



## Original Article

# Global Research Trends and Productivity on Honey (1900-2019)

Ahmad Azam Malik<sup>1</sup> and Muhammad Barkaat Hussain<sup>2</sup>

<sup>1</sup>Department of Family and Community Medicine, Faculty of Medicine in Rabigh, King Abdulaziz University, Jeddah, Saudi Arabia

<sup>2</sup>Department of Microbiology, Faculty of Medicine in Rabigh, King Abdulaziz University, Jeddah, Saudi Arabia

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### \*Corresponding Author:

Ahmad Azam Malik

Department of Family and Community Medicine,  
Faculty of Medicine in Rabigh, King Abdulaziz  
University, Jeddah, Saudi Arabia  
[amalik@kau.edu.sa](mailto:amalik@kau.edu.sa)

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## ABSTRACT

Honey is a natural product with widespread nutritional and therapeutic potential for a long time. Despite expanding magnitude, sparse exploration of related research output is observed. This comprehensive bibliometric study evaluated the honey related literature (1900-2019) through a wide range of known metrics. Data were extracted from the Web of Science database, and the "R-Bibliometrix" package was used for analysis. The search yielded 18197 documents from 3391 sources and 160 countries led by the USA. Articles (77.7%) were the leading publication type. Six (6) authors showed  $\geq 100$  publications with Robinson GE (USA) as the most prolific author. Sixteen (80%) of the 20 highly cited documents were published from 2002 to 2010 with the source 'Food Chemistry' as the major contributor. Nineteen (19) sources showed  $\geq 100$  publications led by the 'American Bee Journal'. Entomology, Food Science Technology, and Chemistry were the most common research areas. Findings showed rising numbers of documents though the majority published in recent decades. The USA contributed  $> 1/4$ th of global publications, while top 20 countries shared  $>80\%$  with limited contributions from other regions. Diverse coverage from basics to therapeutic levels was found, yet more clinical studies are expected and recommended.

## INTRODUCTION

Honey is a marvelous product of nature with tremendous nutritional and widespread therapeutic applications [1]. An increasing body of literature reflects growing evidence to clarify the multiple therapeutic benefits of honey originating from diverse and distinct bioactive substances [2]. Honey is the only natural sweetening product that can be stored for a prolonged period and consumed without any refining or processing technique. It consists of more than 200 distinct substances, stems from both the plant and insect kingdom, and has been considered for a wide range of nutritional, biological, and clinical importance [3]. The therapeutic range of honey encompasses local application to systemic usage. The most notable in this regard is the prevention and treatment of infectious diseases caused by bacteria, viruses, fungi, and ameliorating gastrointestinal

disorders [4-6]. Besides, its role in cancer prevention and as anti-cancer therapy is also expanding. Several recent studies have confirmed that honey can regulate oxidative stress and has anti-inflammatory, immunomodulatory, anti-proliferative, anti-metastatic, and pro-apoptotic properties [7-9]. Moreover, honey prevents the oxidation of low-density lipoprotein and thus prevents the process of atherosclerosis [10]. Honey also can prevent or modulate numerous diseases of respiratory, blood, and nervous system [11-13]. Nearly all the Sacred Scriptures, such as the Holy Quran, the Holy Bible, and the Holy Torah, mention honey's therapeutic properties [14]. The Greeks, Romans, Egyptians, Assyrians, and the Chinese used honey for almost every wound and ailments of the gastrointestinal tract [15]. The Greek doctor, Hippocrates, considered the

father of modern medicine, recommended honey for various diseases, including gastritis and wounds [16]. This has been reported in numerous evidence-based conclusions with effective application of honey for burns and wound healing [17, 18]. Additionally, Jull *et al.*, have shown that honey dressings are more effective in first degree burns than conventional dressings [19]. Although honey has been used in wound care and burns for millennia, however, it is now being integrated into modern medicine based on recent studies. Infectious diarrhea is one of the leading causes of mortality in children under five years of age worldwide despite global success in its management for the past 30 years [20, 21]. Recent scientific knowledge endorsed the effectiveness of honey in gut-associated disorder, including diarrhea [15]. It has been shown that a combination of probiotics and prebiotics (synbiotic mixture) has been more useful in the treatment of diarrhea [22]. Honey, in this context, offers multiple advantages because it contains prebiotics, probiotics, and zinc besides multiple synergistic antibacterial components [23-26]. These bioactive compounds are supposed to operate synergistically, decrease expression of virulence factors, and have unique and broad-spectrum bacterial targets [26]. Moreover, bacterial resistance against honey is unlikely honey as it can block bacterial communication (quorum sensing) [27]. Notably, honey only targets pathogenic bacteria without disturbing the growth of normal flora of the gastrointestinal tract, if taken orally such as diarrheal diseases. The role of honey in different human ailments based on scientific knowledge is expanding on each passing day [28, 29]. Despite a long history, its magnitude of usability, and growth potentials, there has been limited exploration of honey related research trends and performance analysis. Bibliometrics is a known scientific entity used in various fields to evaluate research trends and performance [30-32]. There has been no bibliometric analysis published scientific output on honey to the best of authors' knowledge. The present study aims to identify and analyze research publications on honey to outline the major contributors in terms of authors, affiliations, countries, and sources.

