



Aromatherapy in anxiety, depression, and insomnia: A bibliometric study and visualization analysis

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ABSTRACT

Aromatherapy is a natural treatment method that uses essential oils (EOs) extracted from aromatic plants; EOs and their components exhibit a wide range of pharmacological activities, with a special focus on their implementation toward mental disorders, such as anxiety and depression. This study aimed to identify the scientific output and activity related to aromatherapy in anxiety, depression, and insomnia through bibliometric approaches. In this bibliometric study, we utilized CiteSpace and VOSviewer to evaluate the Web of Science Core Collection publications and to build visualizing maps to analyze the research progress on this topic between 2001 and 2021. A total of 1159 original and review articles in English, published in 578 different peer-reviewed journals by 260 authors, were identified. In the recent two decades, there was a steady increase in the number of published articles, especially in the following five years. All publications were distributed among 88 countries/regions. The United States had the most publications, with 188 (16.22%) articles, followed by China [131 (11.30%)], Brazil [110 (9.49%)], and Japan [85 (7.33%)]. Most studies were published in the Journal of Ethnopharmacology, and Physiology & Behavior was the most cited journal. Hritcu L was the top published scientist and Gupta SC was the most frequently co-cited. The knowledge base of this field research mainly included the related efficacy of aromatherapy/EOs, application status, and biochemical mechanism. And the keyword co-occurrence analysis revealed that the topics “oxidative stress,” “chemical composition,” “systematic review,” and “sleep quality” were research frontiers. In conclusion, this comprehensive bibliometric study provides an updated perspective on research hotspots of aromatherapy in anxiety or depression and developmental tendencies of natural remedies for mental health. In addition, this study could also provide valuable information for research teams, practitioners, and decision-makers when designing and implementing natural treatment methods for mental health-promoting interventions for individuals with mood disorders.

1. Introduction

In aromatherapy, essential oils (EOs) are extracted from herbs, flowers, and other plant parts for therapeutic and preventative uses

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with a history of at least 6000 years [1]. It can be delivered through massage or topical application, inhalation, and water immersion, as a nonpharmacological strategy involving sensory stimulation [2]. Aromatherapy is, therefore, also classified as a subdivision of naturopathic remedies, and EOs have been accepted in traditional or modern healthcare systems of medicine for centuries [3]. The reputed properties of aromatherapy include the ability to improve concentration, cognitive performance [4], memory [5], sleep quality, and emotional well-being [6], as well as providing alleviation for stress, fatigue, pain, anxiety and depression [7].

Anxiety and depression are the two most common psychological health conditions [8]. They were recognized as significant public health challenges with heavy socioeconomic burdens, which are among the leading causes of disability worldwide [9]. According to the COVID-19 Mental Disorders Collaborators, throughout 2020, it was estimated that a significant increase in the prevalence of both major depressive disorders (with an estimated additional 53.2 million [95% uncertainty interval 44.8–62.9] cases worldwide-ie, a 27.6% [25.1–30.3] increase) and anxiety disorders (76.2 million [64.3–90.6] additional cases-ie, a 25.6% [23.2–28.0] increase) since before the pandemic [10]. The quality of life related to health is significantly affected by them, and depression is also the main determinant of suicide attempts and suicide deaths [11]. Meanwhile, insomnia occurs in up to a third of the adult population worldwide [12]. Clinical insomnia symptoms were reported by 36.7% [36.0–37.4] of respondents, and 17.4% [16.9–17.9] met the criteria for a probable insomnia disorder during the first wave of the pandemic [13]. In addition, insomnia, anxiety, and depression tend to coexist in both population-based and clinical populations [14]. On the other hand, those meeting criteria for mood disorders exhibit higher rates of insomnia [15].

Even though aromatherapy for mental health is not a discovery, academic studies have been increasing interest in aromatherapy as an alternative to normal drug therapy for its high efficacy in reducing stress and improving mental health [7,16,17]. The varied biological effects of EOs and their components have been widely studied and reviewed, which can be categorized according to their various mechanisms including increasing synaptic monoamine concentrations, regulation of hypothalamic-pituitary-adrenal (HPA) axis activity, neuroprotective abilities, maintaining the balance of immune system and anti-inflammatory activities, etc. [18–21]. Nevertheless, despite the popularity of aromatherapy in the general population and healthcare settings today, evidence regarding the efficacy of EOs in treating anxiety, depression, or insomnia is inconsistent. For example, systematic reviews and meta-analyses have indicated there remains limited evidence to support the feasibility, acceptability, and effectiveness of aromatherapy in the real-world study [22–26]. Hence, to reach robust conclusions concerning these subjects, further large-scale, well-designed randomized controlled trials are required.

In addition to identifying hotspots and development trends, the bibliometric analysis focuses on literature systems and characteristics through qualitative and quantitative analyses [27]. These findings may help to clarify the current scope of aromatherapy research as well as to establish a framework for current and emerging research priorities. As a result, this study aimed to provide the first comprehensive bibliometric analysis of aromatherapy treatment for anxiety, depression, and insomnia over the last two decades, as well as to provide new insight for scholars who have entered or are about to enter this field on the current status, emerging trends, and future research hot spots of aromatherapy research from a global perspective.

