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Over a Century of Brucellosis Research: Network Analysis, Trends, and Future Perspectives

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ABSTRACT

Aims Brucellosis is one of the most common zoonotic infectious diseases that significantly impacts public health and national economies. Due to the growing scientific interest in brucellosis and its global health burden, this study aimed to conduct a scientometric analysis of global brucellosis publications from 1900 to 2020 to provide a comprehensive overview of research trends, leading countries, prolific authors, and thematic clusters.

Materials & Methods This study was conducted using scientometrics method. All brucellosis-related publications indexed in Scopus (1900-2020) were retrieved. Data were analyzed using Excel for descriptive statistics and VOS viewer for co-authorship, keyword co-occurrence, and thematic clustering.

Findings From 25,846 publications, 86.24% were original articles. The top publishing years were 2020 (852 articles), 2013 (827 articles), and 2019 (800 articles), reflecting a fluctuating upward trend. The United States (15.48%), Turkey (8.96%), and France (5.34%) led in productivity. Keyword analysis identified six clusters, namely immune response, clinical manifestations, zoonosis, diagnosis, pathogens, and epidemiology.

Conclusion This study demonstrated that brucellosis research has grown significantly in recent years, particularly in endemic regions. The findings can assist policymakers and researchers in identifying research strengths and weaknesses, setting research priorities, and strengthening international collaborations.

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Introduction

In recent years, with the advancement of genetics and the identification of emerging pathogens, many diseases have been identified in the world. Due to the speed of pathogenicity and mutagenicity of their causative agents, they are very difficult to control and, in many cases, have affected the health and economy of a country for years. The three causes of Brucella, Ebola, and Chicago are the diseases that have affected many countries in recent years [1]. Brucellosis is one of the most prevalent bacterial infectious diseases common to humans and animals that is transmitted directly or indirectly from infected animals or their products to humans [2, 3]. Brucellosis is caused by microorganisms from the Brucella family [4]. The disease is transmitted to humans through oral, respiratory, dermal, ocular and self-inoculation, even through the placenta, and is more common in spring and summer [5]. The most common method of disease transmission in endemic countries is the consumption of freshly contaminated milk [6]. Brucellosis is transmitted through contaminated dairy products, direct contact with infected animals, or occupational exposure among farmers and veterinarians [3, 7]. Brucellosis is an important disease in the world, especially in the countries of the Persian Gulf basin, the Mediterranean, North and East Africa, the Middle East, the Indian subcontinent, Central and South Asia, South and Central America and parts of Mexico [2].

In recent years, due to the increase in the registration of online articles in databases, the use of methods and strategies for retrieval information from biomedical articles, has attracted the attention of many researchers. In fact, increasing the annual publication of research and due to the diversity of databases, manual inspection of this research is impossible or very time consuming [8]. Examining the process of publishing articles in various scientific fields can provide a good perspective on the efforts of researchers in the field of knowledge, especially in the biological sciences. By checking published articles in the field of biology, in spite of updating information, it is possible to access the direction of biological changes and take action to prevent, fetch information, intelligently categorize information, and identify different areas of information. One of the most important steps in reviewing scientific articles is the collection of scientific update data [9]. Therefore, it is necessary to use methods and techniques that can be used to analyzing scientific publications to provide different types of analysis on scientific publications.

One of the methods of evaluating scientific activities is scientometrics. Scientometrics is in describing, explaining, and predicting the scientific status of researchers and research centers that has many applications in various national and international arenas and always provides an efficient way to monitor and rank organizations, researchers, journals, and countries [10, 11]. Scientometrics is a useful and efficient way to evaluate scientific progress and identify various aspects of scientific publications. These methods are used to quantify the growth of research productivity of the busiest countries and institutions, develop research materials, and determine essential research gaps [12]. Regular identification and evaluation of scientific outputs is very important to be aware of the current situation. Scientometrics is also known as "science of science" and is a common statistical method that thoroughly analyzes scientific backgrounds in a particular field [13]. On the other hand, the evaluation of the scientific products of different countries in this field can help identify the problems, bottlenecks, and shortcomings in this field and help to better understand the research branches and guide the research in line with the macro policy goals. On the other hand, by creating an atmosphere of effort to positively and constructively overtake, to help the spread of science and technology in countries. In addition, scientometrics studies provide important evidence of the results and effects of research programs for policy makers and planners [14].