## METHODS

Among numerous available databases, Web of Science (WoS) was selected as it is largely known as an extensive and specific foundation for systematic assessment [33] and considered suitable for evaluating the research output of different regions, organizations, and authors [34, 35]. This study used a wide range of bibliometric indicators to evaluate publications related to honey. All published documents relevant to the study scope were extracted and analyzed. Initially, the search strategy used for this study scope was TI= (Honey), with all publications with no time

restriction. To remove inconsistencies created by regular database renewals, all records and data were retrieved on 27<sup>th</sup> November 2020, in a single day and incomplete data for the year 2020 (1090 documents) was not included for later analysis. All documents (total = 18197) were extracted in plain text files and detailed analysis was performed using "R-Bibliometrix" package [36] with numerous bibliometric matrices. Top contributors were explored for collaborative networks. Authors (AAM and MBH) did independent search and data extraction followed by scrutinization of leading contributors shared in the results section to avoid inconsistencies.

## RESULTS

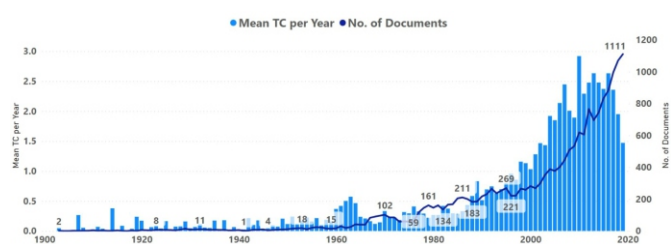
The total number of documents indexed in WoS and focused on Honey were 18197 (Table 1) from 3391 sources and 160 countries with the USA, Germany, China, Canada, and Spain showing 27.6%, 4.6%, 4.3%, 4% & 3.7% respectively. Table 1 below shows the summary of major descriptive findings. The annual growth rate was 5.75 %, and the total number of authors was 31490. The English language represented around 94.75%, followed by German (1.9%). Original articles were the leading document type (77.7%), followed by editorials (3.6%), letters/correspondence (3.3%), and reviews (2.6%). Around 26% were single-authored documents contributed by 2699 authors. The collaborative index was 2.14.

**Table 1:** Summary table

Description	1903-1999	2000-2019	1903-2019
Documents	6022	12175	18197
Annual growth rate (%)	5.37	7.48	5.75
Open access	1118 (18.6%)	2754 (22.6%)	3987 (21.9%)
Sources (Journals, Books, etc.)	1117	2648	3987
Average years from publication	37.2	8.08	17.7
Average citations per documents	16.04	16.61	16.42
Average citations per year per doc	0.51	1.79	1.37
References	43151	167079	201675
Document Contents			
Keywords Plus (ID)	1967	11724	12430
Author's Keywords (DE)	2505	17283	18532
Authors	6061	26309	31490
Author Appearances	12213	49208	61421
Authors of single-authored documents	1646	1154	2699
Authors of multi-authored documents	4415	25155	28791
Authors Collaboration			
Single-authored documents	2784	1941	4725
Documents per Author	0.99	0.46	0.58
Authors per Document	1.01	2.16	1.73
Co-Authors per Documents	2.03	4.04	3.38
Authors' countries	101	143	161
Group Authors	2	36	37
Collaboration Index	1.36	2.46	2.14

Other Information			
Research Areas	135	147	149
Web of Science categories	204	236	242
Organizations	1586	6088	6862
Funding Sources	8(0.5%)	4869(40.7%)	4874(27.4%)
Document Types			
Articles	4573	9576	14149
Editorials	161	492	653
Letters/Correspondences	303	292	595
Reviews	88	394	482
Others	897	1421	2318

Publications and mean total citations are shown year wise in Figure 1 since the first document in 1903 with maximum documents in 2019 (1111). The last 20 years (2000–2019) provided 67% of all publications.



