance measurements. It is commonly believed that the quantity of citations garnered by a particular scholarly work is a reliable indicator of its significance or caliber (Aksnes *et al*., 2019).

Table 1. Publication data trend by year using the Rstudio application

Year	Number of Articles	Mean Total of Citation per Year	Mean Total of Citation per Articles	Citable Year
2013	52	3.3	36.31	11
2014	50	2.78	27.76	10
2015	46	3.1	27.93	9
2016	62	4.13	33.03	8
2017	54	2.64	18.48	7
2018	85	3.81	22.84	6
2019	63	2.97	14.86	5
2020	93	2.75	11	4
2021	114	2.18	6.55	3
2022	115	1.19	2.37	2
2023	31	0.42	0.42	1
Average	69.5	2.7	18.3	

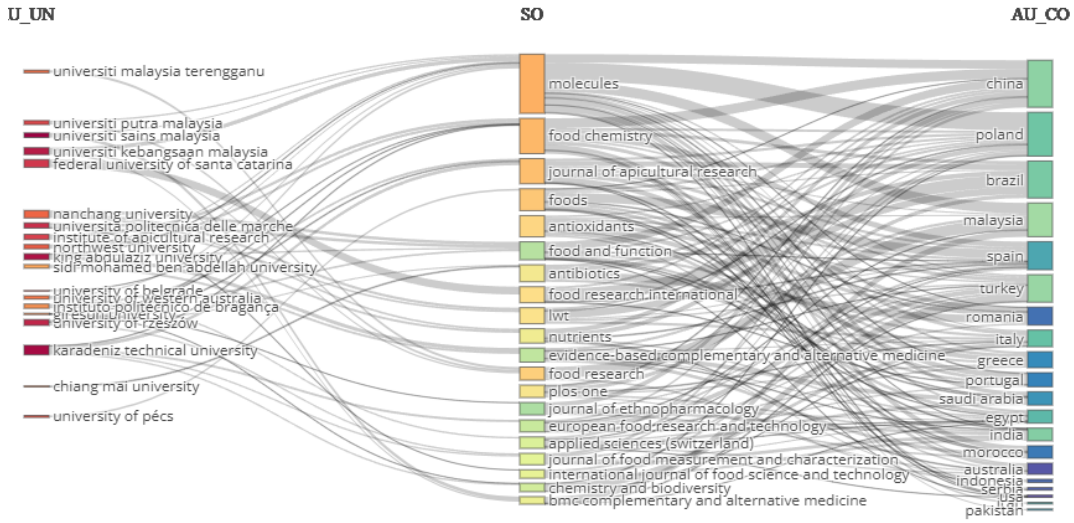

Figure 1. Most country production heatmaps and countries collaborate using the Rstudio application

Analysis of contributing countries

The study of contributing countries utilized RStudio to ascertain the country that has made the most significant contributions in producing studies on honey's antioxidant properties. The partnership map illustrating the nations engaged in investigating the antioxidant activity of honey is depicted in Figure 1. Nations depicted with darker blue hues indicate a higher volume of articles produced during the time frame spanning from 2013 to 2023. The countries with the highest production rates were Malaysia, with 309 products; Turkey, with 306 articles; and China, with 290 articles. The pink line symbolizes the level of coordination between each respective country. Egypt and Saudi Arabia produced the highest number of collaboration papers, totaling 20, while Italy and Spain followed closely with eight collaborative pieces. The study also investigated the number of article citations in each nation to identify the countries with the highest influence in generating research on the antioxidant activity of honey.

Regarding the total number of citations, Italy came in first place. The country had 1135 citations and an average of 35.5 citations per piece. Brazil came in at number two, with 1075 citations and an average of 34.7 per post. Malaysia was in third place with 990 citations and an average of 16.2 citations for each item.

Analysis of contributing institutions

Identifying the most productive institutions was a vital aspect of the bibliometric analysis conducted by Gao *et al*. (2021). The analysis was performed utilizing the Scopus database. Based on the data retrieved from the database, it is evident that Universiti Sains Malaysia, Karadeniz Technical University, and King Abdulaziz University emerged as the leading academic institutions in terms of article production about the antioxidant properties of honey. Universiti Sains Malaysia contributed 53 articles, followed closely by Karadeniz Technical University with 50 articles and King Abdulaziz University with 47 articles.

