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A bibliometric analysis of royal jelly research (1995–2025): Global trends, collaboration networks, and thematic structure

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Abstract

This study presents a bibliometric analysis of scientific literature on royal jelly published from 1995 to 2025. It evaluates publication performance, the most prolific authors and journals, citation structure, international collaboration networks, and thematic trends. The findings reveal a steady increase in research on royal jelly over the years, with publications mainly appearing in journals on beekeeping, food science, and chemistry. Keyword and thematic analyses show that early studies focused on *Apis mellifera* and compositional analysis, whereas later research highlighted molecular and functional aspects, including proteins, gene expression, and biological activity. In recent years, research on biological effects, including antioxidant activity, oxidative stress, and 10-HDA, has increased. Collaboration networks indicate that research output is concentrated in certain countries, with China occupying a central position in the literature. In conclusion, the royal jelly literature has evolved from descriptive studies to mechanistic and application-oriented research, maturing through an interdisciplinary structure.

Keywords: Citation analysis, International collaboration, Keyword co-occurrence, Research Dynamics, Scientific productivity

INTRODUCTION

Royal jelly is a white-cream colored, highly nutritious, viscous food substance secreted from the hypopharyngeal and mandibular glands in the heads of worker bees aged 6–15 days, which feeds the queen bee and young larvae (Akyol and Baran 2015). All larvae are fed royal jelly in the first days of their lives, while the queen bee continues to be fed this substance throughout her life; this is associated with caste differentiation and a long lifespan (Moritz and Southwick 1992). This unique biological role has made royal jelly a notable subject of research from both entomological and biomedical perspectives. Due to its complex chemical composition and numerous bioactive components, royal jelly has attracted interest for many years in both traditional practices and modern scientific research (Maghsoudlou et al. 2019).

In recent years, the growing interest in its molecular mechanisms and potential therapeutic applications has further increased the need for a comprehensive evaluation of the accumulated scientific knowledge in this field. Recent studies on the biological activities of royal jelly reveal that this product exhibits antioxidant, anti-inflammatory, immunomodulatory, and anticancer effects through its bioactive components, such as proteins, lipids, particularly 10-hydroxy-2-decanoic acid (10-HDA), and major royal jelly proteins (MRJPs). These components are reported to play an important role in tissue repair, cellular regeneration, and the regulation of various physiological processes (Sönmez, 2025). Royal jelly displays a wide range of biological activities due to its bioactive components. In particular, royalisin (Park et al. 2020) and jelleine (Romannelli et al. 2011) peptides have been reported to have antimicrobial effects, while 10-hydroxy-2-decenoic acid (10-HDA) has been reported to have antimicrobial (Gao et al. 2023) and anticancer (Albalawi et al. 2022) properties.

Furthermore, major royal jelly proteins (MRJPs) are reported to regulate the immune system (Bagameri et al. 2023) and (Mureşan et al. 2022). The composition of royal jelly includes major royal jelly proteins, free fatty acids, vitamins, amino acids, and phenolic compounds. In particular, 10-hydroxy-2-decenoic acid (10-HDA), a characteristic component of royal jelly, exhibits various biological activities. The antioxidant effects of royal jelly have been demonstrated in different experimental models; water and alkaline extracts have been reported to exhibit free radical scavenging properties and to reduce oxidative damage (El-Nekeety et al. 2007, Kanbur et al. 2009, Liu et al. 2008, Jamnik et al.

2007, Nagai and Inoue 2004, Nagai et al. 2006, Silici et al. 2009).

Furthermore, it has been suggested that royal jelly can prolong lifespan by reducing DNA damage in some animal models (Inoue et al. 2003). However, despite numerous experimental findings on the effects of royal jelly on the neurotrophic, metabolic, immunomodulatory, and cardiovascular systems, clinical-level evidence is limited in some areas, and studies are largely confined to in vitro and animal experiments (Inoue et al. 2003). This indicates that the body of knowledge in the literature is both rapidly expanding and thematically diversifying. Recent studies have particularly focused on emerging topics such as the interaction of royal jelly with gut microbiota (Chi et al., 2021) and its potential roles in neurodegenerative diseases (Sığ et al. 2019, Varol et al. 2024), reflecting the evolving research trends in this field.

A significant increase in publications on royal jelly has been observed over the last two decades; studies range from molecular mechanisms to functional food applications. However, despite this increase, the structural characteristics of the royal jelly literature, prominent thematic clusters, international collaboration networks, and scientific evolution over time have not been sufficiently evaluated from a holistic perspective. The rapid growth and increasing complexity of the literature make it difficult to systematically interpret existing knowledge, underscoring the need for bibliometric approaches to identify research patterns, hotspots, and knowledge gaps. Therefore, the present study aims to reveal the scientific production dynamics, thematic development, and research trends of the field by analyzing royal jelly research through bibliometric methods. Thus, it seeks to map the body of knowledge in the literature, shed light on future research directions, and provide a structured framework for guiding future scientific investigations.

To the best of our knowledge, there is a lack of comprehensive bibliometric studies that systematically evaluate the royal jelly literature over an extended period. Although a recent scientometric study (Espinoza-Carhuancho et al. 2025) examined royal jelly research on oxidative stress and inflammatory mediators within a limited time frame (2019–2024), its scope was restricted to specific biological contexts and did not comprehensively cover the overall evolution of the royal jelly literature. In contrast, the present study provides a broader, more comprehensive bibliometric evaluation by spanning a wider time frame and capturing the broader research landscape, thematic evolution, and emerging trends in royal jelly studies.

MATERIALS AND METHODS

This study conducted a bibliometric analysis of scientific literature on royal jelly. The Web of Science (WoS) Core Collection database was selected as the data source (Xie et al. 2020). WoS is considered one of the most widely used and reliable databases in bibliometric research due to its long-term citation indexing and standardized bibliographic structure. Ellegaard and Wallin (2015) state that WoS provides a powerful resource for the structural and temporal analysis of scientific output. Similarly, Hassan and Duarte (2024) emphasize that the use of reliable, comprehensive databases in bibliometric analyses is critical to the validity of results.

The search covered the years 1995–2025 (Data were retrieved on 15-25 January 2026), using the terms "*royal jelly*", "*royal jellies*", "*bee milk*", and "*larval jelly*" in the Topic field, along with "*bee*", "*bees*", "*queen jelly*", and "*worker jelly*", while excluding "*varroa*" and "*destructor*". The initial search yielded 773 records. Passas (2024) specifically highlights that data cleaning and suitability assessment are crucial steps in bibliometric analysis. Accordingly, only publications classified as "articles" were included; reviews, book chapters, editorial materials, and conference papers were excluded. Additionally, only articles indexed in SCI-Expanded (SCI-E) and ESCI were selected, and off-topic publications were removed through manual review.

The SCI-Expanded and ESCI indexes were specifically selected because they provide high-quality, standardized, peer-reviewed publications and are widely used in bibliometric studies due to their reliable citation indexing. After this process, 506 articles were deemed suitable for analysis and formed the final dataset. The complete records and citation information of the selected articles were exported from the WoS database, and the dataset was cleaned before analysis (Huang et al. 2022). Variations in author names were checked, repetitions and spelling differences in keywords were reviewed, and the dataset was prepared for analysis software.