In this regard, scientometrics methods have been widely used to evaluate the trend and growth of knowledge in health science research, including the analysis of cancer cells [15], Zika virus [16], tuberculosis [17], microbiota, COVID-19 [18], and the White Spot Syndrome Virus (WSSV) domain [19]. In this regard, Dastani et al. in their study analyzed Iranian scientific publications on brucellosis up to 2020 using scientometric methods and social network analysis. Based on 816 articles retrieved from Scopus, the study identified three main research clusters—prevalence, diagnosis, and treatment—while also highlighting the central role of certain authors and the importance of international collaborations, particularly with the United States, the United Kingdom, and Germany [20].

Similarly, Ghavidel et al. in their study entitled “Brucellosis: Co-authorship Network of Researchers Using Centrality Indicators” examined the scientific collaboration patterns in brucellosis research indexed in WOSCC from 1901 to 2019. Using scientometric and social network analysis, the study showed an increasing trend in publications, with the peak in 2019, and identified key authors and journals with the highest impact and centrality measures [21].

Building on this line of research, Danesh and Ghavidel in “A Century of Scholarly Collaboration by Brucella and Brucellosis Researchers: A Scientometric Study” analyzed a hundred years of publications indexed in WOSCC to examine productivity, efficiency, and collaboration patterns among researchers in this field. Their findings highlighted key influential authors, such as Cloeckaert and Kim, who held central positions in the co-authorship network, and revealed that higher centrality scores were strongly associated with productivity and citation impact. Despite identifying one main collaboration cluster, the study noted relatively low network density, suggesting limited overall connectivity among researchers [22]. Given the significant health and economic impact of brucellosis, understanding global research trends and gaps through scientometric analysis is essential for guiding future studies. Accordingly, the present study aimed to examine and analyze the global publications on the brucellosis using

scientometrics methods.

Materials and Methods

Study Design

This applied study was conducted using a scientometric approach with an analytical perspective. The aim was to map, analyze, and visualize the scientific output related to brucellosis at global level. Scientometric indicators were used to examine publication trends, thematic structures, and collaboration patterns within the field.

Data Source

The Scopus citation database was selected as the primary data source due to its extensive multidisciplinary coverage and its inclusion of peer-reviewed journals, conference proceedings, and book chapters. Compared to other databases, such as Web of Science and PubMed, Scopus provides broader international coverage and a more comprehensive representation of scientific production, making it particularly suitable for scientometric studies [23, 24].

Search Strategy

To develop a precise and comprehensive search strategy, Medical Subject Headings (MeSH) were used in combination with expert consultation in the fields of microbiology and infectious diseases. MeSH is a controlled and hierarchically structured thesaurus developed and regularly updated by the U.S. National Library of Medicine and is widely used for indexing and retrieving biomedical literature [25, 26]. The use of MeSH terms enhanced search precision and ensured that synonymous and related terms for brucellosis were systematically captured, thereby reducing the likelihood of missing relevant publications.

The search was conducted in the Title field of the Scopus database for publications published between 1900 and 2020, using the following query:

[TITLE (brucelloses) OR TITLE (malta AND fever) OR TITLE (gibraltar AND fever) OR TITLE (rock AND fever) OR TITLE (cyprus AND fever) OR TITLE (brucella AND infection) OR TITLE (brucella AND infections) OR TITLE (undulant AND fever) OR TITLE (brucellosis) OR TITLE (bangs AND disease) OR TITLE (bang AND disease) OR TITLE (brucella) OR TITLE (pulmonary AND brucellosis) OR TITLE (mediterranean AND fever)]

All retrieved records were exported in CSV format for further analysis.

Data Processing and Analysis

After data extraction, the records were cleaned and organized using Microsoft Excel to remove duplicates and prepare the dataset for analysis. Scientometric analyses and visualizations were performed using VOS viewer software.

VOS viewer is a widely used tool for constructing and visualizing bibliometric networks, including co-occurrence of terms, citation relationships, and co-authorship networks [27]. The software enables the creation of two-dimensional maps in which the size of nodes represents the frequency or weight of items (e.g., keywords, authors), and the distance between nodes reflects the strength of their relationships, typically measured through co-occurrence or citation links [28].

The analysis focused on annual publication trends, the most productive authors, institutions, and countries, as well as keyword co-occurrence patterns and co-authorship networks at the author, institutional, and country levels.

Statistical Methods and Visualization Techniques

The analyses were primarily descriptive and network-based, consistent with standard scientometric methodologies. Frequency counts, citation counts, and link strength measures were used to quantify scientific productivity and impact. Network visualization techniques, including co-occurrence analysis, citation analysis, and co-authorship analysis, were applied to identify thematic clusters, research hotspots, and collaboration patterns among researchers and institutions [29, 30].