Analysis of contributing sources

According to the Scopus database, 765 papers from 389 global sources have been documented, focusing on examining honey as an antioxidant. Table 2 visually represents the top five sources or journals demonstrating high productivity regarding the number of papers produced and the cumulative number of citations received by these publications. The Food Chemistry journal exhibits a highly productive source, distinguished by a corpus of 24 scholarly articles and an average citation count of 64.8 per article. The subsequent publication under consideration is "Molecules," which encompasses 39 scholarly articles and exhibits an average citation rate of 13.6 citations per article. The Journal of Agricultural Research, comprising 17 scholarly publications, shows a commendable average citation count of 15.5 per piece, establishing its significance as a reputable and informative resource within the field.

Figure 2 illustrates the interconnectedness between the author's country (AU_CO), sources/journals (SO), and affiliation (AU_UN). The main aim of this study was to analyze the usage patterns of the top 20 sources, top 20 authors, and top 20 keywords in the domain of published literature. Gray lines connect the three regions. The rectangle's dimensions correspond to the number of associated items in each compartment. As the length of the rectangle increases, the clarity regarding the number of items included within each box improves. The source that exhibited the highest degree of association was "Molecules," as indicated by the inflow analysis, which revealed that publications produced by writers from eight distinct institutions were included in this source. The analysis of the outflow of publications in the journal "Molecules" reveals that writers from 14 nations have contributed papers.

Analysis of contributing author

The analyses conducted by the contributing author were performed using RStudio. The author's contribution and influence were examined using the RStudio program (Fatimah *et al*., 2022). Table 3 presents the names of the five most prolific authors who have contributed to many publications on honey as an antioxidant. The researcher Kolayli S has the highest number of publications, comprising 15 articles. Following Kolayli S, Dzugan M, Lyoussi B, Battino M, Nanda V, and Giampieri F also have notable publication records. From 2014 to 2023, Kolayli S. from Karadeniz Technical University authored 15 papers, each receiving an average of 33.53 citations. Following closely, Dzugan M. from the University of Rzeszów published 14 articles between 2017 and 2023. Lyoussi B, affiliated with Sidi Mohamed Ben Abdellah University, has contributed to the academic community by publishing 14 articles from 2013 to 2022.

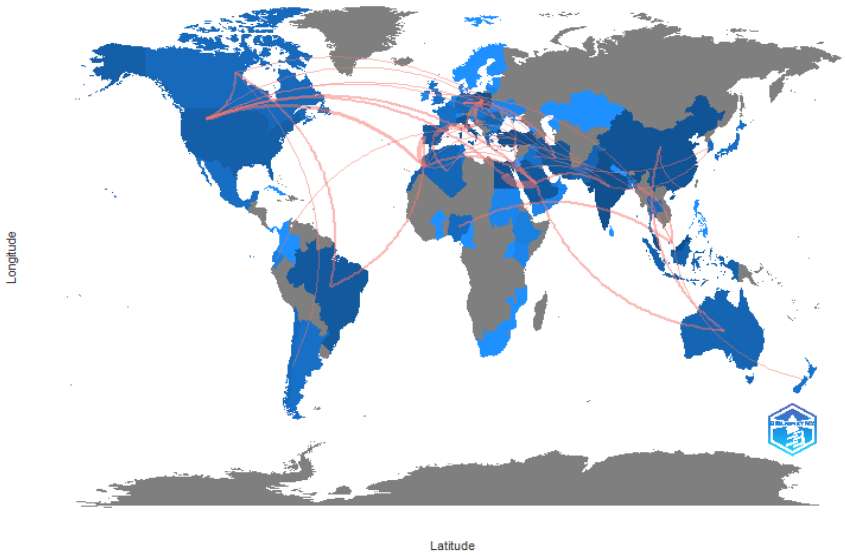

Figure 2. Three-field plot between Author's Affiliations (AU_UN), Source (SO), and Author's Country (AU_CO) using the Rstudio application

Table 2. The most productive source using the VOSviewer application

Source	Documents	Total Citation	Average Citation per Article
Food Chemistry	24	1554	64.8
Molecules	39	529	13.6
Journal of Apicultural Research	17	263	15.5
Foods	14	184	13.1
International Journal of Food Science and Technology	12	218	18.1

Similarly, Battino M, associated with the Polytechnic University of Marche, has made significant contributions by publishing ten articles between 2013 and 2021. Nanda V, affiliated with Deemed University, has also published ten articles within the same period, further enriching the scholarly discourse. Lastly, Giampieri F, from the University of Vigo, has contributed to the academic field by publishing nine articles between 2013 and 2021.