Hassan and Duarte (2024) state that bibliometric studies should not be limited to presenting annual publication numbers but should also include citation indicators and impact measures. Therefore, both performance analysis and science mapping techniques were used in the study. For performance analysis, indicators such as publication counts by year, the most prolific authors, countries and institutions, total citations, and the h-index were evaluated.

Citation analysis is considered a fundamental method for measuring impact and visibility in a research field, and Ellegaard and Wallin (2015) state that it plays a central role in evaluating research performance. In line with the science-mapping approach, keyword co-occurrence, co-authorship, and co-citation analyses were conducted. Hassan and Duarte (2024) emphasize that keyword dynamics and thematic clusters are particularly important for understanding the evolution of the field of research. Passas (2024) states that co-citation, co-word, and bibliographic matching methods are fundamental techniques for revealing the intellectual structure of the field in bibliometric analyses. VOSviewer (version 1.6.20) software was used for network analyses and visualization. VOSviewer is widely used for visualizing bibliometric networks and can handle large datasets. Liaqat et al. (2024) showed that VOSviewer is effective for clustering-based visualization of co-occurrence, co-authorship, and citation networks. In this study, node sizes were interpreted as representing the frequency of the relevant element, and link thicknesses as representing total link strength.

The Bibliometrix beta package was also used in the RStudio Version 4.5.0 environment to calculate performance indicators and support thematic analyses. Passas (2024) states that the Bibliometrix package provides a comprehensive, flexible tool for bibliometric data processing, performance analysis, and science mapping. Thus, in this study, both quantitative performance indicators and network-based structural analyses were evaluated together to reveal the scientific production dynamics, thematic orientation, and collaboration structure of the royal jelly and related bee product literature with a holistic approach. The study selection process, including identification, screening, and inclusion, is illustrated in a PRISMA flow diagram (Figure 1).

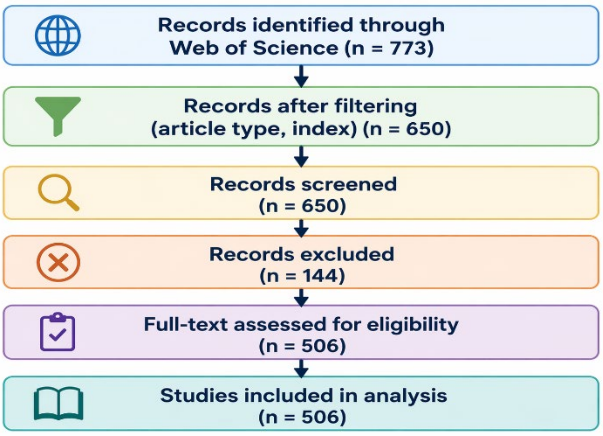

Figure 1. PRISMA Flow Diagram of the Study Selection Process for Royal Jelly Literature (1995–2025)

RESULTS

Figure-2 shows the distribution of annual publication numbers in the field of royal jelly over time. The findings reveal a significant upward trend, particularly after 2018. The highest number of publications was recorded in 2023 and 2024 (approximately 50 publications). While there were few publications in the early 2000s, remarkable growth in the literature has been observed in the last decade. The annual article growth rate is 13.69%.

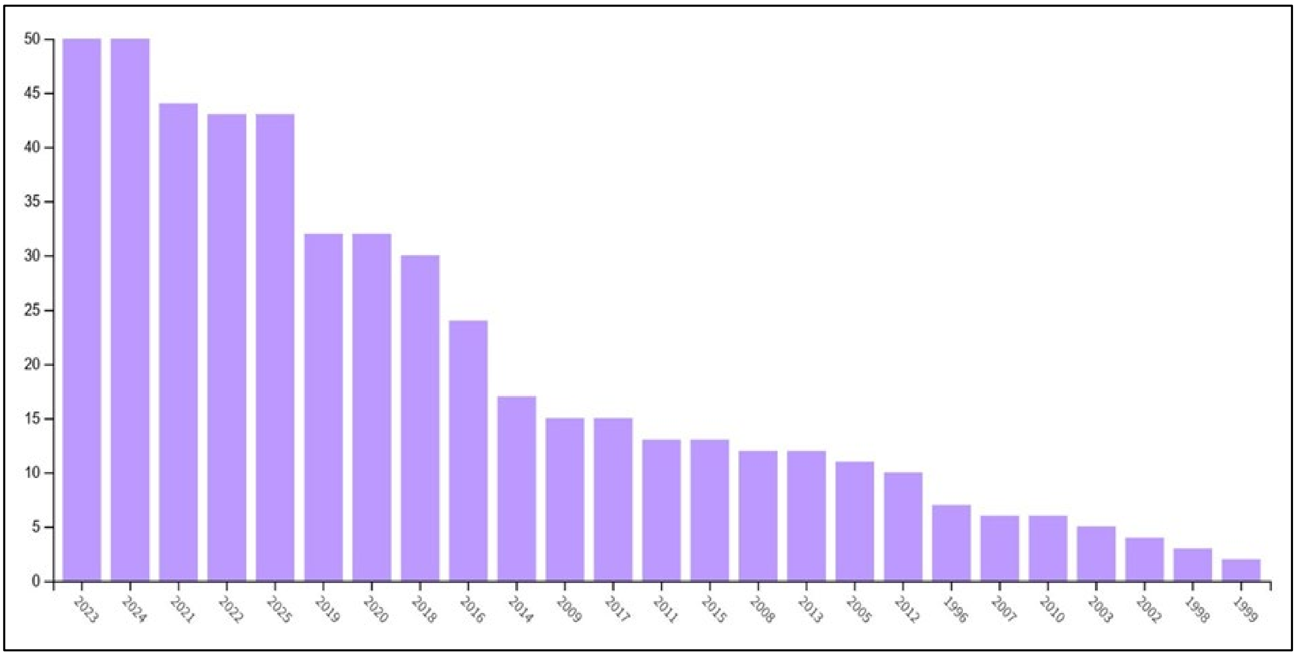

Figure 2. Annual Scientific Production in Royal Jelly Research (1995–2025)

This indicates that scientific interest in royal jelly research has increased significantly in recent years. Figure-3 shows the network of scientific cooperation between countries. China is the most central country, with the highest publication output. The US, Germany, and Japan have strong international cooperation links. Türkiye's inclusion in the same cluster as European and Asian countries indicates regional cooperation. Overall, the literature appears to have an international and multi-centered structure.

Figure 4 illustrates the co-authorship relationships among authors in the research area. Node sizes represent the authors' publication output, and connections indicate the number of collaborative studies. Authors such as Li, Jianke, Wu, Liming, Hu, Han, and Chen, Di are centrally positioned in the network and form dense collaborative structures around specific research clusters. This clustering indicates that certain research groups and academic teams are prominent in the literature, suggesting that the field is developing collaboratively.