Results

A total of 25846 publications related to brucellosis were extracted from the Scopus database. The data in Table 1 presents the trend of scientific publications of Brucellosis from 1900 to 2020. Accordingly, the highest number of publications was in 2020 (852 articles), 2013 (827 articles), and 2019 (800 articles).

Figure 1 shows that 86.24% of brucellosis scientific publications were related to original articles, 4.85% were related to reviews, 4.64% were related to letters, and the rest were other types of publications.

Table 1. Annual publications of Brucellosis disease from 1900 to 2020

Year	No. (%)	Year	No. (%)	Year	No. (%)	Year	No. (%)	Year	No. (%)
1900	1 (0.004%)	1925	2 (0.01%)	1950	221 (0.86%)	1975	261 (1.01%)	2000	305 (1.18%)
1901	0 (0%)	1926	7 (0.027%)	1951	249 (0.96%)	1976	280 (1.08%)	2001	307 (1.19%)
1902	0 (0%)	1927	13 (0.05%)	1952	226 (0.87%)	1977	261 (1.01%)	2002	441 (1.71%)
1903	2 (0.008%)	1928	11 (0.04%)	1953	182 (0.70%)	1978	296 (1.15%)	2003	427 (1.65%)
1904	2 (0.008%)	1929	30 (0.116%)	1954	175 (0.68%)	1979	250 (0.97%)	2004	393 (1.52%)
1905	3 (0.012%)	1930	39 (0.151%)	1955	199 (0.77%)	1980	273 (1.06%)	2005	478 (1.85%)
1906	11 (0.043%)	1931	34 (0.132%)	1956	155 (0.60%)	1981	262 (1.01%)	2006	511 (1.98%)
1907	8 (0.031%)	1932	41 (0.159%)	1957	185 (0.72%)	1982	278 (1.08%)	2007	516 (2%)
1908	7 (0.027%)	1933	24 (0.093%)	1958	176 (0.68%)	1983	233 (0.90%)	2008	562 (2.17%)
1909	5 (0.019%)	1934	45 (0.174%)	1959	147 (0.57%)	1984	329 (1.27%)	2009	600 (2.32%)
1910	6 (0.023%)	1935	32 (0.124%)	1960	138 (0.53%)	1985	270 (1.04%)	2010	635 (2.46%)
1911	6 (0.023%)	1936	30 (0.116%)	1961	189 (0.73%)	1986	275 (1.06%)	2011	646 (2.50%)
1912	3 (0.01%)	1937	18 (0.070%)	1962	158 (0.61%)	1987	261 (1.01%)	2012	792 (3.06%)
1913	0 (0%)	1938	45 (0.174%)	1963	187 (0.72%)	1988	245 (0.95%)	2013	827 (3.20%)
1914	2 (0.008%)	1939	19 (0.074%)	1964	188 (0.73%)	1989	281 (1.09%)	2014	778 (3.01%)

1915	1 (0.004%)	1940	22 (0.085%)	1965	198 (0.77%)	1990	287 (1.11%)	2015	794 (3.07%)
1916	2 (0.008%)	1941	15 (0.058%)	1966	219 (0.85%)	1991	266 (1.03%)	2016	744 (2.88%)
1917	0 (0%)	1942	13 (0.05%)	1967	256 (0.99%)	1992	262 (1.01%)	2017	775 (3%)
1918	2 (0.008%)	1943	9 (0.035%)	1968	240 (0.93%)	1993	256 (0.99%)	2018	795 (3.08%)
1919	1 (0.004%)	1944	9 (0.035%)	1969	234 (0.91%)	1994	218 (0.84%)	2019	800 (3.10%)
1920	0 (0%)	1945	33 (0.128%)	1970	233 (0.90%)	1995	237 (0.92%)	2020	852 (3.30%)
1921	1 (0.004%)	1946	93 (0.360%)	1971	212 (0.82%)	1996	273 (1.06%)		
1922	3 (0.01%)	1947	114 (0.44%)	1972	224 (0.87%)	1997	255 (0.99%)		
1923	4 (0.015%)	1948	101 (0.39%)	1973	289 (1.12%)	1998	273 (1.06%)		
1924	6 (0.023%)	1949	97 (0.375%)	1974	323 (1.25%)	1999	311 (1.20%)		