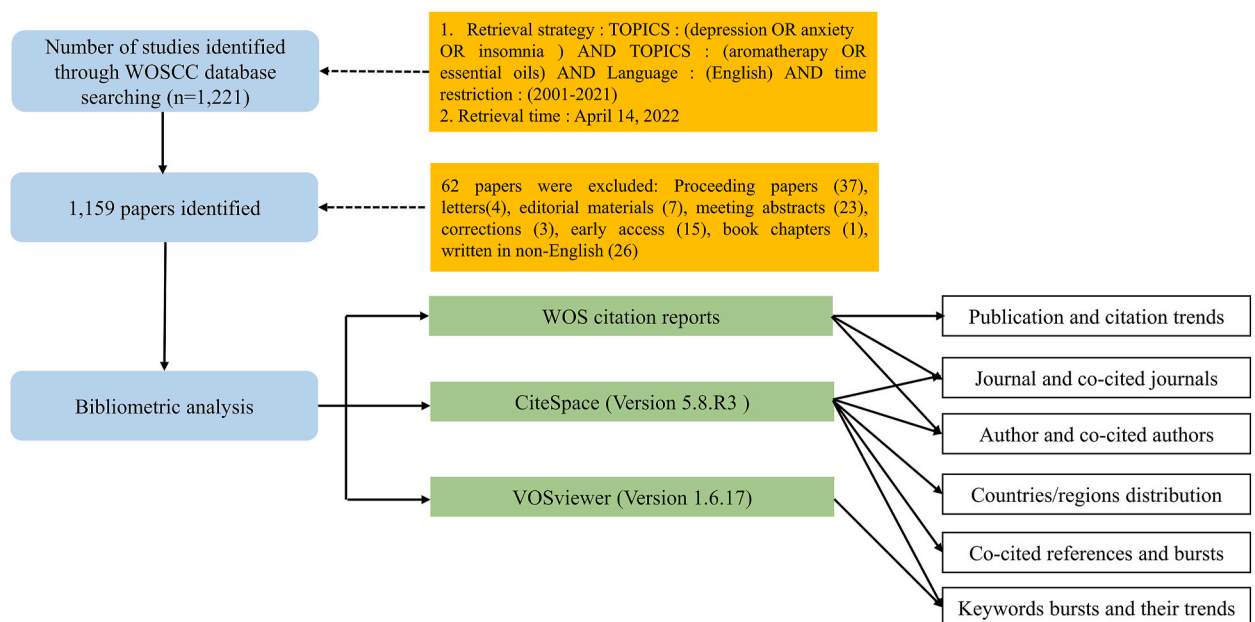


Fig. 1. Flow diagram of literature filtering.

2. Methods

2.1. Strategies for data collection and search

Searches were conducted in the Web of Science Core Collection (WOSCC) database for published literature (only articles and reviews) restricted to Science Citation Index-Expanded (SCIE) in English on the treatment of anxiety, depression, and insomnia with aromatherapy (EOs). Using WOSCC as the search source could provide researchers with quality literature and give a solid basis for the study [28]. To avoid biases introduced by daily database updates, all searches were conducted on the same day, April 14, 2022. Incorporating search strategies was done as follows: TS = (depression OR anxiety OR insomnia) AND TS = (aromatherapy OR essential oils). There were 1159 records identified from WOS between 2001 and 2021. These entries were cited 27,495 times in total, with an average of 23.72 citations per publication. All of these 1159 records were analyzed, including 905 articles and 254 reviews. Two authors (MLL and XC) independently extracted relevant records from screened articles and saved them as plain text files on April 15, 2022, including titles, keywords, authors, institutions, journals, publication dates, countries/regions, citations, etc. (Fig. 1).

2.2. Data extraction and data cleaning

Because of the spelling variations in this topic, a country/institution/author/journal may be classified into multiple countries/institutions/authors/journals. As such, pre-processing the data is necessary for accurate analysis. We set up a uniform export format for Endnotes (for example, authors' names formatted as Last name, A.B.). Then the data was imported into Microsoft Excel 2019 (Microsoft Corporation, Redmond, Washington, WA, United States) for manual data cleaning. To ensure reliability, data extraction, analysis, and literature selection were independently performed by two researchers. From the selected articles, we gathered data on the number of publications, the frequency of citations, the countries of origin, the authors, journals, institutions, and funding sources. Based on the Journal Citation Reports (JCR) 2021 (available at: <http://thomsonreuters.com/journal-citationreports/>), the journal impact factor (IF) and category of each journal were determined. Data cleaning and analysis were done manually in Excel after discrepancies between the researchers were discussed^{35, 36}, a process involved finding the missing value, merging different spellings of the same country/institution (e.g., Hong Kong, Macao, Taiwan all belong to China; Harvard University and Harvard Univ are the same institutions). To prevent counting the same article more than once, the nations and institutions were studied following the first author's country and institution. As a result of reviewing the titles and abstracts of the articles, duplicate records were removed, and articles not related to research topics were deleted.

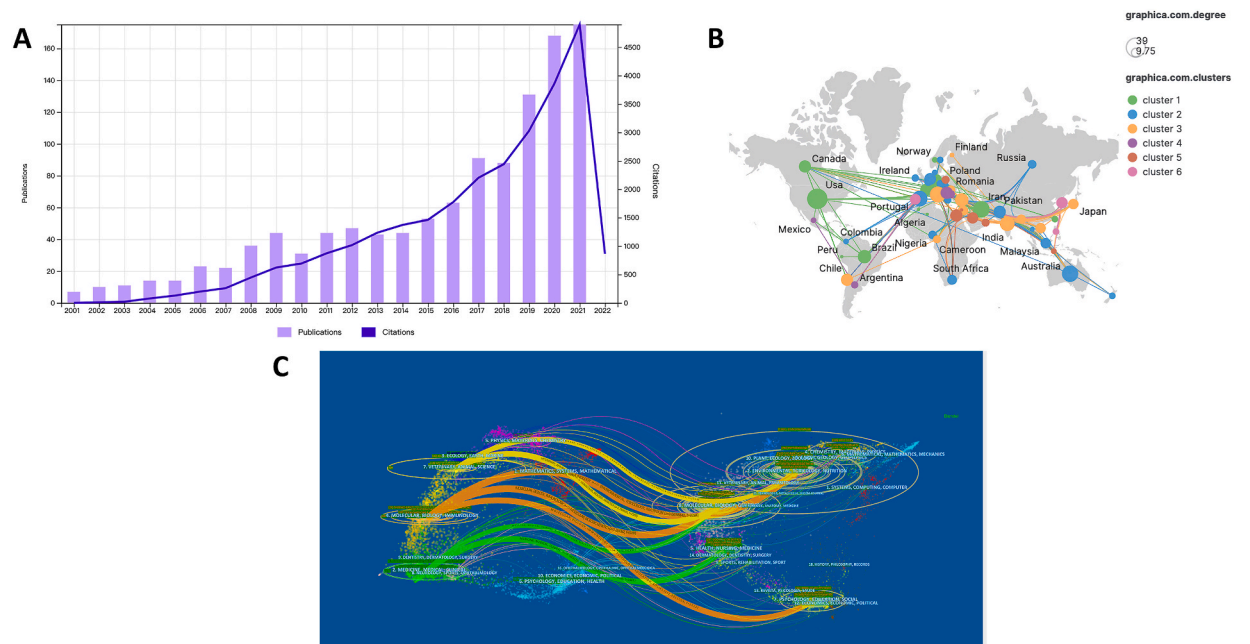


Fig. 2. Distribution of publications and citations from different years, countries, and journals. (A) The number of publications and citations during different years (2001–2021). (B) Regional distribution and network map of countries/regions related to this field. (C) The dual-map overlay of journals related to this field.