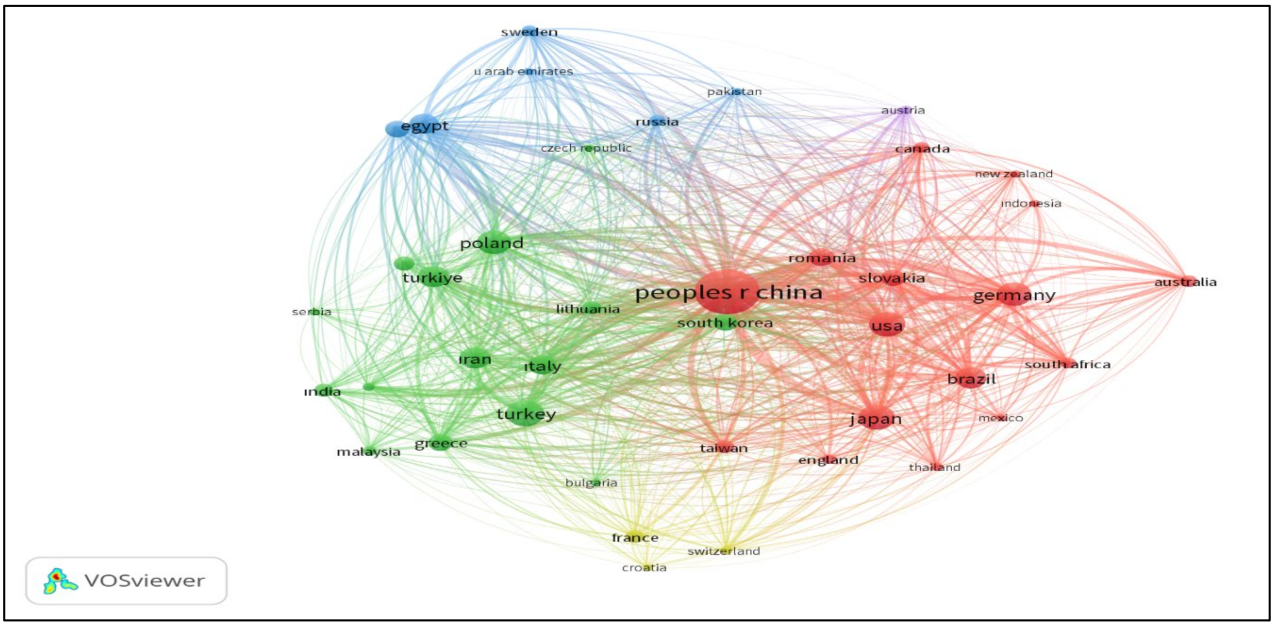

Figure 3. Country Collaboration Network (*In this map, each circle represents a country. The size of the circles indicates the volume of publications produced by each country, while the connecting lines show the number of joint publications between countries. The larger nodes for China (People's Republic of China), Germany, and the USA indicate that these countries are central actors in the literature. Countries of the same color form clusters of intense collaboration, reflecting regional or strategic academic partnerships)

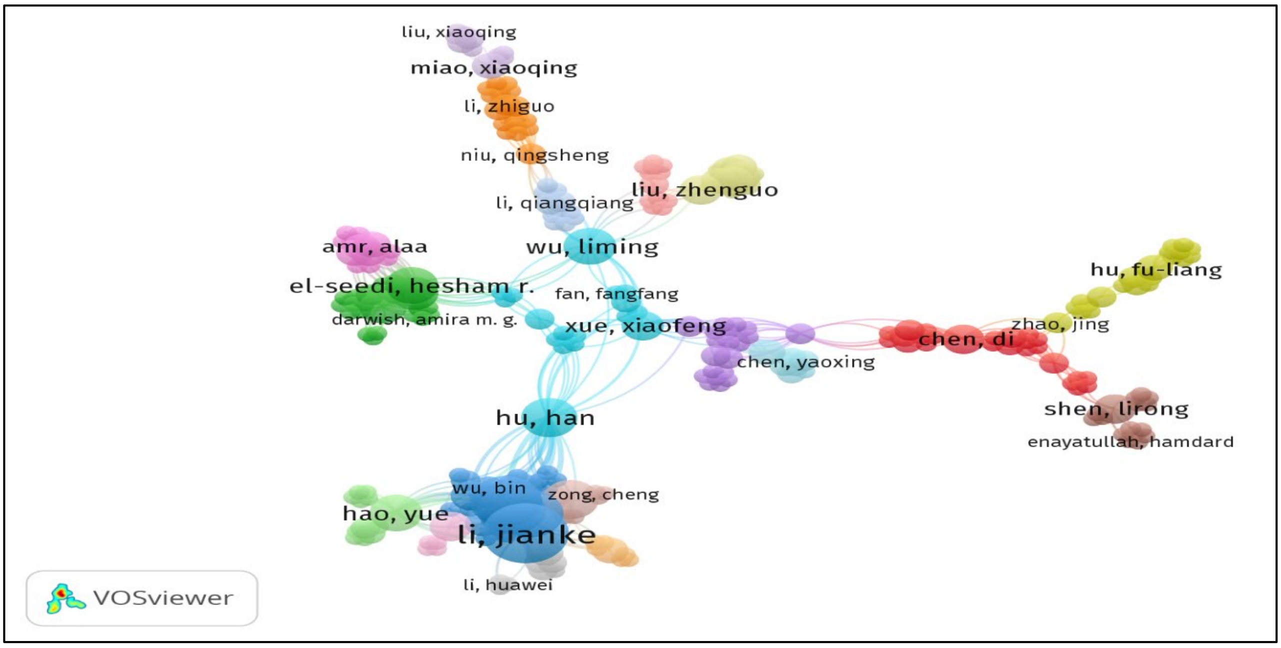

Figure 4. Author Author Co-authorship Network – Cluster Visualization (*Each circle represents an author, with the size of the circle indicating the author's publication count or collaboration strength. The lines between circles indicate collaborative work, and their thickness indicates the intensity of collaboration. Authors of the same colour belong to the same collaborative group, and those positioned close to each other tend to collaborate more frequently.)

Figure 5 shows the most frequently occurring words and their frequency in the titles of the publications examined. The terms "royal" and "jelly" have the highest frequency, indicating that the literature is directly focused on royal jelly. Additionally, terms such as "bee," "*Apis mellifera*," "honey," "protein," "pollen," and "antioxidant" indicate that the studies focus on biological properties, component analysis, and functional effects.