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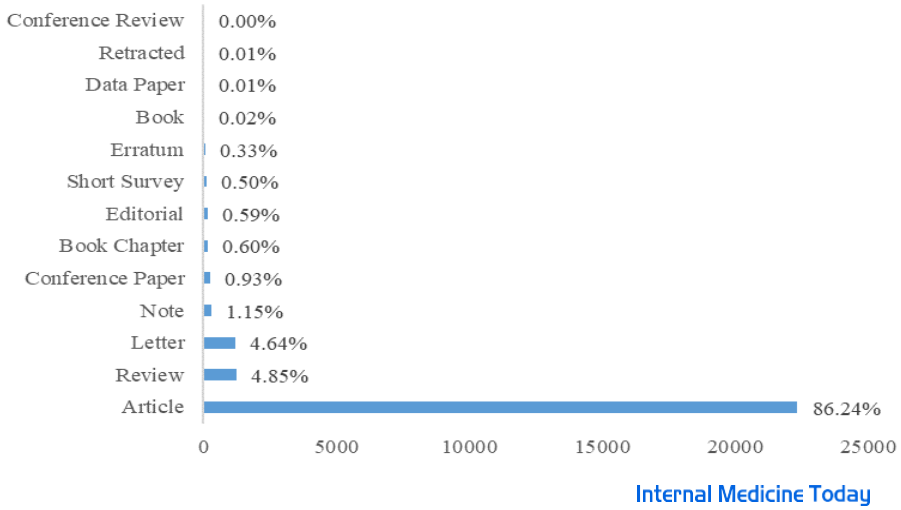

Figure 1. Distribution of various scientific publications on brucellosis

Figure 2 shows the journals with the highest rate of scientific publications of brucellosis. The data presented in Figure 2 indicate that "Zhurnal Mikrobiologii Epidemiologii Immunobiologii" accounted for the highest share of brucellosis-related publications (2%) as a source of immunology information, followed by Infection and Immunity (1.68%) and Veterinary Microbiology (1.10%).

In the field of scientific cooperation of Brucellosis Publications, Figure 3 also shows the international cooperation network of different countries with each other in Brucellosis Publications.

In Figure 3a, the circles indicate the number of publications. Larger circles represent the country with the highest brucellosis publications. In this figure, the circles and the connections among them are shown with 6 distinct colors. Each color represents a cluster of countries with the most cooperation in Brucellosis publications. Figure 3b shows the density of scientific collaborations. In this figure, the range of yellow to blue colors is the lattice density. The colors yellow, green, and blue indicate the weight density from high to low. In areas where busy and influential countries are present, the density and color of the map are yellow.

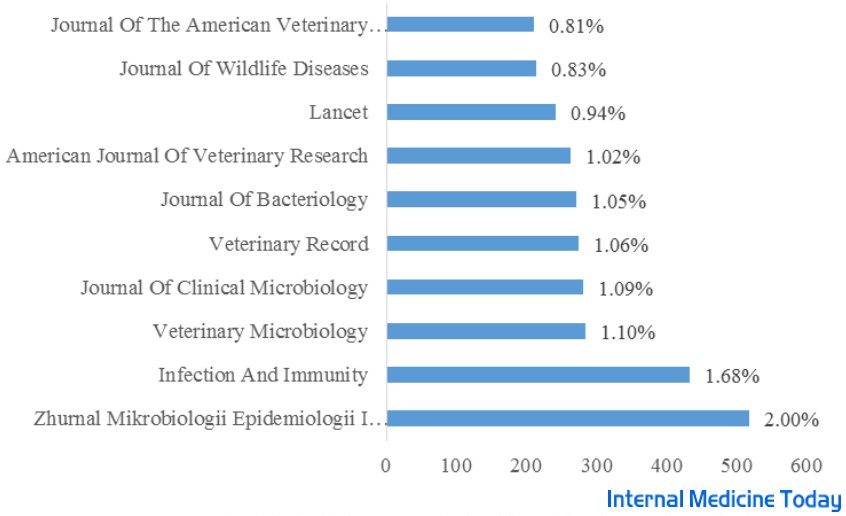

Figure 2. Journals with the highest rate of scientific publications on brucellosis