The author's scholarly influence is demonstrated by the numerical value of the H index, as presented in Table 3. Battino M, with an H-index of 10, has made a substantial contribution to the literature on the antioxidant properties of honey. Similarly, Lyoussi B, with an H-index of 10, has notably impacted this subject matter. Giampieri F and Kolayli S have an identical H-index of 9, but Nanda V has an H-index of 8. Table 3 displays the findings from the three most recently published papers. This knowledge is advantageous for authors of articles, namely researchers, in preparing and effectively communicating the importance of their study findings.

Analysis of contributing paper

An article's citation count is a good proxy for the importance of the research to which it refers. A study's impact in the field of honey-related antioxidant preparations increases as the number of times it is cited grows. A total of 765 scholarly articles have made significant contributions to the body of research focused on the antioxidant properties of honey. According to the bibliographic coupling study conducted using the VOSviewer document analysis unit, the total count of publications with at least one reference was determined to be 645. A mere 15.68% of publications did not receive citations from other articles, indicating that most papers, primarily authored between 2021 and 2023, influenced subsequent publications. Table 4 presents the top five papers that have received the highest number of citations.

The most influential article, "An investigation of Turkish honeys: their physicochemical properties, antioxidant capacities, and phenolic profiles", was written by (Can *et al.*, 2015) with 294 citations. This study aimed to evaluate the physicochemical and bio-

Table 3. Top 5 most productive authors using RStudio

No	Author	3 Latest Title of Document (Year)
1.	Kolayli S - Total Documents: 15 - Citations: 503 - Average Citation per Document: 33,53 - H index: 9 - Affiliation: Karadeniz Technical University	1. The phenolic composition, aroma compounds, physicochemical and antimicrobial properties of Nigella sativa L. (black cumin) honey (Kolayli *et al*., 2023). 2. Identification of the main phenolic markers in Turkish pine honeys and their biological functions (Sahin *et al*., 2022). 3. Floral authentication of some monofloral honeys based on volatile composition and physicochemical parameters (Yildiz *et al*., 2022).
2.	Dzugan M - Total Documents: 14 - Citations: 149 - Average Citation per Document: 10,64 - H index: 7 - Affiliation: University of Rzeszów	1. The antioxidant, antibacterial and anti-biofilm properties of rapeseed creamed honey enriched with selected plant superfoods (Miłek *et al*., 2023). 2. SDS-PAGE protein and HPTLC polyphenols profiling as a promising tool for authentication of goldenrod honey (Dżugan *et al*., 2022). 3. Antiviral and antibacterial effect of honey enriched with Rubus spp. as a functional food with enhanced antioxidant properties (Grabek-Lejko *et al*., 2022).
3.	Lyoussi B - Total Documents: 14 - Citations: 278 - Average Citation per Document: 19,85 - H index: 10 - Affiliation: Sidi Mohamed Ben Abdellah University	1. Exploring the palynological, chemical, and bioactive properties of non-studied bee pollen and honey from morocco (Bakour *et al*., 2022). 2. Arbutus unedo honey and propolis ameliorate acute kidney injury, acute liver injury, and proteinuria via hypoglycemic and antioxidant activity in streptozotocin-treated rats (Touzani *et al*., 2022). 3. The synergistic beneficial effect of thyme honey and olive oil against diabetes and its complications induced by alloxan in Wistar rats (Lafraxo *et al*., 2021).
4.	Battino M - Total Documents:10 - Citations: 658 - Average Citation per Document: 65,8 - H index: 10 - Affiliation: Polytechnic University of Marche	1. The roles of strawberry and honey phytochemicals on human health: a possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation (Battino *et al*., 2021). 2. Protective effects of manuka honey on lps-treated raw 264.7 macrophages. Part 1: Enhancement of cellular viability, regulation of cellular apoptosis and improvement of mitochondrial functionality (Afrin *et al*., 2018). 3. Protective effects of manuka honey on lps-treated raw 264.7 macrophages. Part 2: Control of oxidative stress induced damage, increase of antioxidant enzyme activities and attenuation of inflammation (Gasparrini *et al*., 2018).
5	Nanda V - Total Documents: 10 - Citations: 201 - Average Citation per Document: 20,1 - H index: 8 - Affiliation: Deemed University	1. Response surface approach to optimize temperature, pH, and time on antioxidant properties of wild bush (Plectranthus rugosus) honey from high altitude region (Kashmir valley) of India (Ahmad Nayik *et al*., 2022). 2. Development and characterization of a nutritionally rich spray-dried honey powder (Suhag *et al*., 2021). 4. Modelling of moisture sorption isotherms and glass transition temperature of spray-dried honey powder (Suhag *et al*., 2018).

logical characteristics of several varieties of honey derived from the flora of Turkey. The results indicate that honey's physicochemical and biological characteristics are closely linked to the specific flowers from which it is derived. Additionally, it is seen that honeys with darker hues, such as oak, chestnut, and heather varieties, possess considerable medicinal potential (Can *et al*., 2015).