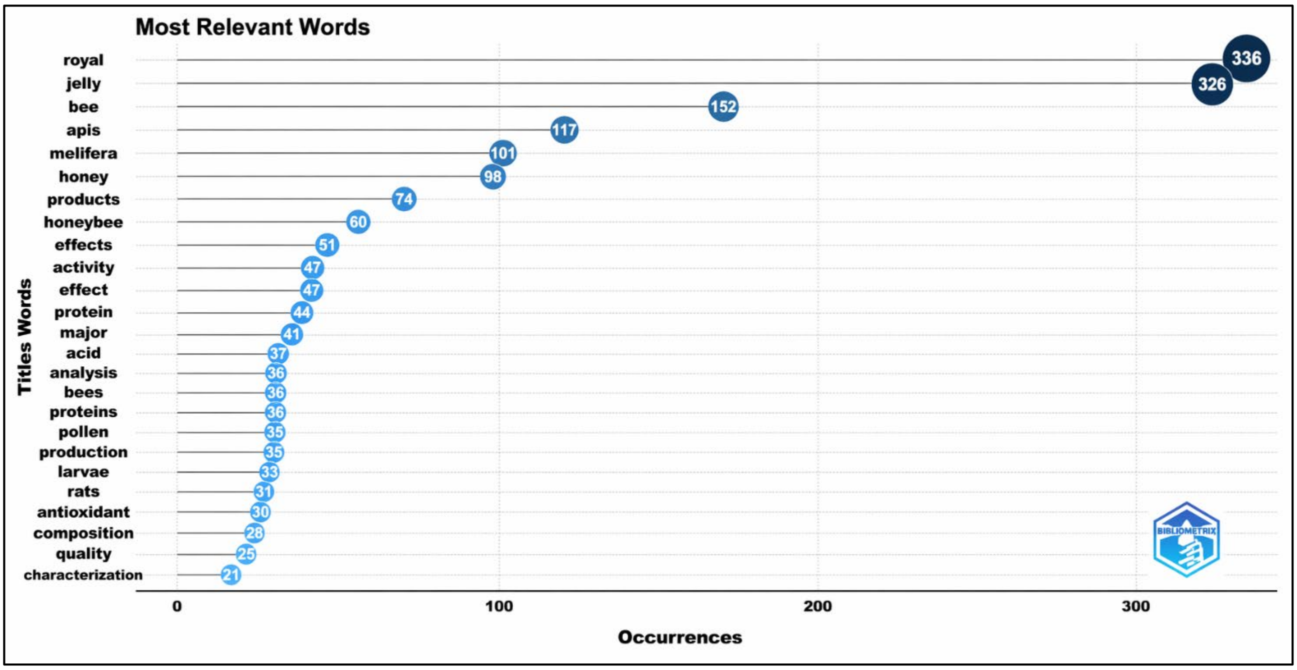

Figure 5. Most Frequent Words in the Titles of Publications on Royal Jelly

Figure-6 shows the journals with the most publications in the field of royal jelly and their publication counts. The Journal of Apicultural Research and Apidologie have the highest number of publications, indicating that the field is primarily concentrated in journals focused on beekeeping and Apidology. Furthermore, the presence of journals such as Molecules, Scientific Reports, Food Chemistry, and the Journal of Agricultural and Food Chemistry indicates that research also focuses on chemical composition, biological activity, and functional properties.

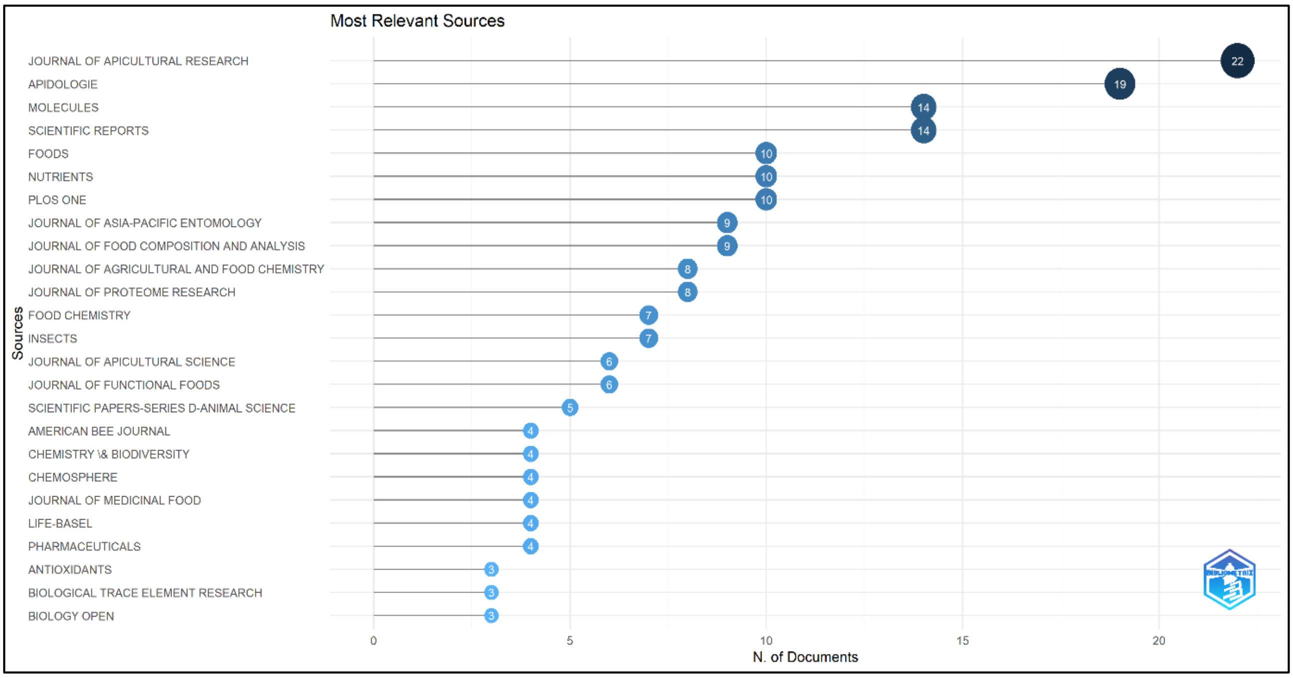

Figure 6. Most Productive Journals in the Royal Jelly Literature

Figure 7 illustrates the co-occurrence relationships between the keywords. The term “royal jelly” is central to the network and shows strong connections with concepts such as “honey”, “propolis”, “antioxidant”, “chemical composition”, and “oxidative stress”. The network structure reveals that biochemical analysis themes are integrated with health and antioxidant studies. The literature is clustered along both basic biology and functional food axes.