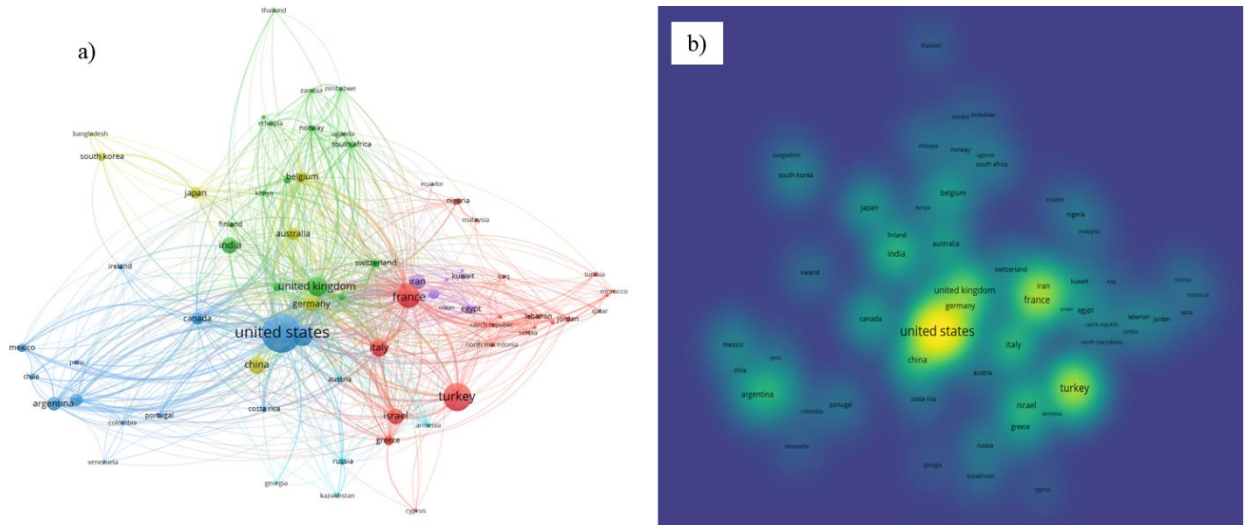

Figure 3. Co-author visualization map of countries/ regions on brucellosis disease scientific publication. Note: (a) network visualization map was based on documents;(b) density visualization map was based on documents.

Figure 4 also shows the scientific collaboration of the authors in the scientific publications on brucellosis.

In Figure 4a, the circles indicate the number of publications. Larger circles represent the largest amount of publications of each researcher. In this figure, the circles and the connections among them are shown with 8 distinct colors. Each color represents a cluster of the most collaborating authors in Brucellosis Publishing. Figure 4b illustrates the density of authors' scientific collaborations. In this figure, the spectrum of yellow to blue colors is the density of the grid. The colors yellow, green, and blue indicate the weight density from high to low. In the sections where prolific and influential writers are present, the density and color of the map are yellow.

In Figure 5, the circles represent the frequency of each keyword. Larger circles represent the highest number of keywords. In this figure, the circles and the connections among them are shown with 5 distinct colors. Each color represents a cluster of the most co-occurring keywords in brucellosis publications.