**Figure 1:** Publications and mean total citations

Table 2 shows the 10 most prolific authors. In total, 29 authors showed  $\geq 50$  documents, while 6 had  $\geq 100$  publications, namely; Robinson GE, Rinderer TE, Mangum WA, Page RE, Oldroyd BP, and Evans JD. One author, Robinson GE had  $\geq 10000$  total citations (TC). Among top authors, 7 showed an H-index of  $\geq 30$ .

**Table 2:** Top 10 most productive Authors and their impact (1903-2019)

Authors	*PY start	No. of Documents	% as *FA	% as *CA	*AF	h-index	*TC
Robinson GE	1981	163	14.1	35.0	53.4	62	10866
Rinderer TE	1969	143	36.4	32.2	44.6	27	2500
Mangum WA	1996	136	100.0	97.1	136	1	12
Page RE	1980	115	20.0	18.3	41.8	46	6494
Oldroyd BP	1985	114	25.4	41.2	36.5	30	2899
Evans JD	1999	103	22.3	31.1	27.7	40	6343
Winston ML	1979	90	18.9	21.1	34.5	33	3265
Taber S	1954	77	79.2	53.2	63.1	13	581
Seeley TD	1976	74	43.2	51.4	38.3	35	4005
Pettis JS	1986	72	22.2	20.8	16.4	31	4987

PY - Publication year, FA - First author, CA - Corresponding author, AF - Articles Fractionalized, TC - Total citations  
 Table 3 shows the top 10 countries with Corresponding authors. The leading 10 and 20 countries produced 62.6% & 80.6%, respectively. The USA was foremost followed by China, Brazil, Germany, and Spain (Table 3). Total citations per country trends showed relatively more citations from the USA, Spain, Germany, United Kingdom (UK), and Italy with  $>10000$  citations.

**Table 3:** Top 10 countries with corresponding authors

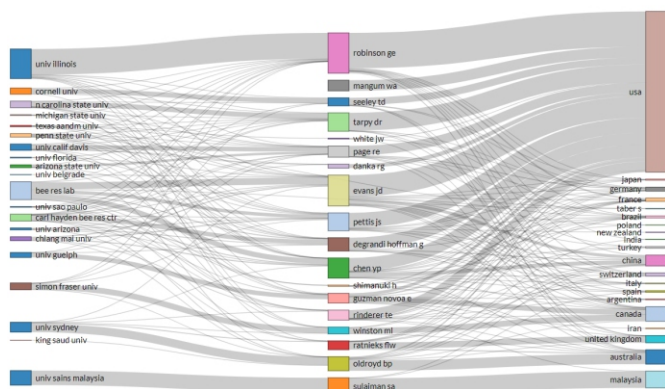
Country	Documents	CA	Percentage Contribution	SCP	MCP	MCP Ratio	TC
USA	6980	4142	29.50	3744	398	0.10	84374
CHINA	1725	730	5.20	586	144	0.20	9974
BRAZIL	1302	537	3.83	471	66	0.12	7756
GERMANY	1270	582	4.15	467	115	0.20	13105
SPAIN	1122	518	3.69	448	70	0.14	14133
TURKEY	1101	434	3.09	396	38	0.09	5761
ITALY	1069	479	3.41	400	79	0.16	10770
CANADA	983	505	3.60	431	74	0.15	9280
UK	941	461	3.28	343	118	0.26	12042
AUSTRALIA	881	396	2.82	286	110	0.28	8724

CA - Corresponding author, SCP: Single or Intra-country publication, MCP: Multiple or Inter-country publications, TC - Total citations

Amongst funding sources, 5 organizations showed  $> 200$  contributions; National Natural Science Foundation of China (298), United States Department of Agriculture (USDA) (235), United States Department of Health Human Services (234), National Institutes of Health (233) and National Science Foundation (218). Entomology, Food Science Technology, and Chemistry were the leading WoS categories and research areas. Top 50 authors' network showed 6 clusters, as shared in Figure 2a and Figure 2b shows three field plots for the top 20 most productive affiliations, authors, and countries. Among countries, the USA, China, Malaysia, Australia, and Canada, displayed main contributions. University of Illinois, Bee Research Lab, and University Sains Malaysia were the major contributing affiliations for these top authors and countries. Furthermore, the University of Sao Paulo showed relatively more authors other than leading authors. Seven (70%) of the top 10 highly cited documents were published from 2002 to 2010 and 'Food Chemistry' was the leading source (Table 4).