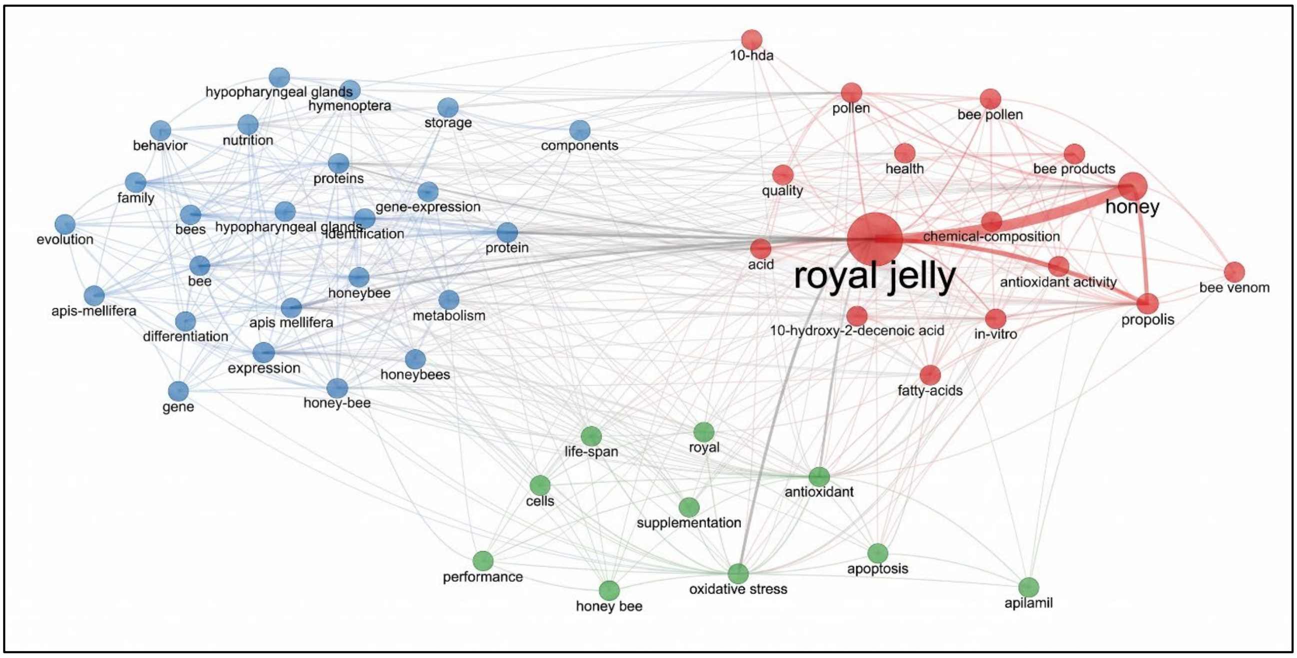

Figure 7. Keyword Co-occurrence Network (*Each circle represents a keyword, with the size of the circle indicating the frequency of the keyword's use. The lines between the circles indicate the frequency of keyword co-occurrence, and the thickness of the lines shows the strength of the relationship. Keywords of the same color belong to the same thematic cluster, and concepts located close to each other are more frequently discussed together in the literature)

Figure 8 shows the distribution of themes by centrality and intensity. "Expression", "*Apis mellifera*", and "identification" stand out as motor themes. "Royal jelly", "honey", and "propolis" are core themes. The concepts of "oxidative stress" and "antioxidant" are among the emerging themes. This distribution indicates that the field is progressing in a balanced manner between molecular and health-based research.

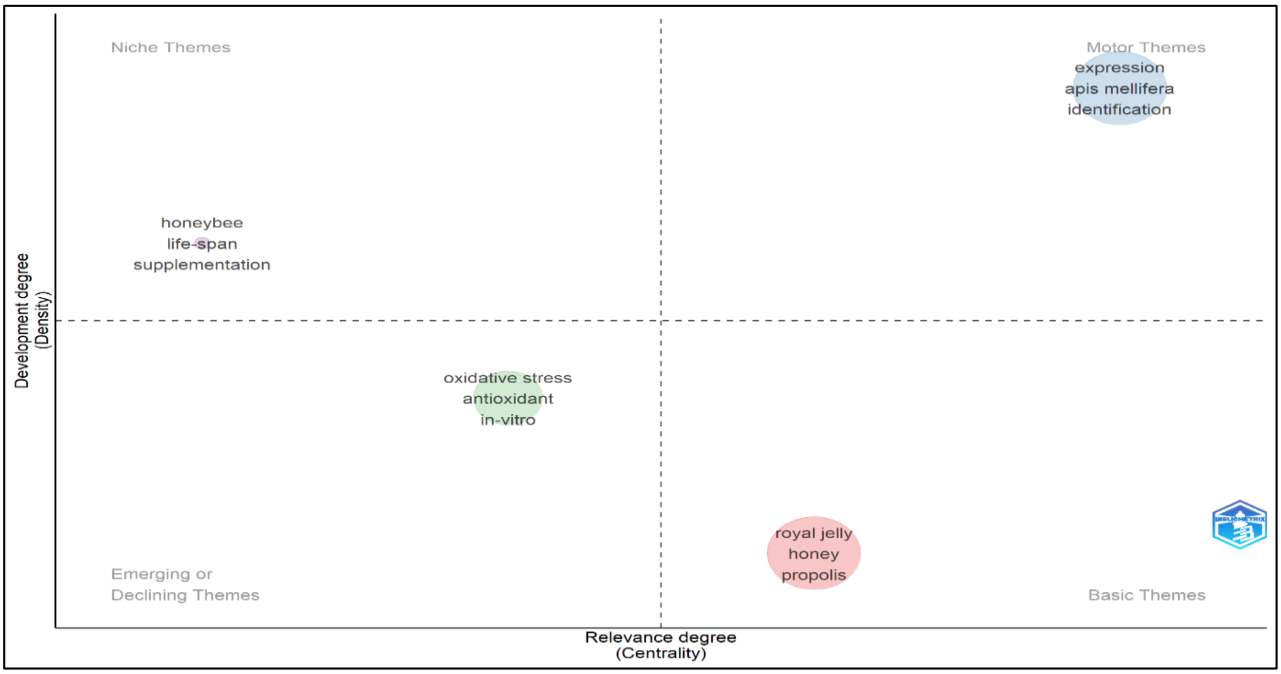

Figure 8. Thematic Map Based on Centrality and Density of Research Themes (*The horizontal axis represents the centrality (level of importance within the field) of the themes, while the vertical axis represents their density (level of development). Themes in the upper-right section are motor themes, indicating important and well-developed topics. The lower-right section represents core themes, the upper-left section represents niche themes, and the lower-left section represents emerging or declining themes. The size of the balloon indicates the weight or frequency of the relevant theme in the literature)

Figure 9 illustrates the changing trends of prominent keywords in the research field over the years. Balloon sizes indicate the frequency of term usage, while horizontal lines indicate the period during which each topic was active in the literature. In early studies (1998–2008), molecular and genetic themes, such as gene expression, polymorphisms, and molecular cloning, were more prominent. After 2010, biological and product-oriented topics such as royal jelly, honeybee, and hypopharyngeal gland attracted more attention. In recent years (post-2020), health and functional component themes such as antioxidants, oxidative stress, bioactive compounds, and wound healing have increased significantly. This trend suggests that the research field is shifting from basic molecular studies to applied, health-focused research.