2.3. Bibliometric analyzing

Then, these datasets were imported into CiteSpace 5.8. R3 (Drexel University, Philadelphia, PA, USA) and VOSviewer1.6.17 (Leiden University, Leiden, The Netherlands). Prior to conducting co-word analysis and document co-citation analysis, we removed duplicates from CiteSpace and created a unique record. The WOS citation reports were used to determine the trends in the publication and citation of the literature. And the following analyses were performed by CiteSpace: collaboration network analysis, co-citation analysis (countries/regions, authors, journals, and institutions), keyword burst analysis, and co-cited references analysis. Each node in the visualization map represents the type of research being analyzed, and its size corresponds to its number of occurrences or citations. The strength of collaborations, co-citations, or cooccurrences between nodes is represented by links between them. Nodes are colored according to the distribution time. In the diagram, neighbor nodes form clusters according to related topics, and the flow of knowledge between clusters can be seen in the change of color between clusters. A network of hotspots (keywords) associated with mood disorders treated with aromatherapy research was mapped and visualized using VOSviewer. Nodes in the network graphs generated by the VOSviewer indicate different keywords. Different colored nodes represent different taxonomies or occurrence times. And bigger nodes represent a higher betweenness centrality, which is calculated by calculating the betweenness centrality for each keyword. Links between the nodes characterize certain correlations among keywords. Referring to previous studies [29,30], based on the co-occurrence analysis, hotspots were grouped into disparate clusters and colored by their time of occurrence [30]. Detailed procedures are described in the flowchart shown in Fig. 1.

3. Results

3.1. Trends in publication and citation

The number of publications and citations indicates the amount of research that has been conducted in this field over a given period of time. Fig. 2A provides an overview by year of the number of articles that have been published on the topic of using aromatherapy to treat anxiety, depression, and insomnia. Publication numbers have steadily increased over the last two decades, especially in the following five years, which demonstrates that the field of aromatherapy to alleviate emotional and mental distress began to receive attention. From 2001 to 2010, fewer than forty articles were published per year, and the average increased to about 50 from 2011 to 2016 and then jumped to 130 per year from 2017 to 2021 (Fig. 2A). A remarkable increase was noted in publication outputs and citations by 2021, with 193 publications and 4684 citations both reaching record highs (Fig. 2A). From 2001 to 2021, the number of citations for these publications steadily increased as well (Fig. 2A). In light of these findings, EOs may become more and more popular for treating mood disorders and sleep disorders.

3.2. Countries/region analysis

In total, 88 countries and regions contributed to this topic research. As a result, the top 10 countries/regions were distributed among three continents (Asia, North America, and Europe), of which 6 were located in Asia (Table 1). Approximately 16% of the publications originated from the United States (188, 16.22%). Iran (184, 15.88%), China (131, 11.30%), Brazil (110, 9.49%), and Japan (85, 7.33%) also made significant contributions to the field in recent years (Table 1). We constructed a Country/region co-authorship network (25/88, 28.41%) using countries and regions with at least 10 publications ($T = 10$) (Fig. 2B). The visualization map reflects the degree of collaboration among these Countries/regions in this field. Clusters are colored according to the mutual citation relationships between countries. The length of a line represents how close countries/regions cooperate. Bigger nodes represent more influential countries/regions in this field. On the network map, the United States is the largest node. There were more cooperation papers in the United States, Iran, and Australia with larger bubbles. Unfortunately, China's international research cooperation in this field is not prominent. Cooperation between countries/regions was moderately active; for example, for instance, the United States and Portugal had relatively close cooperation, while India had relatively close cooperation with Japan.

Table 1
The top 10 most productive countries/regions for relevant research.

Rank	Countries/regions	Counts (%)
1	United States	188 (16.22)
2	Iran	184 (15.88)
3	Peoples R China	131 (11.30)
4	Brazil	110 (9.49)
5	Japan	85 (7.33)
6	Turkey	61 (5.26)
7	Italy	54 (4.66)
8	England	49 (4.23)
9	South Korea	45 (3.88)
10	India	44 (3.80)

3.3. Journals and co-citations analysis

The extracted studies mainly comprised five disciplines given that each document can include multiple disciplines: pharmacology pharmacy (n = 265, 22.86%), integrative complementary medicine (n = 241, 20.79%), chemistry medicinal (n = 137, 11.82%), nursing (n = 100, 8.63%), and plant science (n = 100, 8.63%). In total, 575 academic journals published the included literature. According to Table 2, the Journal of Ethnopharmacology delivered the largest number of documents (40, 3.45%), followed by the Journal of Alternative and Complementary Medicine (32, 2.76%), Complementary Therapies in Medicine (32, 2.76%), Evidence-Based Complementary and Alternative Medicine (29, 2.50%), and Complementary Therapies in Clinical Practice (27, 2.33%). Phytotherapy Research has the highest IF (5.88) of these 8 top journals. Co-citation analysis is used to evaluate the degree of relationship between articles, exploring their development and evolution. Citations are one of the main factors in determining a journal's academic impact. Meanwhile, the top eight journals cited close to 160 times are shown in Table 2., and the most frequently cited journal was Physiology & Behavior (566 times), followed by Annals of Internal Medicine (387 times), Molecular Medicine Reports (271 times), and Molecular Nutrition & Food Research (193 times). In the 2020 Journal Citation Reports (JCR), six of the top 8 co-cited journals ranked in the first or second quartile (Q1/2), except for Molecular Medicine Reports and the International Journal of Neuroscience (Table 2).

In this dual-map overlay, citation journals are positioned on the left and cited journals are positioned on the right [31]. Seven more visible citation paths exist, including three orange paths, two yellow paths, and two green paths (Fig. 2C). Through the presentation of these paths, we can analyze the topic distribution of academic journals. Such as on the top and middle orange paths, papers published in Molecular/Biology/Immunology journals mostly cited papers published in Molecular/Biology/Genetics journals, but on the bottom orange path, papers published in Psychology/Education/Social journals were mainly cited by the studies published in Molecular/Biology/Immunology journals.