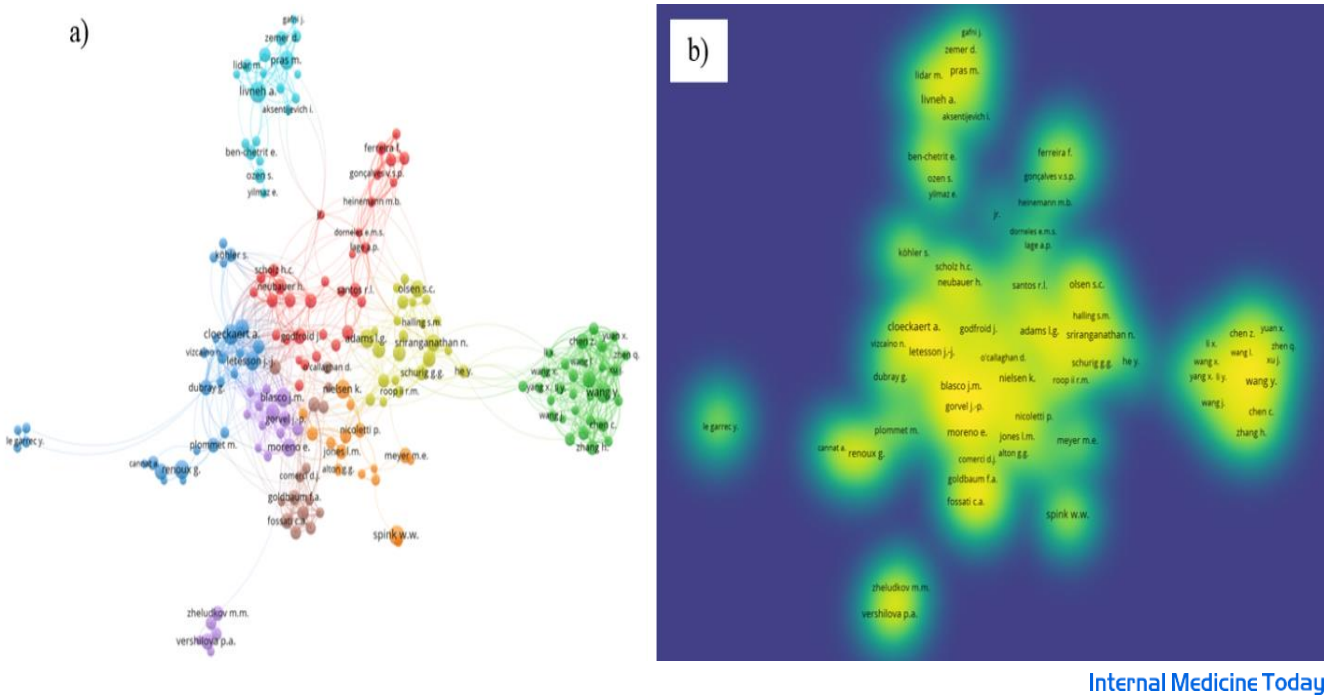

Figure 4. Authors cooperation network in brucellosis disease scientific publication. Note: (a) network visualization was based on documents; (b) density visualization was based on documents.

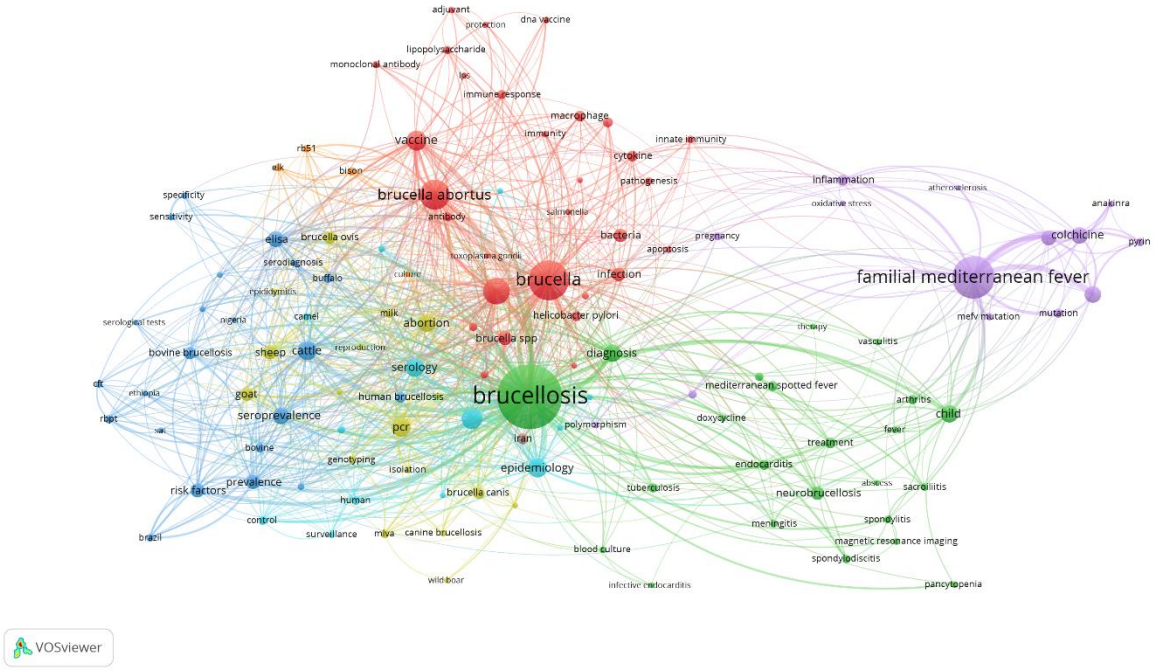

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Figure 5. Co-keyword network visualization was based on occurrences

Cluster No. 1, shown in red, contains 30 keywords, the most common of which are:

Brucella, Brucella abortus, Brucella melitensis, Vaccine, Brucella spp., Infection, Bacteria, Cytokine, Macrophage, and Helicobacter pylori.