**Figure 2a:** Top 50 Authors Collaboration Network



**Figure 2b:** Three Field Plot for top 20 most productive affiliations, authors and countries

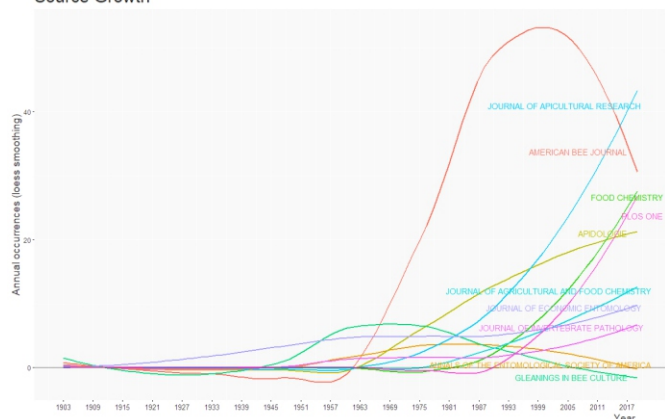
**Table 4:** Top 10 highly cited documents

Document	Year	*IC	*GC
ANKLAM E, 1998, FOOD CHEM	1998	446	538
GHELDOF N, 2002, J AGR FOOD CHEM	2002	381	487
COX-FOSTER DL, 2007, SCIENCE	2007	355	1061
BOGDANOV S, 2008, J AM COLL NUTR	2008	302	396
MULLIN CA, 2010, PLOS ONE	2010	286	653
MOLAN PC, 1992, BEE WORLD	1992	285	351
BERTONCELJ J, 2007, FOOD CHEM	2007	258	332
ALLEN KL, 1991, J PHARM PHARMACOL	1991	251	319
GHELDOF N, 2002, J AGR FOOD CHEM-a	2002	242	331
VANENGELSDORP D, 2010, J INVERTEBR PATHOL	2010	240	543

IC - Internal Citation (Citations within study selected documents), GC - Global Citation (Citation in Web of Science), TC: Total Citations

Nineteen (19) sources showed  $\geq 100$  publications. Among them, the top 3 sources were namely; American Bee Journal (2189), Journal of Apicultural Research (792), and Apidologie (703), while leading sources growth over the years is shown in the Figure 3a.

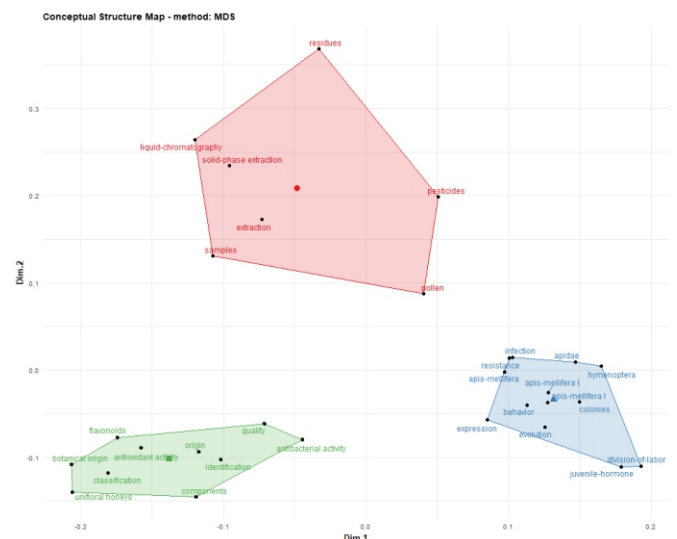
Source Growth



**Figure 3a:** Year wise growth of 10 most productive sources

In total, 18532 Keywords and 12430 Keywords plus (ID) were used. Honey, *Apis mellifera*, Honeybee, and Varroa destructor were the top 5 most frequent keywords. The word map of top 30 keywords is shared in Figure 3b. The

upper (pink) cluster included 07 keywords mainly led by honeybee research related to the identification of pesticide residues in pollens, honey samples, and honeybees. The lower left cluster (green) words are mainly related to honey's antioxidant potential and antibacterial activity. The lower right cluster (blue) represents the area of honey research regarding honey's role in the prevention and treatment of human infections.