"Honey as a source of dietary antioxidants: structures, bioavailability and evidence of protective effects against human chronic diseases" was the second most impactful piece of writing, written by (Alvarez-Suarez *et al*., 2013) with 188 citations. The present article analyzes

the absorption, metabolism, and advantageous physiological impacts of the various constituents found in honey when consumed by individuals. There exists a positive correlation between the content of polyphenols in honey and its possession of antioxidant and anti-inflammatory properties. These properties, in turn, contribute to several advantages, including cardiovascular benefits, antiproliferative effects, and antibacterial properties (Alvarez-Suarez *et al*., 2013).

The third most influential article was "Nutritional value and antioxidant activity of honeys produced in a European Atlantic area", written by (Escuredo *et al*., 2013) with 184 citations. This study aimed to analyze the nutritional profiles and antioxidant capabilities of 177 honey specimens collected from an Atlantic European region and to explore any potential links between these variables. Based on the available data, it can be observed that heather honey had the most substantial phenolic content in comparison to diverse antioxidant constituents. Conversely, honeydew and chestnut honey displayed the highest quantities of flavonoids. The results of a multivariate analysis indicated a strong correlation between antioxidant activity and many factors, including mineral, protein, phenol, and flavonoid levels (Escuredo *et al*., 2013).

"Biological properties and therapeutic activities of honey in wound healing: A narrative review and meta-analysis" was the fourth most influential article written by (Oryan *et al*., 2016) with 167 citations. This review elucidates the mechanics and therapeutic advantages of honey in the context of wound healing. The fundamental mechanisms underlying wound healing encompass hydrogen peroxide, high osmolality, acidity, non-peroxide constituents, nitric oxide, and phenols in honey. Based on empirical investigations conducted in laboratory settings and clinical trials, it has been observed that honey possesses the capacity to facilitate autolytic debridement, enhance the proliferation of wound tissue, and initiate anti-inflammatory mechanisms, thereby accelerating the process of wound healing (Oryan *et al*., 2016).

The fifth most influential article was "Physicochemical and antioxidant properties of Malaysian honey produced by Apis cerana, Apis dorsata, and Apis mellifera", written by (Moniruzzaman *et al*., 2013) with 148 citations. The main aim of this study was to assess the antioxidant and physicochemical characteristics of various types of Malaysian monofloral acacia honey samples, including pineapple honey, Borneo honey, and tualang honey. The findings of this experiment indicate that Malaysian honey varieties exhibit a notable level of quality, with tualang honey demonstrating much higher antioxidant content than other types (Moniruzzaman *et al*., 2013).

Analysis of keyword co-occurrence

In the present study, the software tool VOSviewer was employed to analyze the co-occurrence of keywords within all phrases. The present study can be utilized to delineate contemporary or prospective areas of investigation about the antioxidative properties of honey, predicated on the substantive content encapsulated within the published literature. (Donthu *et al*., 2021). The concept of co-occurrence refers to quantifying the frequency at which a particular term appears in academic articles. The research employed a comprehensive counting calculation strategy to determine the frequency of keyword occurrences. This approach involved tallying the

Table 4. Most cited articles using RStudio

No	Reference	Tittle	Source	Total Citation
1	(Can *et al*., 2015)	"An investigation of Turkish honeys: Their physico-chemical properties, antioxidant capacities and phenolic profiles"	Food Chemistry	294
2	(Alvarez-Suarez *et al*., 2013)	"Honey as a source of dietary antioxidants: structures, bioavailability and evidence of protective effects against human chronic diseases"	Current Medicinal Chemistry	188
3	(Escuredo *et al*., 2013)	"Nutritional value and antioxidant activity of honeys produced in a European Atlantic area"	Food Chemistry	184
4	(Oryan *et al*., 2016)	"Biological properties and therapeutic activities of honey in wound healing: A narrative review and meta-analysis"	Journal of Tissueviability	167
5	(Moniruzzaman *et al*., 2013)	"Physicochemical and antioxidant properties of Malaysian honeys produced by Apis cerana, Apis dorsata and Apis mellifera"	BMC Complementary and Alternative Medicine	148