3.4. Authors and co-cited authors analysis

The use of EOs in anxiety, depression, or insomnia treatment was documented by 260 authors (Table 3). Hritcu L from the Department of Biology, Alexandru Ioan Cuza University, Romania, published the most papers (29, 2.50%), followed by Satou T (27, 2.33%), and De Sousa DP (27, 2.33%). Citation count is a measurement indicating a scientific impact. Additionally, the 10 authors with the most co-citations are listed in Table 3, including Gupta SC (464 times), Lorenz KA (387 times), and Lorenz KA (271 times). It is worth noting that the topmost cited scholars in this field do not rank at the top concerning the total number of published articles.

3.5. Co-occurring keywords and burst term analysis

3.5.1. Cluster visualization of the co-occurring keywords

Keywords analysis can reveal the changes in research hotspots in a certain subject area to some extent. The co-occurrence of keywords is the appearance of two keywords in the same publication. That indicates that there is a cooccurrence relationship between them. In comparison to single keywords, co-occurring keywords can give a better sense of hotspots in research. The original records of these keywords without repetition were obtained by removing duplicates and merging the singular and plural forms (e.g., "aromatherapy", "aromatherapies", and "aroma therapy"), abbreviations (e.g., "EOs" and "essential oils"), and synonyms (e.g., "anxiety disorder" and "anxiety", "insomnia" and "hyposomnia"). The primary keywords were mapped using the VOS viewer technique to identify the different research hot spots, with the unit of analysis as "all keywords" and the type of analysis as "co-occurrence" in this soft.

Additionally, we set a threshold of 15 minimum co-occurrences of each keyword and then derived 30 keywords out of 5379 words

Table 2
Top 8 journals and co-cited journals.

Rank	Journal	Country/ Region	Count (%)	IF/JCR (2020)	Co-cited Journal	Country/ Region	Citation Count	IF/JCR (2020)
1	Journal of Ethnopharmacology	Irish	40 (3.45)	4.36/Q1	Physiology & Behavior	United States	566	3.24/Q2
2	Journal of Alternative and Complementary Medicine	United States	32 (2.76)	2.58/Q2	Annals of Internal Medicine	United States	387	25.39/Q1
3	Complementary Therapies in Medicine	England	32 (2.76)	2.45/Q2	Molecular Medicine Reports	Greece	271	2.95/Q3
4	Evidence-Based Complementary and Alternative Medicine	England	29 (2.50)	2.63/Q2	Molecular Nutrition & Food Research	Germany	193	5.82/Q1
5	Complementary Therapies in Clinical Practice	Netherlands	27 (2.33)	2.45/Q2	International Journal of Neuroscience	England	186	2.29/Q4
6	Phytotherapy Research	England	22 (1.90)	5.88/Q1	International Journal Of Clinical Practice	England	170	2.50/Q2
7	Molecules	Switzerland	20 (1.73)	4.41/Q2	BMJ Open	England	168	2.69/Q2
8	Phytomedicine	Germany	16 (1.38)	5.34/Q1	Lipids in Health and Disease	England	158	2.62/Q2

Table 3
Top 10 authors and co-cited authors.

Rank	Author	Country	Count (%)	Co-cited author	Country	Citation count
1	Hritcu L	Romania	29 (2.50)	Gupta SC	United States	464
2	Satou T	Japan	27 (2.33)	Lorenz KA	United States	387
3	De Sousa DP	Brazil	27 (2.33)	Srivastava JK	United States	271
4	Koike K	Japan	25 (2.16)	Lehrner J	Germany	217
5	Yao L	Peoples R China	20 (1.73)	Hunt KJ	England	168
6	Bagetta G	Italy	19 (1.64)	Abraha I	Scotland	167
7	Murakami S	Japan	19 (1.64)	Herz RS	United States	154
8	Hancianu M	Romania	18 (1.55)	Soden K	England	153
9	Hayashi S	Japan	17 (1.47)	Linck VM	Brazil	143
10	Cioanca O	Romania	16 (1.38)	Marder M	Argentina	129

to form three clusters with different colors (purple, pink, and red) as shown in Fig. 3A. Cluster 1 (purple cluster): aromatherapy was used for anxiety and depression treatment; Cluster 2 (pink cluster): EOs were used to reduce the risk of insomnia, cognitive decline, and oxidative stress; Cluster 3 (red cluster): the neuropsychiatric efficacy of EOs.

3.5.2. Time-zone visualization of the co-occurring keywords

To identify the evolution of research hotspots over time in the area, we presented a time-zone diagram of the co-occurrence network for keywords (Fig. 3B and C). The full counting method was used to generate a network visualization map and an overlay visualization map based on 445 keywords that were occurrences more than five times. Co-occurrence links between keywords are indicated by the thickness of the connecting lines in the visualization map, revealing the association of their respective research focuses. The bubble size represented the frequency of occurrence of the keyword. The colors exhibited in the network visualization map indicate the various clusters formed by the keywords, while the colors displayed in the overlay visualization map represent the average publication year of the detected keywords. All of the detected keywords may be grouped into five clusters, as shown in Fig. 3B: “essential oil basic research,” “aromatherapy to improve anxiety research,” “aromatherapy to improve depression research,” “aroma research,” and “related clinical studies”. These clusters indicated the most significant subjects in aromatherapy research to date. For example, for the “aromatherapy to improve anxiety research” cluster, the primary keywords were aromatherapy, anxiety,