**Figure 3b:** Conceptual structure word map of keywords

## DISCUSSION

Researchers have been exploring the evolving role of honey in nutrition and therapeutic dimensions for a long time. In order to have a better picture of global honey research output, this study offers an overview of trends and performance over the decades. It provides a reference to explore the trends in scientific research on honey using bibliometrics podium. In general, growing numbers of publications over the years starting in 1903 was observed. The number of documents relatively showed more rise over the last 2 decades (2000-2019), contributing around 67% of documents. Among countries, the USA contributed to  $> 1/4^{\text{th}}$  of global honey related publications, followed by China, Brazil, Germany, Spain, and Turkey. Leading countries were the major contributors of total documents. Similar trends were observed in terms of corresponding authors and total citations per country. Authors from the USA; Robinson GE, Rinderer TE, and Mangum WA were leading as prominent authors. All top authors had h-index of  $> 10$  and total citations of  $> 500$  except the author 'Mangum WA'. Perhaps the reason for low impact despite being among top authors might be due to his all publications from one source 'American Bee Journal' and mostly as single author and editorials. Among top authors, Sulaiman SA (Malaysia) and Chen YP (USA) were the only 2 authors with starting

publication year in the last 20 years (2000-2019) as compared to other top authors with earlier publications starts. Most of these documents were found to be single country publications with relatively more multi-country publications from Switzerland, Australia, and the UK, suggesting more needed collaborative research activities. Top authors were mainly from top countries and affiliations, showing evidence of collaborative links among them. University of Illinois, Bee Research Lab, and University Sains Malaysia were the major contributing affiliations for these top authors and countries. In addition, the University of Sao Paulo showed relatively more authors other than leading authors. In general, these findings suggest research and publications mainly from resourceful settings dominated by the USA, Europe, and China. Notably, limited contributions from the less resourceful countries were found. Moreover, the variations in the presence and concentration of different bioactive components in kinds of honey collected from different geographical areas of the world also need to be considered [37]. Variation has been observed in its color, aroma, flavor, sugar composition, pH, flavonoids, phenolic acid, level of antibacterial activity, and other properties [38]. Numerous factors can potentially affect, like geographical areas, flowering plants, storage conditions, age, processing procedure, the concentration of hydrogen peroxide, phenolic components, soil composition, climatic conditions, species of bees and others [39]. It would be worthwhile to explore honey from different world regions because of the high diversity level in different honey samples. This exploration might contribute to many other venues for future honey research and provide an opportunity for researchers from low and middle-income countries. Manuka honey is the most widely researched honey. The reason for its popularity is the presence of a high level of the non-peroxide antibacterial compound in its certain samples, collected from specific regions of New Zealand [40]. According to phenol equivalence, Peter Molan and his team have standardized the non-peroxide antibacterial activity of Manuka honey and designated it as a Unique Manuka Factor (UMF) [41]. The UMF-related work is among the top 20 widely cited documents and results in the inclusion of Manuka honey in mainstream medicine as a topical therapeutic agent for burns and infected wounds (Table 4). Since then, many research pieces have been carried out in different countries to find a honey with high medicinal value regarding skin burns and infected wounds [42-44]. As a result, several honey-impregnated dressings; Medihoney from Australia, Beri honey from Pakistan, Revamil honey from Netherland, Tualang honey from Malaysian were developed and are available for the treatment of burns, ulcers, and wounds [4, 5, 45-48]. The