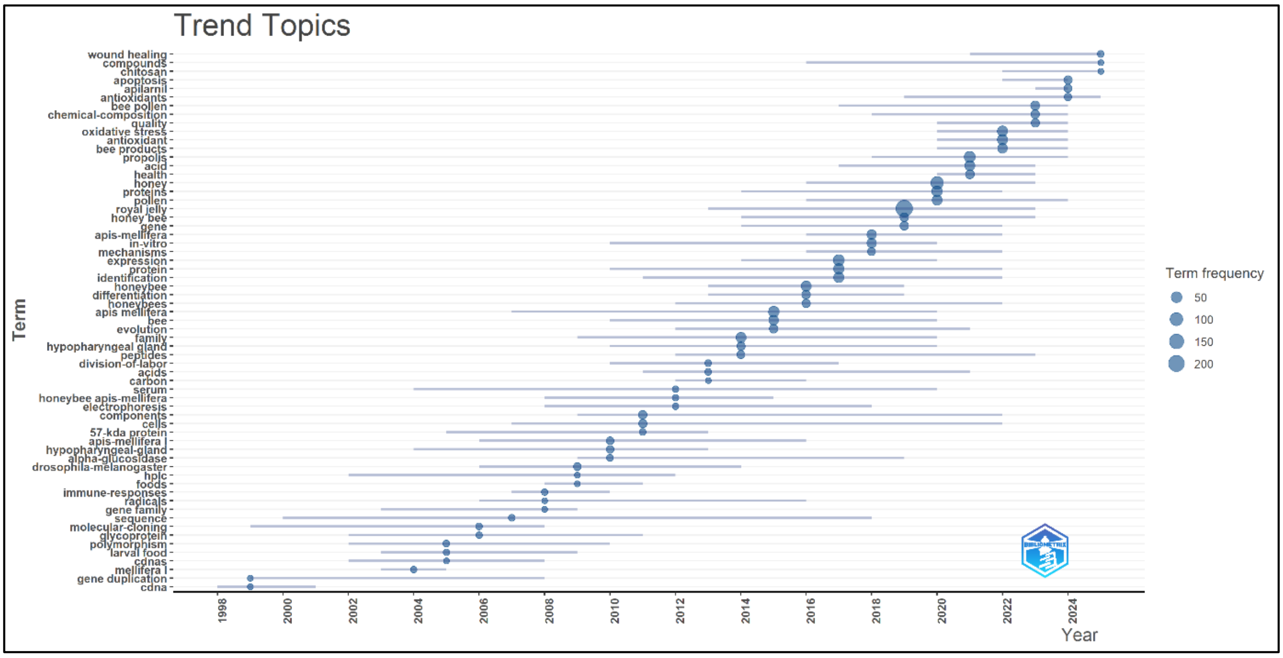

Figure 9. Trend Topics Analysis Over Time (*The horizontal axis represents the years, while the vertical axis shows the keywords. Each bubble indicates the usage of a specific term in a given year, with the bubble size reflecting its frequency. The horizontal lines indicate the periods during which each topic was active in the literature. This graph illustrates thematic trends in the field over time and highlights which topics were prominent during particular periods)

Figure 10 illustrates the positioning of concepts within the research area on a two-dimensional plane using multiple correspondence analysis (MCA). Concepts situated close together on the map represent themes that are frequently addressed together in the literature. Biological and physiological themes (hypopharyngeal gland, gene expression, *Apis mellifera*, metabolism, proteins) are clustered on the left, while concepts related to product composition and health effects (honey, royal jelly, propolis, antioxidant activity, bee products, chemical composition) are concentrated on the right. This distribution indicates that the literature is organized around two main axes: (i) bee biology and molecular mechanisms, and (ii) the chemical composition and health effects of bee products. Thus, the field exhibits a bidirectional conceptual structure, encompassing both basic science and applied health research.

Figure 11 depicts the inter-institutional scientific collaboration network using an overlay (time-layered) visualization. Node sizes indicate the publication output intensity of the institutions, while links represent collaborative relationships. The Chinese Academy of Agricultural Sciences is the most central institution in the network, with the highest publication volume. Examining the colour scale (2010–2025), it is clear that institutions based in China have produced more recent and intensive academic output, particularly in recent years. The network structure shows a clustering trend in international collaborations and indicates that certain institutions occupy leading positions in research areas.

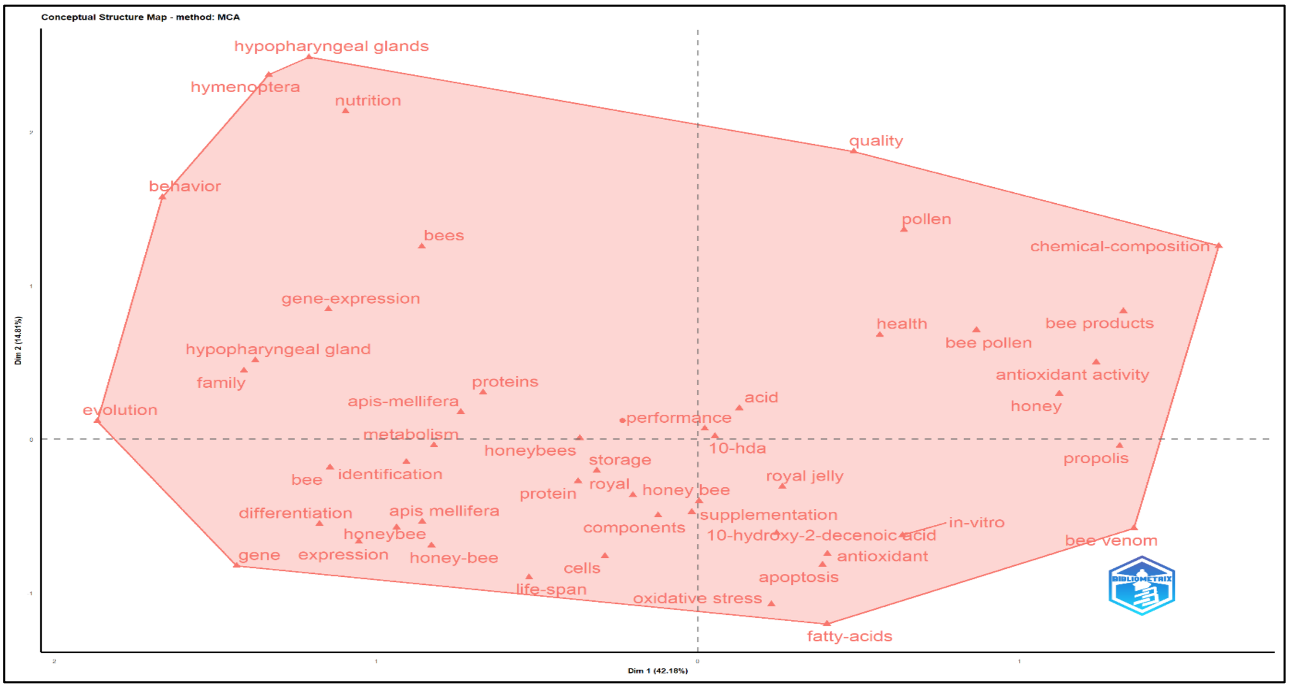

Figure 10. Conceptual Structure Map Based on Multiple Correspondence Analysis (MCA) (*Each point on the map represents a keyword, and concepts located close together are often discussed together in the literature. The axes display the distribution of concepts in a two-dimensional plane, while spatial proximity indicates conceptual relationships. This map reveals the thematic structure of the research area and the relational clustering of concepts)