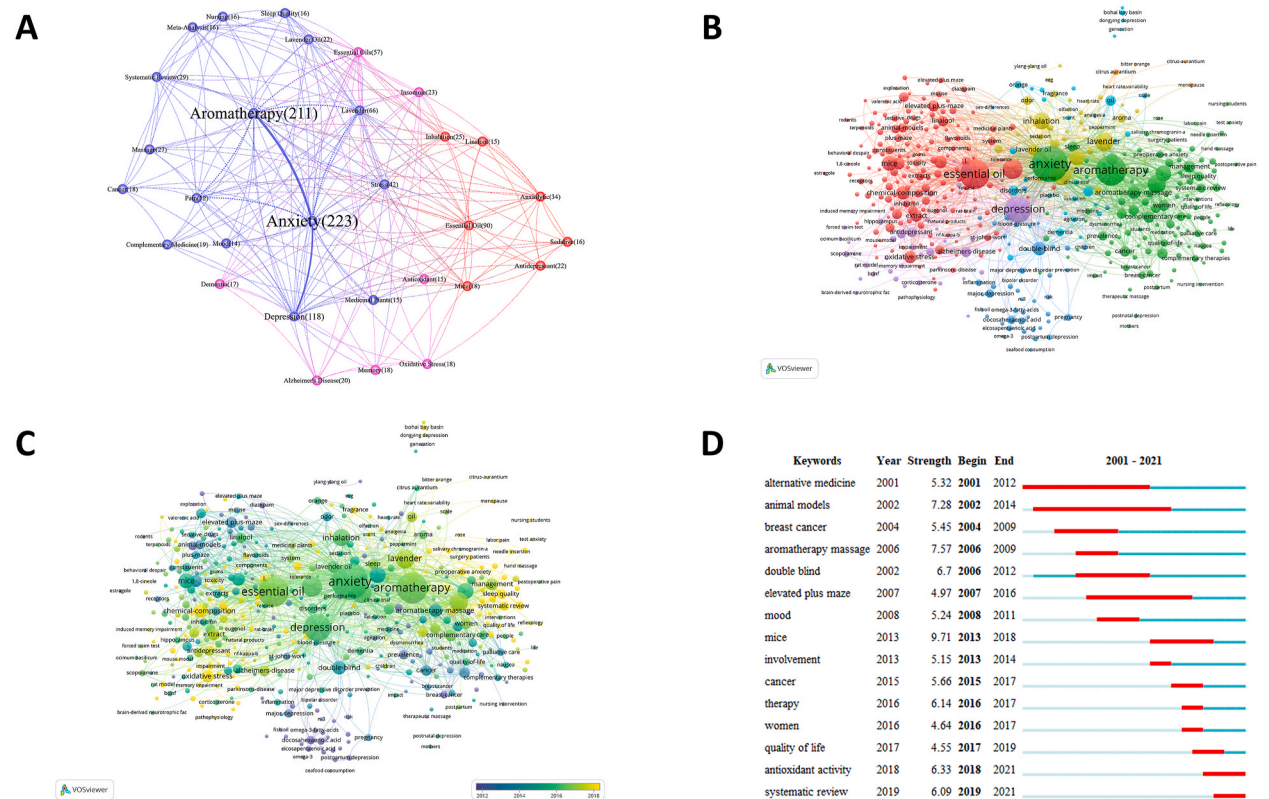


Fig. 3. Co-occurrence analysis of keywords. (A) Cluster visualization of the co-occurring keywords. (B) Network visualization map of keywords. (C) Overlay visualization map of keywords. (D) Time trends of burst keywords.

aromatherapy massage, sleep quality, complementary care, and women. Using overlay visualization, the keywords were grouped by the average publication year (Fig. 3C), based on VOSviewer selected years (2012–2018). The color of keywords such as “chemical composition”, “oxidative stress”, and “systematic review” is closer to yellow, indicating that these fields have gained popularity recently and may become hotspots in the coming years.

3.5.3. Keyword-term burst analysis

In CiteSpace, the burst detection function helps discover research frontiers. Fig. 3D demonstrates the 15 keywords with the strongest citation bursts. Time intervals are indicated by blue line segments, while active times are indicated by red line segments. The blue line segment indicates the time interval, while the red line segment displays the active time of keywords. Keywords with red lines extending into the latest year may indicate future research frontiers, the quality of life, antioxidant activity, and systematic review were keywords with recent citation bursts. These keywords presented us with the main areas of current aromatherapy for mood disorders research.

3.6. Co-cited references and burst references

3.6.1. Top-cited references

Reference co-citation analysis was used to describe two documents' co-occurrence in the references list of another publication. The 10 most frequently cited articles related to mood disorders and aromatherapy are listed in Table 4. Among these references, the top two received over 200 citations each, with each obtaining 120 or more citations. Based on the most cited source, a systematic review described the curative and preventative properties of chamomile by examining its use in traditional medicine [32]. The second most cited paper analyzed the effect of orange and lavender essential oils on anxiety, mood, alertness, and calmness in dental patients, suggesting that odors could help relieve dental anxiety [33].

3.6.2. Cluster visualization of co-citation network

CiteSpace divided the co-citation network into 14 major clusters, with references closely connected within one cluster, but loosely connected among them (Fig. 4A). We used the log-likelihood ratio test to extract terms from the titles of the most representative articles in each cluster. Articles included in each cluster are inversely correlated with the number of cluster tags. As a result, the cluster of #0 contains the most articles. In terms of cluster size, the largest cluster #0 was labeled “Systematic review,” the second largest cluster #1 was “Sleep quality,” and the third largest cluster #2 was “Anxiolytic-like effect”.

3.6.3. References burst analysis

Citation bursts, characterized as frequent citations at a given point in time, can be used to identify the evolution of a knowledge domain [34]. Twenty-five references with the strongest bursts of citations were identified (Fig. 4B). Referencing bursts were displayed as a red line segment. Citation bursts began in 2001, and citation bursts of 14 references ended in 2017 or later. An article titled “Essential oils used in aromatherapy: A systemic review” published in the Asian Pacific Journal of Tropical Biomedicine by Ali et al. had the highest burst score (strength = 11.44) of the 25 references lasting from 2018 to 2021 [35], followed by “A randomized controlled trial of aromatherapy massage in a hospice setting” published by Soden et al. with a citation burst lasting from 2006 to 2009 (strength = 7.97) [36]. References with citation bursts ending in the most recent year deserve special attention. 2017 to 2020 (97.81).

Table 4
Top 10 co-cited references.