Cluster No. 2, marked in green, contains 23 keywords, the most commonly used of which are:

Brucellosis, Diagnosis, Child, Neuro brucellosis, Treatment, Endocarditis, Mediterranean spotted fever, Arthritis, Tuberculosis, and Spondylodiscitis.

Cluster No. 3, which is marked in blue, includes 22 keywords, the most commonly used of which are: Cattle, Seroprevalence, Elisa, Prevalence, Risk factors, Bovine brucellosis, Human brucellosis, Buffalo, Bovine, and Rbpt.

Cluster No. 4, which is marked in yellow, contains 21 keywords, the most commonly used of which are: Pcr, Abortion, Sheep, Goat, Brucella ovis, Brucellacanis, Milk, Mlva, Bison, and Rb51.

Cluster No. 5, which is marked in purple, contains 14 keywords, the most commonly used of which are: Familial mediterranean fever, Mefv, Colchicine, Amyloidosis, Inflammation, Mutation, Turkey, Pregnancy, Pyrin, and Mefv mutation.

Cluster No. 6, which is highlighted in pale blue, contains 14 keywords, the most commonly used of which are: Zoonosis, Epidemiology, Serology, Iran, Human, Control, Camel, Livestock, Surveillance, and Public health.

Accordingly, the thematic clusters of scientific publications of brucellosis have been in six thematic trends: immune response, clinical signs, zoonosis, diagnosis, pathogens, and epidemiology.

Discussion

Scientific models and maps are a good way to show the growth of scientific activities and organize the intellectual and scientific structure that constitutes a thematic domain [31]. In this study, the structure of scientific publications of brucellosis in Scopus citation database is shown using scientometrics methods. Studies have shown that scientific publications on brucellosis have been on the rise since 1900. In 2020, 2013, and 2019, it had the highest number of scientific publications during a year. The increasing trend of publications in the field of brucellosis in recent years shows the importance of research and also the interest of researchers in this field. Past research has also shown that the publication of scientific studies in health-related fields has been on the rise [32, 33]. Dastani and Danesh (2020) have also shown that the trend in publications in health-related fields has increased with the advent of new viruses or epidemics, disease outbreaks, or prevention and treatment programs [34].

In the case of brucellosis, Zhao et al. in (2020) also showed that the incidence of brucellosis in China was increasing between 2011 and 2015, and also showed a decreasing trend in the incidence from 2015 to 2018 [35]. Yang et al. (2020) also showed the prevalence of brucellosis in China between 1950 and 2018, and according to the results of their study, the incidence rate of the disease suddenly increased in 2004 and reached its peak in 2014 [36]. Enkelmann et al. in 2020 also showed that the number of brucellosis cases in Germany has increased since 2011 and peaked in 2014 [37]. Amro et al. (2021) also showed that the prevalence of brucellosis in Palestine in west bank was declining until 2012; however, the prevalence has increased significantly since 2013 [38]. The results of other studies also indicated that the number of brucellosis cases increased in Turkey in 2013 and 2014 [39]. Furthermore, Ghavidel et al. (2021) analyzed WOSCC-indexed

brucellosis publications (1901–2019) using scientometric and social network methods. They showed a steadily increasing publication trend, peaking in 2019 with 398 papers. Their findings emphasized the complexity of scientific collaboration and highlighted influential figures shaping the global brucellosis co-authorship network [21]. Accordingly, it can be mentioned that one of the reasons for the growth of scientific publications on brucellosis since 2011 and its significant increase in 2013, has been the increase in cases of brucellosis in some countries.

The results of this study have shown that most of the articles in these scientific publications have been original articles. Original articles include a variety of types, such as Basic research (i.e., laboratory investigations, animal experiments), Epidemiological research (i.e., cohort studies, case-control studies, and cross-sectional studies), and Clinical research (i.e., case reports, open observational studies, and the gold standard of research in clinical medicine-randomized clinical trials) [40]. The large number of original articles on brucellosis indicates the presentation of advances, innovations, and new knowledge by researchers in this field. Most scientific publications on brucellosis have been in the fields of Medicine, Immunology and Microbiology, as well as Veterinary.

In line with these findings, Dastani et al. (2022) mapped the scientific structure of Iranian brucellosis research using co-authorship and co-occurrence network analysis. They extracted 816 publications from Scopus. Their study revealed three main thematic clusters: prevalence, diagnosis, and treatment, emphasizing the collaborative and thematic structure of Iranian contributions [20].

Analysis of the results of this study also showed that the United States, Turkey, and France have the highest scientific output in the field of brucellosis, in descending order. In the United States, due to the large investment in the study of various diseases and the study of its various aspects, for example, in the field of tuberculosis and COVID-19, the United States has the most global publications [17, 41,42].