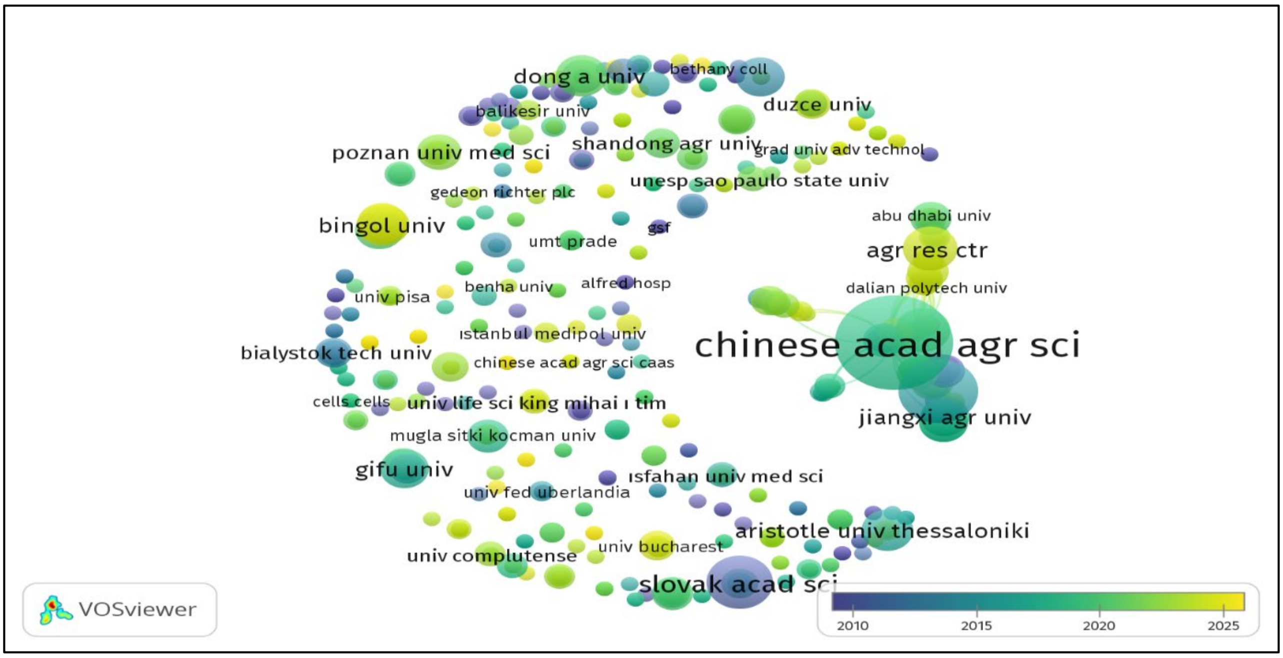

Figure 11. Institutional Collaboration Network (Overlay Visualization) (*Each circle represents an institution, and the size of the circle indicates the institution's publication output volume or total networking power. The lines between the circles show collaboration between institutions. The colors represent the average publication year, with blue indicating older years and yellow indicating more recent years. Institutions located close to each other tend to have more intensive collaborative relationships in the literature)

Figure 12 illustrates the thematic evolution of dominant keywords across four time periods (1995–2010, 2011–2015, 2016–2020, and 2021–2025). Early studies mainly focused on royal jelly, acid, and *Apis mellifera*. Between 2011 and 2015, themes expanded to include pollen, honey bee, and species-related research. In 2016–2020, molecular topics such as expression, identification, and proteins became more prominent. In the most recent period (2021–2025), research has shifted towards bioactive compounds and functional properties, including antioxidant activity, oxidative stress, 10-HDA, and proteins, indicating growing interest in biochemical characterization and health-related applications.

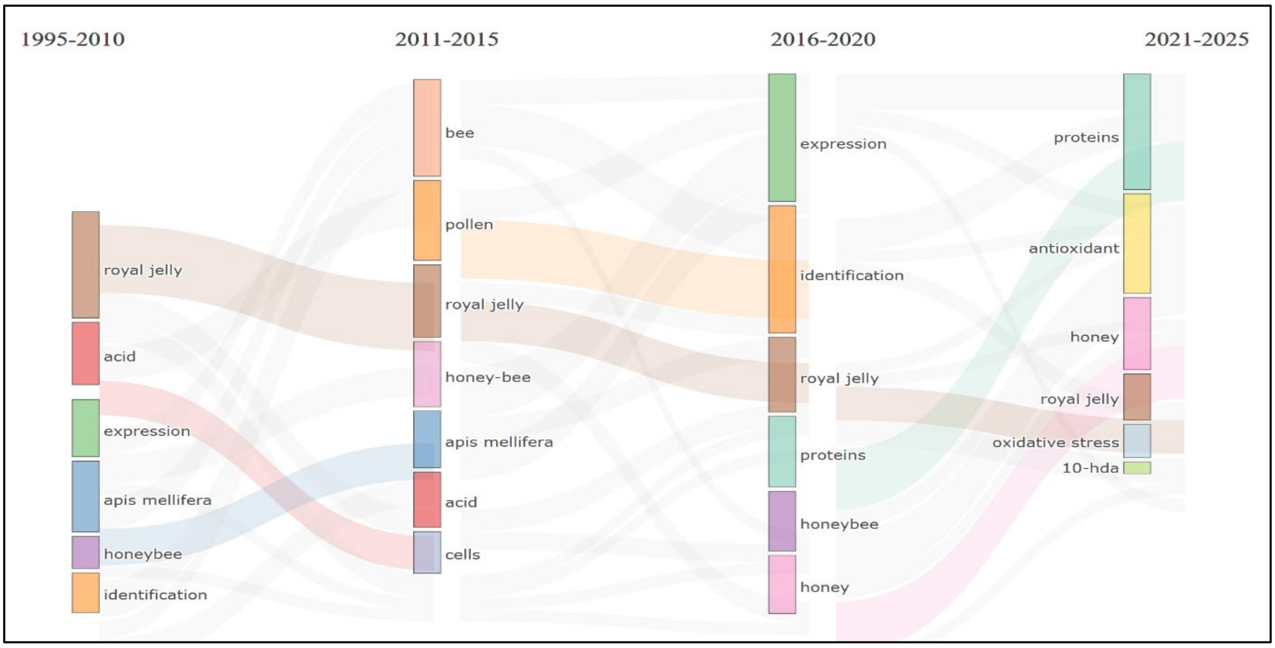

Figure 12. Thematic Evolution of Keywords in Royal Jelly Research (1995–2025) (*This Sankey diagram illustrates the evolution of major keywords across four time periods. Colors represent thematic groups, and the connecting flows indicate the continuity and transformation of research topics over time)

DISCUSSION

When examining the temporal development of the royal jelly literature, it is evident that the research focus has evolved significantly from content analysis and reporting of general biological activity to the elucidation of molecular mechanisms. Oršolić and Jazvinščak Jembrek (2024) emphasize that the anti-inflammatory and immunomodulatory effects of are particularly mediated by 10-HDA and major royal jelly proteins (MRJPs). This demonstrates that the field has shifted from focusing solely on chemical component identification to elucidating cellular signaling pathways, gene expression, and molecular targets. The clustering of the terms “royal jelly”, “10-HDA”, “antioxidant”, “expression”, and “Apis mellifera” in bibliometric thematic maps further supports this transformation. Notably, interest in MRJP proteins has increased significantly in recent years. Wang et al. (2020) purified MRJP1–3 proteins and characterized their structural and functional properties, while Tian et al. (2018) analyzed the architecture of the MRJP1 oligomer and showed that biological activity is associated with its structural organization.