Rank	Author	Reference title	Journal	Year	Citation count
1	Srivastava JK	Chamomile: A herbal medicine of the past with a bright future	Molecular Medicine Reports	2010	271
2	Lehrner JM	Ambient odors of orange and lavender reduce anxiety and improve mood in a dental office	Physiology & Behavior	2005	217
3	Gupta SC	Multitargeting by turmeric, the golden spice: From kitchen to clinic	Molecular Nutrition & Food Research	2013	193
4	Sarris JB	A systematic review of insomnia and complementary medicine	Sleep Medicine Reviews	2011	180
5	Hunt KJ	Complementary and alternative medicine use in England: results from a national survey	International Journal of Clinical Practice	2010	168
6	Abraha Iosief	Systematic review of systematic reviews of non-pharmacological interventions to treat behavioural disturbances in older patients with dementia.	BMJ Open	2017	167
7	Herz RS	Aromatherapy Facts and Fictions: A Scientific Analysis of Olfactory Effects on Mood, Physiology and Behavior	International Journal of Neuroscience	2009	154
8	Soden K	A randomized controlled trial of aromatherapy massage in a hospice setting	Palliative Medicine	2004	153
9	Linck VM	Effects of inhaled Linalool in anxiety, social interaction and aggressive behavior in mice	Phytomedicine	2010	143
10	Marder M	6-Methylpigenin and hesperidin: new valeriana flavonoids with activity on the CNS	Pharmacology Biochemistry and Behavior	2003	129

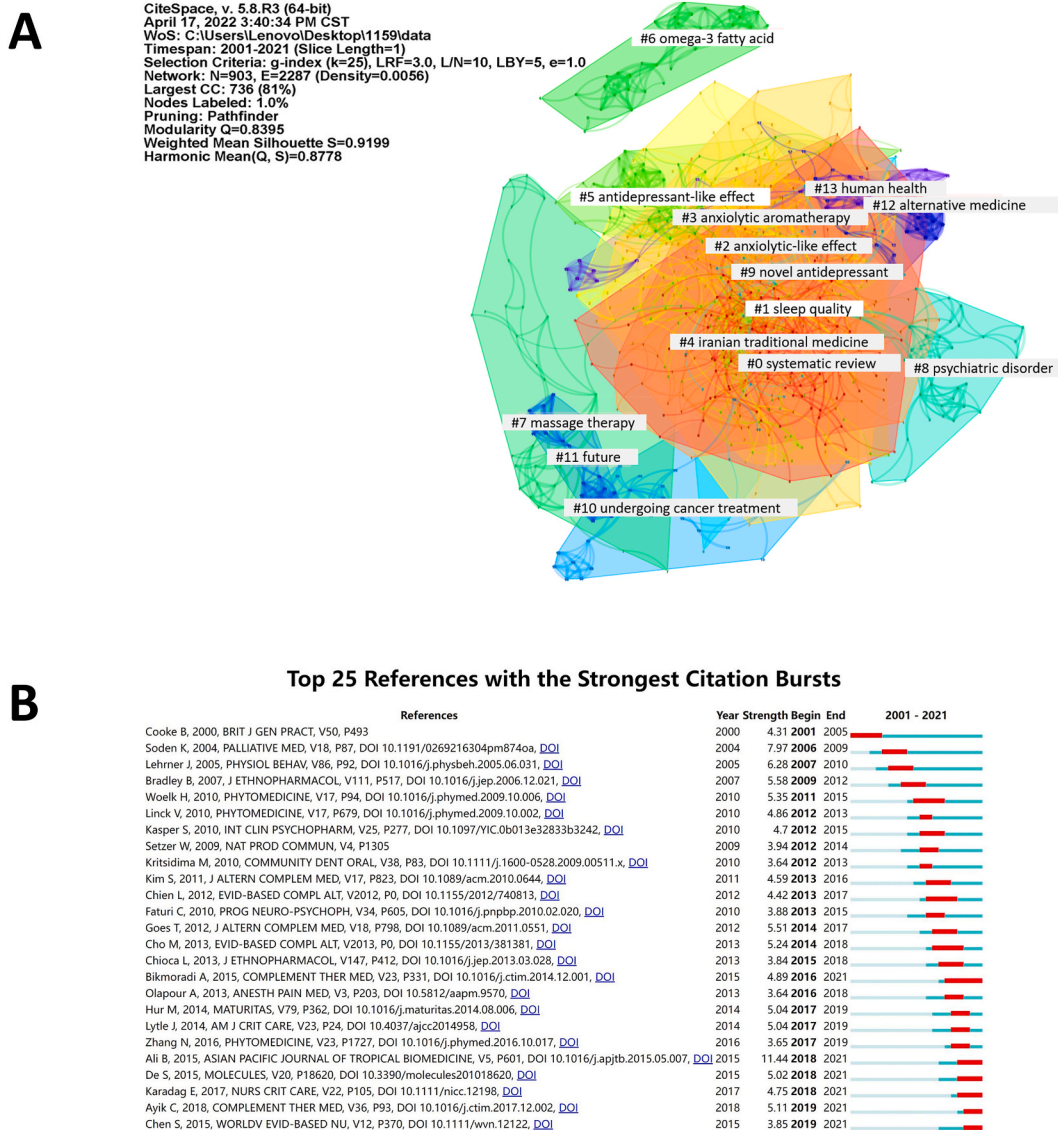


Fig. 4. Co-cited references and burst references. (A) CiteSpace visualization clusters of co-cited references. (B) The references with strong citation burst of publications from 2001 to 2021.

4. Discussion

4.1. Basic information

Using the WOSCC to review relevant literature from 2001 to 2021 relating to aromatherapy in the treatment of anxiety, depression, and insomnia, a bibliometric analysis was conducted to assess research hotspots, and potential trends, and provide reference guidelines for future researchers. In a certain sense, a research area's publication rate indicates the speed of its development [37]. There were only seven papers published in 2000 and ten in 2001, most likely because this field was still in its infancy. The annual output however showed an upward trend during the last two decades, particularly in 2017, when over 90 papers were published, suggesting related topics have received increased attention over the past few years. The United States, Iran, and Peoples R China were the top three productive countries. The top 10 countries/regions in this area comprised six Asian countries/regions (i.e., Iran, China, Japan, Turkey, South Korea, and India), indicating that the intensity of research in this area is relatively high in Asian countries/regions. These countries' research output may be attributed to the fact that aromatherapy is inherited from Eastern medicine and has a long history of practical application and scholarly interest. But in terms of international research cooperation in this field, it seemed moderate active collaborations between countries/regions, the United States, Iran, and Australia were more influential. Since China's previous aromatherapy research was mainly focused on the field of Chinese medicine, such as "fumigation therapy", there was less international

cooperation. In the future, with the integration of aromatic cultural exchanges, China's international cooperation in this area is expected to strengthen.