number of times specific keywords appeared across all papers. The "All keyword" category encompasses author and indexed keywords (Arifah *et al.*, 2022). The network representation of the topic, as generated by VOSviewer, is depicted in Figure 3. The VOSviewer investigation yielded the formation of seven distinct clusters. Each cluster exemplifies the interconnectedness between many issues. The software can visually represent bibliometric mapping, as illustrated in Figure 3. The keywords were visually represented as dynamic circles, with the size of each circle corresponding to the frequency of its occurrence in the titles and abstracts. As a result, the sizes of the letters and circles were established based on their occurrence rates. The frequency of a keyword's occurrence is directly proportional to the number of letters and circles present. A total of 7,320 keywords were identified within a corpus of 765 publications, all focusing on promoting honey as an antioxidant. Figure 3 illustrates the clusters seen within each of the topic areas that were examined. The use of a consistent color for each word conveys a strong correlation. As an illustration, it may be observed that the terms "honey," "antioxidant activity," "phenols," and "DPPH" have a shared circular hue, indicating their interconnectedness and categorization. "Honey" and "antioxidant activity" were the keywords most often mentioned, with 576 occurrences and 10,938 total link strength, 408 occurrences, and 9,072 total link strength, respectively. This material provides insights into the antioxidant properties of honey, allowing us to learn about its new characteristics.

CONCLUSIONS

According to a bibliometric review, 765 scholarly works have been dedicated to examining the antioxidant effects of honey. The average annual publication count was 69.5, although the average number of citations per publication was 18.3. Most publications, specifically 309 papers, were contributed by researchers hailing from Malaysia. Universiti Sains Malaysia emerged as the most prolific institution, generating 53 articles. The periodical "Food Chemistry" exercised the most substantial influence, as evidenced by its inclusion in one paper and the reception of 1554 citations. Based on a scientific mapping analysis, it is evident that Kolayli S has made a significant scholarly addition to the existing literature on honey's antioxidant properties. This is substantiated by their impressive H index of 9, which indicates a high level of impact and productivity and an average citation count of 33.53 per article. The scholarly article authored by Can *et al.* in 2015 has garnered considerable recognition within the academic community, evident by its notable citation count of 294. With this bibliometric science mapping study, researchers can plan, think about, and construct probable future re-

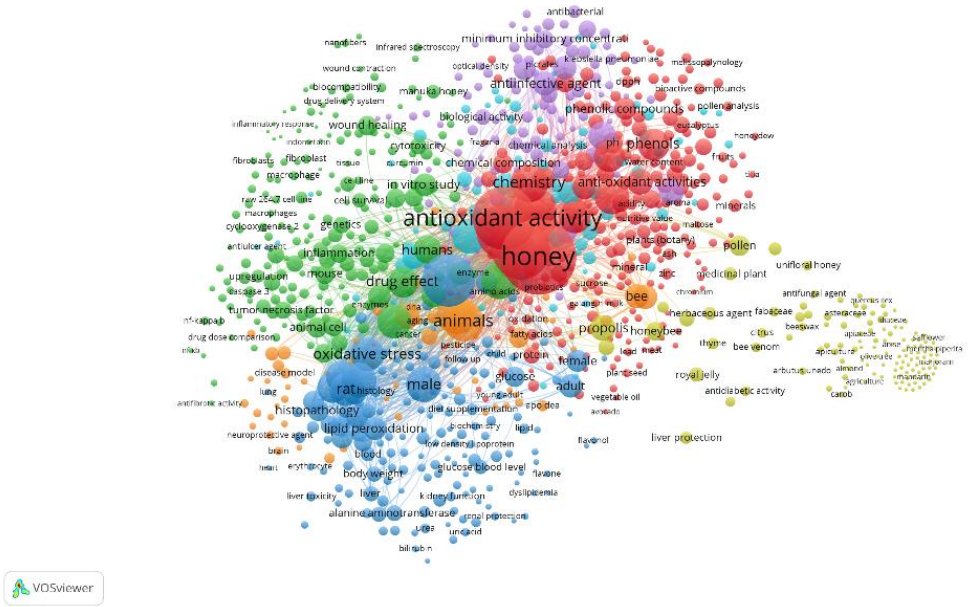

Figure 3. Network visualization of the topic by VOSviewer

search projects that meet pharmacological criteria for manufacturing honey as antioxidants. However, this study was subject to several limitations. Initially, the scope of our research was limited to papers that were published in the English language throughout the time frame of 2013 to 2023. Furthermore, incorporating existing scholarly works has significantly shaped the choice of keywords, potentially impacting the quantity and variety of articles in our research.

CONFLICT OF INTEREST

None to declare

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