methods used to assign UMF containing honey have also been patented [49]. Among sources, the 'American Bee Journal' was leading, followed by 'Journal of Apicultural Research' and 'Apidologie', and these top 3 journals collectively contributed around 20% of total documents. Interestingly, the 'Journal of Apicultural Research', 'Food Chemistry', and 'PLOS ONE' showed relatively growing contributions in the last two decades in contrast to the 'American Bee Journal' that showed a relative decline in numbers over the last 2 decades. Honey, *Apis mellifera*, Honeybee, Honey bees, and *Varroa destructor* were the most frequent keywords. Among 3 clusters found on word map, the Cluster 1 showed mainly themes of honeybee research related to the identification of pesticide residues in pollens, honey samples, and honeybees. The other two keywords were related to well-known in vitro assays; solid-phase extraction and liquid chromatography are widely used for analyzing pesticide residues in honey, pollens, and honey bees. This area of research has immense health implications for both humans and honeybees. The 2<sup>nd</sup> cluster showed other important themes of honey publications and was mainly related to honey's antioxidant potential and antibacterial activity. The term flavonoid in the cluster represents another important theme. The antibacterial and antioxidant potential of honey mainly stems from flavonoids contents in honey. Nevertheless, other factors contribute to the antioxidant and antibacterial activity of honey, including phenolics, organic acids, peptides, enzymes, methylglyoxal, hydrogen peroxide, and Maillard reaction products. However, the occurrence of flavonoids term is more in the honey publication as compared to others. The cluster reveals that both antioxidant and antibacterial activity are linked to unifloral floral honey samples. Besides, the cluster also shows the correlation between variation in antibacterial activity and the antioxidant capability of honey samples. In this cluster also the association of antibacterial components in honey with botanical origin was highlighted. The 3<sup>rd</sup> cluster showed honey's role in preventing and treating human infections, particularly against multi-drug-resistant organisms. This also reflects the important themes concerning honeybee behavior, evolution, gene expression, and honeybee colonies. The term Apidae and Hymenoptera represent the family of a honeybee. The keywords infection and resistance represent important emerging themes in honey research, which elaborate on honey's role in treating wound infections, particularly those infections where multi-drug resistant bacteria are involved. A wide range of research areas and WoS categories were found to be related to honey, that shows scientific contributions from basics to therapeutic and interventional scopes. Entomology, Food Science

Technology, and Chemistry were the most common research areas and WoS categories. Besides, Zoology, Multidisciplinary Sciences, Nutrition Dietetics, Pharmacology-Pharmacy, and Medicine General Internal, were found to be on the relative rise in the last decade. This perhaps shows the trend of recently increased output from health dimensions of honey, supplemented by keywords trends evolution over the years, and suggests relatively more health-related terms in the last 2 decades. Possibly the complete understanding of its wide and diverse range of bioactive substances, interaction among its constituents, and their synergistic impact on human body cells and organs have led to recognize honey as a therapeutic agent more as compared to past [50]. Initial research on honey was related to its composition that can be traced back to 1950 when its different constituents were started to be identified and quantified [51]. Later, research focused on other identification markers of honey regarding its botanical and geographical origin, authenticity issue, and detailed analysis of its diverse and distinct bioactive substances, particularly antibacterial compounds. Investigating antibacterial compounds and their standardization by phenol equivalence led to creating a new term, Unique Manuka Factor (UMF). The UMF became the de facto test standard for medical honey and was used to assign the medically graded honey a UMF value to treat burns, wounds, and ulcers [41]. This is the essence of the limited therapeutic application of honey so far. There is a need for more in-depth and widespread research regarding its role in gastrointestinal disorders, systemic infections, neoplastic disorders, and particularly those human diseases where modern medicine has a limited therapeutic role. In general, the top 30 recurring terms in the conceptual structure map are related to the antibacterial and antioxidants potential of honey, its constituents, its role in infectious diseases, honeybee behavior, division of labor among honeybees, gene expression, and the colonies of the honeybee. However, clinical trials evaluating honey's role in treating multiple human diseases are absent in these top recurring terms. Therefore, there is a need for more clinical studies regarding honey utilization in different diseases. Only one source, 'WoS,' was selected to be considered a limitation of this study. Additionally, the limitations in the database might have indirectly affected some data. Perhaps, exploring the topic in other databases is also recommended to be explored in future research. Besides, sparse relevant literature restricted the comparison with previous studies.

## CONCLUSIONS

The study revealed the rising numbers of honey research documents with time with major contributions in the last 20 years. The few leading and developed countries were

the major contributors led by the USA with > 1/4th of global honey related publications which was followed by China, Brazil, Germany, Spain, and Turkey. Diverse coverage of areas and scientific contributions from basics to therapeutic levels were found, yet more clinical studies are expected and recommended. Most of the publications focused on physicochemical, pharmacological, microbiological, and nutritional aspects of honey against infections, inflammation, malignancy, atherosclerosis, and oxidative stress. 'American Bee Journal' was the leading source and the journal 'Food Chemistry' was found to be a prominent source of highly cited documents.

## Authors Contribution

Conceptualization: AAM, MBH

Writing-review and editing: AAM, MBH

All authors have read and agreed to the published version of the manuscript.

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## Conflicts of Interest

The authors declare no conflict of interest.

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