The author's analyses aid in gaining a more thorough understanding of a study topic and objectively evaluating the researchers' contributions, as well as their level of research and academic standing in this subject. The top 10 most-published authors were all active scholars in this field. Gupta SC has the most citations per paper, whereas Hritcu L produced the most papers. Based on these indicators, we can identify the most academically influential and authoritative authors in the field of aromatherapy. Significantly, most of the authors were from institutions in universities and hospitals. Several researchers studied biology, chemistry, or biochemistry, while others studied biophysics and medicine. Hritcu L, from the Alexandru Ioan Cuza University, contributed greatly to the basic research on essential oils, including the anti-acetylcholinesterase, anti-inflammatory, and antioxidant activities in rats and zebrafish models [38,39]. Gupta SC was more concerned about the applications and commercial prospects of EOs [32,40].

In terms of journals, the *Journal of Ethnopharmacology and Physiology & Behavior* was the most cited and productive. Regarding the top 8 active journals as well as the top 8 co-cited journals, European journals had the largest share (87.5% and 75.0%, respectively), which indicates that European journals are highly influential in this field. The dual-map overlay of journal analysis revealed that most papers were published in molecular, biology, immunology, animal science, and clinical journals. These journals cover not only basic but also clinical research, indicating that related topic research has already moved from the laboratory to clinical application. Their citations primarily comprised journals in the fields of molecular research, biology, genetics, psychology, health, and nursing, which could serve as a guide to beginners looking to conduct research in these areas.

4.2. Knowledge base

It is generally believed that highly-cited references constitute a source of the knowledge base in a specific subject area. The knowledge base related to aromatherapy for mood disorders was evaluated by choosing the top 10 co-cited references. In total, five articles reviewed the effectiveness of aromatherapy or the effects of essential oil plant extracts; three of these studies focused on clinical aromatherapy applications; and two articles were concerned about animal experiments.

The study described the use of chamomile in traditional medicine about its curative and preventive properties having the most citations ($n = 271$) published in 2010 by Srivastava JK et al. [32], and highlighted some findings related to its potential as a sedative or sleep aid, and as a treatment for generalized anxiety disorder (GAD). As a result of the many pharmacologic effects of EOs, aromatherapy has been used in a variety of diseases and symptoms, particularly for stress management. Other similar reviews about the extracts from aromatic plants used for neuropsychiatric disease prevention and treatment were previously published [41]. Two of them ranked among the top 10 co-cited references, occupying third place [40] and seventh place [42] ($n = 193$ and $n = 154$), respectively. Gupta et al. introduced the chemical constituents, biological activities, cellular targets, and clinical potential of turmeric in 2013. In this review, two animal-based studies about the antidepressant activity of ethanolic extract from *C. longa* were mentioned. By modulating the neurochemical and neuroendocrine systems, the extract significantly attenuated swam stress-induced decreases in serotonin, 5-hydroxy indoleacetic acid, noradrenaline, and dopamine levels for mice [43,44]. As Herz RS et al. found in 2009, there is credible evidence that odors of aromatic chemicals have an impact on physiology, mood, and behavior, though there are inconsistencies between dependent measure and laboratory measures [42].

In the second publication ($n = 217$), the smell of orange and lavender in the waiting room reduced anxiety and improved mood among dental patients [33]. In the ninth and tenth co-cited references ($n = 143$ and $n = 129$) published in 2010 and 2003, Linck et al. [45] and Marder et al. [46] also reported results similar to the relaxation effect of aromas reported in animal model tests. Linck et al. extended previous studies on the psychopharmacological effects of inhaled linalool and linalool-rich EOs in 2010. Marder et al. reported in 2003 that valerian contains 2S (-)-hesperidin and described its sedative and sleep-enhancing properties. Furthermore, 6-methyl apigenin exhibited anxiolytic properties and enhanced the sleep-inducing property of hesperidin. The eighth most co-cited study in 2004 ($n = 153$) was by Soden et al., which evaluated the efficacy of absorbing aroma, unlike the above references [36]. The results indicated that adding lavender essential oils to massage seems not to increase its benefits to patients with advanced cancer undergoing hospice care.

The fourth co-cited reference was published in 2011 by Sarris et al. ($n = 180$) (Sarris and Byrne 2011), which discussed complementary and alternative medicine (CAM) interventions for insomnia, including herbal remedies. Surprisingly, in the systematic review, several mainstream CAM treatments (e.g., massage, aromatherapy) were either not identified or did not meet basic inclusion criteria, and future researchers were urged to employ acceptable methods, including appropriate sample sizes and adequate controls. The other review is in the sixth co-cited reference of Abraha et al.'s paper in *BMJ Open* ($n = 167$) from 2017, focusing on behavioral and psychological symptoms of dementia (BPSD) through non-pharmacological interventions. The results showed music therapy and behavioral management techniques, not including sensory stimulation interventions (e.g., acupressure, aromatherapy, massage/touch therapy) were effective in reducing BPSD. Hunt et al. published the fifth co-cited reference in 2010 ($n = 168$) [47]. It was an investigation into the prevalence and predictors of complementary and alternative medicine (CAM) use in England, which data were obtained from the 2005 National Health Survey for England. CAM use was found to be 44.0% in a lifetime and 26.3% per year, and massage, aromatherapy, and acupuncture were the most popular therapies. As of yet, there have been no large-scale representative studies on aromatherapy in certain populations. According to the top 10 co-cited references, aromatherapy for mood disorders research predominantly focuses on the following aspects: related efficacy of aromatherapy/EOs, application status, and biochemical mechanism.

Overall, people have observed that EOs have particular effects on the central nervous system (CNS), such as boosting intelligence, affecting slumber, promoting cognition and memory, anti-anxiety and anti-depression, sedation, and so on [18]. Aromatherapy in

clinical settings has been tried by some researchers and nursing staff via EOs in a variety of methods (including inhalation through the nostrils, oral ingestion, and oil rubbing), and it appears to be practicable as a complementary or alternative treatment due to the affordability, ease of use, mild effects, fast elimination, low toxicity, and significant efficacy of EOs [48]. EOs are complex combinations of more than 500 volatile organic chemicals derived from plants, such as camphene and linalool. In recent years, EOs have received a lot of interest as a supplemental and alternative medicine for the treatment of anxiety, depression, and insomnia, due to their great efficacy and low side effects. The underlying important mechanism for this is the EO's bioactive effect on the central nervous system (CNS) [49]. In general, EOs exert their possible neuropharmacological effects primarily through blood circulation (blood route) or direct olfactory nerve transmission (nerve route) [50]. Since their low polarity, EOs molecules can easily pass through physiological barriers (mucosa, skin, blood-brain barrier, etc.) and reach brain tissue via blood circulation, where they exhibit neuropharmacological effects [50]. While for the nerve route, EOs are inhaled through the nasal cavity and pass through the olfactory epithelium, where they attach to dendritic receptors of olfactory sensory neurons. The specific signals are transmitted to the "limbic system" and can trigger emotional responses via the amygdala, stimulate the hypothalamic autonomic nerve, and influence the function of many organs [51]. Even though various studies have highlighted the favorable pharmacological effects of EOs on mood disorders and have examined the likely underlying mechanisms, additional study is still needed to pay greater attention to the complexity and diversity of EOs on the CNS.