Similarly, Bagameri et al. (2023) and Mureşan et al. (2022) highlighted the anti-inflammatory and biological activities of MRJP-derived peptides. These findings indicate that keywords such as “protein structure”, “bioactive peptides”, “MRJP”, and “identification” have become more central in the royal jelly literature in recent years. The inclusion of “expression”, “*Apis mellifera*”, and “identification” among the motor themes in thematic maps reveals that the field is now concentrated on the molecular biology axis. The biological effects of royal jelly are not limited to inflammation. Royal jelly displays a wide range of biological activities, depending on its bioactive components. Royalisin and jelliin peptides have been reported to show strong antimicrobial effects (Romanelli et al. 2011, Park et al. 2020), while 10-HDA displays both antimicrobial and anti-inflammatory properties (Yang et al. 2018, Gao et al. 2022).

The antioxidant capacity of royal jelly is also well supported in the literature. Royal jelly extracts have been shown to possess free radical scavenging properties and to reduce oxidative stress (Moraru et al. 2024, Li et al. 2023). In addition, the anticancer potential of royal jelly and its components is noteworthy. It has been reported that 10-HDA suppresses cell proliferation and induces apoptosis (Albalawi et al. 2022), while MRJPs contribute to antitumour effects at the cellular level (Abu-Serie and Habashy 2019). The immunomodulatory effects of royal jelly have also been demonstrated in various studies. Royal jelly is reported to play a regulatory role in the immune system (Bagameri et al. 2023), MRJPs increase immune cell activity, and 10-HDA modulates inflammatory responses (Fan et al. 2020, Wang et al. 2023). Finally, the anti-ageing effects and wound-healing potential of royal jelly and its components are also well documented. Royal jelly has been reported to have life-extending effects (Moraru et al. 2024), MRJPs support cellular regeneration, and 10-HDA plays a role in tissue repair processes (Majd et al. 2022, Huang et al. 2024).

Shahzad et al. (2016) reported that the addition of royal jelly to semen extenders improved fertility parameters, and Alcay et al. (2019) demonstrated the protective effect of royal jelly-supported extenders on sperm quality in cryopreservation processes. These studies show that royal jelly research is increasingly oriented towards translational applications in reproductive biology and veterinary biotechnology. The clustering of the terms “oxidative stress”, “antioxidant”, “in vitro”, and “supplementation” in bibliometric keyword networks reveals that royal jelly is widely studied in experimental and applied contexts.

Furthermore, Demirkaya and Sağdıçoğlu Celep (2022) highlighted the broad spectrum of biological effects of royal jelly by emphasizing its antioxidant, antifungal, antiviral, anticancer, and anti-obesity properties. In the context of human studies, Yan et al. (2024) contributed to translational research at the clinical level by examining the antioxidant and anti-inflammatory effects of royal jelly peptides. The chemical composition of royal jelly varies according to seasonal, ecological, and geographical factors (Zheng and Hu 2010). Generally, royal jelly contains 50–70% water, 9–18% protein, 7–18% carbohydrates, 3–8% fatty acids and lipids, and 1.5% minerals (Shahzad et al. 2016, Alcay et al. 2019).

In royal jelly samples from Anatolia, 10-HDA values have been reported to range from 1.0–3.9%, and moisture content from 62.6–73% (Kolaylı et al. 2015). This variability highlights the importance of standardisation and quality control in the literature. Oršolić and Jazvinščak Jembrek (2024) state that 10-HDA is used as a quality marker but can be influenced by production and storage conditions, underscoring the limitations of quality assessment based on a single biomarker.

Özkök et al. (2023) evaluated the relationship between acidity and 10-HDA; Boyracı et al. (2023) assessed anti-hyaluronidase, antioxidant, and antimicrobial activities; and Balkanska and Kashamov (2011) examined parameters such as water, protein, lipid, and total acidity. These studies confirm that the keywords “chemical composition”, “quality”, and “characterization” are among the main themes. Examination of countries and collaboration networks reveals China’s central position. China’s prominence in both production and publication numbers is linked to the widespread breeding of the *Apis mellifera ligustica* strain (Ma et al. 2022).

The inclusion of countries such as Iran, Egypt, and Türkiye among the productive nations demonstrates that royal jelly and apitherapy research has a strong network centered in the Middle East and Asia. These findings are consistent with Şenel and Demir (2018), who emphasized China’s leadership in apitherapy. Ahmad et al. (2020) noted that studies on royal jelly have increased since the 2000s; Martinello and Mutinelli (2021) stated that international collaborations have strengthened interest in the potential antioxidant and anti-inflammatory effects of royal jelly. The concentration of publications in high-impact journals and the rise in review articles indicate that the field has entered a maturing phase. The biological significance of MRJP1 (royalactin) and MRJP9 (49-87 kDa), which constitute most of the main protein fraction of royal jelly, is widely discussed in the literature (Bagameri et al. 2023, Mureşan et al. 2022, Wang et al. 2020, Tian et al. 2018). Kamakura (2011) demonstrated the importance of royal jelly in epigenetics and developmental biology by showing that royalactin (MRJP1) triggers the transformation of larvae into the queen phenotype. This explains why, in bibliometrics, the terms “gene expression”, “differentiation”, and “evolution” are among the earliest themes.

Overall, royal jelly research initially focused on composition and general biological activity; over time, molecular mechanisms, protein structural analyses, quality standardization, and translational applications have come to the fore. The central position of “royal jelly” as a core theme in thematic maps, the emergence of “oxidative stress” and “antioxidant” as developing themes, and the presence of “expression” and “*Apis mellifera*” as motor themes indicate that the field is advancing along molecular and applied biology axes. This trend suggests that the interdisciplinary nature of the royal jelly literature is strengthening, moving towards a more mechanism-oriented, standardized, and clinically integrated research framework. Recent studies indicate that royal jelly exerts neuroregulatory effects through mechanisms involving neuroinflammation and neurotransmitter modulation (Zhu et al. 2025). In addition, emerging evidence suggests that royal jelly may influence brain function via the gut–brain axis and molecular-level regulatory pathways (Zhi et al. 2023).

Conclusion

This bibliometric analysis reveals the structural and thematic development of royal jelly research from 1995 to 2025. Literature has grown steadily, with publications concentrated in journals of beekeeping, food science, and chemistry. Early studies focused primarily on royal jelly, and its basic compositional analysis. Over time, research has shifted towards molecular topics such as proteins, gene expression, and bioactive compounds. In recent years, themes such as antioxidant activity, oxidative stress, and 10-HDA have become more prominent, reflecting increased emphasis on functional and health-related applications. Collaboration networks show that a limited number of countries – particularly China – play a central role in research production and international cooperation. Overall, the field has evolved from descriptive studies to more mechanistic and application-oriented research, demonstrating increasing scientific maturity and interdisciplinary integration.

Data Availability: The data used in this study were obtained from the Web of Science Core Collection database. The dataset generated and analyzed during the current study is available from the author upon reasonable request.

Declaration: The author declares that this manuscript has not been published previously and is not under consideration for publication elsewhere. The author is solely responsible for the content of the article.

Ethics Statement: This study is based on a bibliometric analysis of published scientific literature and does not involve human participants or experimental animals. Therefore, ethical approval is not required.

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Declaration of AI: The author declares that, except for minor assistance in reference formatting, this manuscript was not generated or written by artificial intelligence.

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