Turkey is one of the countries where brucellosis has been endemic. It is also bordered by countries such as Iran, Iraq, and Syria, where brucellosis is also common and causes extensive economic losses to countries affected by the disease annually. France has also conducted extensive and in-depth studies on how to prevent this disease and design and manufacture vaccines and study the disease in animals as a zoonotic disease and is still one of the leading countries in this field. In this regard, studies have shown that increasing the prevalence of the disease increases the interest of researchers in research and dissemination of disease-related results in those countries [43]. Previous studies have also shown that one of the reasons for the large number of scientific products and publications is the income of countries, so that high-income countries have more scientific publications and low-income countries have fewer publications [44, 45]. Complementing this, Danesh and Ghavidel (2023) conducted a century-long scientometric study (1920–2020) of brucellosis publications in WOSCC. This study highlighted how scientometric indicators directly relate to research productivity, impact, and international collaboration in the brucellosis domain [22].

One of the indicators of scientometrics is the network of cooperation among authors with different specializations or affiliations of organizations and universities [30]. In this regard, the analysis of the results has shown that that the United States, Turkey, France, and Iran have the most scientific cooperation in the field of brucellosis scientific products. Regarding international cooperation in the global trypanosomiasis research, Hassan et al. (2020) state that international cooperation exists not only in countries with close geographical distances, but also intercontinental cooperation. International is not just for countries with parasites and diseases [43]. Chen et al. 2020 state that countries or regions with more international cooperation also have higher production [46]. International scientific cooperation is very important in ending diseases, but there are many obstacles to international cooperation that require the cost of many resources such as manpower and financial resources [17]. In this regard, due to the importance of scientific cooperation in the production of science, many studies have examined scientific cooperation between countries as well as different authors [12, 47, 48].

The results of clustering of each lexical event show that the scientific publications of brucellosis have been published in six thematic trends: immune response, clinical signs, zoonosis, diagnosis, pathogens, and epidemiology. Similar studies have identified thematic clusters of diseases using the co-occurrence of words. Accordingly, Meskarpour et al. 2020 also showed COVID-19 publications in three main thematic clusters of health research, basic sciences, and clinical research [22]. Dehdarirad et al. 2019 also indicate six thematic clusters "Metabolic engineering and its role in biofuel production", "Isolation and purification methods and the use of preservatives in food safety", "Animal models and cell culture for the investigation of human viruses"," Computational microbiology and algorithms in genetics", "Bacterial physiology and pathogenesis", and "Phylogenetics and microbial ecology" For the publication of microbiology between 2012 and 2016 [29].

Conclusion

The findings of the present study revealed that scientific publications on brucellosis have shown an upward trend in recent years, a growth that has been closely associated with the prevalence and spread of the disease in various countries. Furthermore, the high proportion of original research articles in this field reflects researchers' strong emphasis on generating new knowledge across diverse dimensions, including basic, epidemiological, and clinical research. Thematic analysis also demonstrated that scientific outputs are primarily concentrated in six key areas: immune response, clinical manifestations, zoonosis, diagnosis, pathogens, and epidemiology. The results further highlighted the importance of international scientific collaborations in enhancing knowledge production and contributing to the control of the disease.

Overall, this study provides a clear picture of the global scientific landscape of brucellosis research. Such insights can equip researchers and policy-makers with a more comprehensive understanding of the leading countries, influential authors, key journals, and recurrent keywords in this field, thereby enabling more targeted directions for future research and informed scientific policy-making. Nevertheless, similar to many scientometric studies, this research is subject to certain limitations, particularly its reliance on a single database (Scopus), which may have led to the exclusion of relevant scientific outputs indexed in other databases.

Ethical Considerations

Compliance with ethical guidelines

This study was conducted in accordance with ethical principles and approved by the Research Ethics Committee of Gonabad University of Medical Sciences, Gonabad, Iran, with the ethics code IR.GMU.REC.1400.036.

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Authors' contributions

Study design: Meisam Dastani, Jalal Mardaneh; Data collection: Elaheh Moradi, Hamideh Mohammadzadeh; Data analysis: Meisam Dastani, Jalal Mardaneh; Manuscript writing: Meisam Dastani, Elaheh Moradi, Hamideh Mohammadzadeh; Critical revision and approval of the final manuscript: All authors.

Conflicts of interest

The authors declared no conflicts of interest.

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