4.3. Emerging topics

Using keywords as a way to describe hotspots in the field is reasonable. In the keyword co-occurrence analysis, the main focus was on the use of EOs to treat anxiety and depression, emerging in 2012, and EOs, anxiety, and depression were the three most relevant topics in the purple cluster. A recent network meta-analysis has shown that the anxiolytic effect of lavender essential oil taken as 80 mg silexan capsules was observed to be the same as that of paroxetine, according to the Hamilton Anxiety Scale (HAMA) score. Additionally, another randomized controlled trial compared the follow-up effects of compound EOs (lavender, sweet orange, and bergamot) through massage or inhalation on depression symptoms in older people living in the community [52]. It was suggested that the use of aromatherapy massage and aromatherapy inhalation may be helpful for older adults suffering from depression. Thus, EOs has been proposed potential as a therapeutic assistance in the treatment of neuropsychiatric disorders, such as anxiety, insomnia, neurodegenerative disorders, etc. [53,54]. An overlap analysis identified oxidative stress, chemical composition, and systematic review as emerging topics in this field, and the yellow cluster in the keyword co-occurrence network contained these keywords. According to Nasiri et al., by using a randomized controlled trial design, inhaling lavender can improve sleep quality, quality of life, and mood in diabetic patients with insomnia [55]. Additionally, Cheong et al. reported inhalation aromatherapy was effective in improving sleep problems such as insomnia and inhaling lavender had the greatest effect of all the single inhalation methods [16].

The emerging trends can, to a certain extent, be identified by analyzing the high citation burst of the literature [56]. CiteSpace was used to identify the top 25 references with large citation bursts; 14 of them ended in 2017 or later, underscoring the recent attention paid to these topics. As far as the end dates of these 14 references are concerned, nine of them ended in 2019 or later. Inhalation and massage with EOs have been shown to improve mood states and sleep quality in the majority of these 14 references [57–61]. The publication with the strongest burst of citations is a study published by Ali et al., in 2015 (2018–2021, strength = 11.44), followed by a publication by Soden et al., in 2004 (2006–2009, strength = 7.97) with the second highest burst of citations. As a systematic review of aromatherapy with a broad vision in recent years, the study by Ali et al. [35] summarized some of the pharmacological actions of EOs for common problems, including anxiety, stress, challenging behaviors, fatigue, insomnia, burnout, etc. Meanwhile, the authors observed that scientific and technological progress helped reduce the unwanted effects of modern medicine by EOs if properly exploited to their full potential. The benefits of aromatherapy extend not only to patients but also to the general public.

However, there seems to be a lack of high-quality real-world research about the clinical effectiveness of aromatherapy for mood disorders, with some meta-analyses or reviews producing conflicting results, as stated in the preface. Recent research focus or outputs were still mainly systematic reviews identified with the cluster visualization of the co-citation network. There is a need for additional RCTs to adequately assess the effect of aromatherapy on mood disorders such as anxiety or depression. Meanwhile, there have been only a few studies that have examined the constituents of these essential oils and their anxiolytic and antidepressant activity [62,63]. Since EOs are mixtures of many organic compounds, their chemical composition determines their biological activity and fragrance [64]. The biological activity of EOs cannot be attributed to a single component, but rather to its synergistic effects. However, there has been little in-depth research on the efficacy of a single component [65]. More research about single essential oil samples for drug exposure assay is warranted to better evaluate and compare the activity of anxiolytic or antidepressant components among different EOs.

4.4. Strengths and limitations

Several strengths of this study can be identified. First, research hotspots, research trends, and landmark manuscripts of aromatherapy research on anxiety, depression, and insomnia over the past two decades were presented in this study for the first time. Second, bibliometric analysis is relatively more comprehensive and intuitive than traditional literature reviews. In addition, there are limitations inherent in bibliometric studies. First, the data was retrieved exclusively from the WoSCC database, which may have led to some publications being missed. Despite this, the WoSCC database is frequently used to analyze scientometric data [37]. Second, our retrieval strategy included only some specific terms referring to the main target objects and conditions, so the publications retrieved may contain potential false positives and false negatives since no search query is 100% accurate. Third, CiteSpace and VOSviewer were

both used in this study, so the search algorithm may not be perfect and can generate some bias [29]. Despite these limitations, our findings provide a solid global view of aromatherapy for mood disorders from the last two decades, providing an informed perspective on the current research in this area and orienting future research in this area.

5. Conclusions

To our knowledge, this study was the first bibliometric analysis of aromatherapy for the treatment of mood disorders worldwide during the past two decades. Related research fields are experiencing rapid growth and attracting increasing attention from scholars. The United States ranked first for productivity and research activities. More widespread global collaboration may be necessary, particularly for China. *Journal of Ethnopharmacology and Physiology & Behavior* was the most productive journals and most co-cited journals, respectively. The knowledge base of this field research mainly included the related efficacy of aromatherapy/EOs, application status, and biochemical mechanism. The research frontiers identified in our study included oxidative stress, chemical composition, systematic review, and sleep quality. Although there are still technical limitations and a lack of high-quality preclinical and clinical studies, the topic of aromatherapy for mood disorders deserves continued research, and we believe that our study provides practitioners and researchers with a useful reference.

Ethics approval and consent to participate

This study did not require the approval of an ethics committee since we analyzed a secondary database.

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Author contribution statement

Xia Cao: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Performed the experiments; Wrote the paper. Jiansong Zhou: Conceived and designed the experiments; Analyzed and interpreted the data. Jiali Liu: Performed the experiments; Analyzed and interpreted the data. Hui Chen: Analyzed and interpreted the data; Wrote the paper. Wei Zheng: Conceived and designed the experiments; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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List of abbreviations

EOs Essential Oils
WOSCC Web of Science Core Collection

Appendix. ASupplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.heliyon.2023.e18380>.

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