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Bibliometric Analysis of Articles on Essential Oil Nanoemulsions

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ABSTRACT

Essential oils are complex volatile mixtures, many of which have various demonstrated pharmacological effects. However, their ability to penetrate tissues and their stability are affected by their hydrophobic character and volatility. To overcome these challenges, nanoemulsions are reported to be among the most suitable strategies. Therefore, this study aimed to conduct a bibliometric analysis of scientific articles on essential oil nanoemulsions published between 2015 and 2025. VOSviewer and biblioshiny tools were used to identify peer-reviewed publications in the Scopus database. A total of 1460 relevant publications from 81 nations were identified, the majority being classified as Biological and Agricultural Science. Iran was at the forefront of this field of study, and the National Research Centre was the most prominent affiliate. The International Journal of Biological Macromolecules was the leading publication. The results showed that essential oil, antibacterial action, and nanoemulsion were the terms used most often. A total of 4 clusters were identified through analysis of the co-citation network, including geographical application, transdisciplinary studies, food, and pharmaceutical. Essential oil, nanoemulsion, *Escherichia coli*, and thymol were terms identified using author keyword analysis. Over the specified period, the number of articles increased, suggesting a consistent rising trend.

Keywords: Bibliometric, Essential Oil, Nanoemulsion, Bioactive compounds

Introduction

Essential oils are complex volatile mixtures that are usually found in aromatic plants in low concentrations.[1] The mixtures have been reported to have antiviral, antifungal, anticancer, antibacterial, and anti-inflammatory properties.[2] These bioactivities can be attributed to the presence of terpenes, such as limonene, menthol, carvone, and thymol. Due to their high phenolic content and antioxidant activity, essential oils are often used for effective skin penetration with little systemic toxicity.[1] Essential oils are soluble in alcohol, ether, and lipids but are insoluble in water. They are generally liquids and colorless at room temperature, have a characteristic odor, and have relative densities of less than one.[3] However, challenges to their utilization include their hydrophobicity, instability, high volatility, and toxicity risks.[4] This indicates the need to develop a more stable delivery form, such as a the nanoemulsion drug delivery system. These thermodynamically stable systems are clear, transparent, and have high solubility.[3,5] Nanoemulsions are nanoscale dispersions of 2 immiscible fluids, such as water and oil, that are stabilized by adding appropriate emulsifiers, with sizes ranging from 20–200 nm. Several studies have shown that these preparations are kinetically stable heterogeneous systems compared to microemulsions.

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Nanoemulsions are unique due to their prolonged physical stability and lack of apparent flocculation and aggregation. The effectiveness and functional attributes of pharmaceutical formulations are being significantly increased through development of nanoemulsions for various drug delivery systems.[5] Bibliometric analysis has emerged as a powerful tool for assessing the evolution of study trends in various fields, including essential oil nanoemulsions. Using a set of documents, this approach can quantitatively find trends and patterns. In addition, it offers a methodical and repeatable evaluation procedure that may assess the overall profile of a study area.[6] The value of the approach is in its ability to measure the quality and to evaluate the progression of a topic by comparing results across institutions, documenting changes, identifying focal areas, and forecasting new studies.[7] Numerous bibliometric analysis have been conducted, including investigations on materials, microemulsion, nanoencapsulation, chemical engineering, and manufacturing nanocrystalline cellulose. Despite the existing literature, there is no information on the progress in bibliometric analysis in the field of essential oil nanoemulsions. Therefore, this study aims to conduct a bibliometric analysis of scientific articles on essential oil nanoemulsions published between 2015 and 2025. The results are expected to serve as a source of knowledge to advance studies on formulations for essential oil nanoemulsions.

Materials and Methods

Search strategy and data retrieval

The Scopus database was used to carry out an extensive search for relevant papers. The data search was carried out on April 30, 2025, using an author keyword, abstracts, and titles search strategy, during the period from January 1, 2015 until April 30, 2025. The search query used the following string: (TITLE-ABS-KEY (“essential oil” nanoemulsion) AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , “ar”)) AND (LIMIT-TO (LANGUAGE , “English”)) AND (LIMIT-TO (SRCTYPE , “j”))). Only studies published in peer-reviewed journals between 2015 and 2025 were included. Letters, notes, editorials, documents in press, and other kinds of publications were excluded. Conference proceedings, publications, and book chapters were also excluded, and English was selected as the publication language.

Data extraction

The total number of retrieved publications was taken from the Scopus database on the same search day to prevent any potential bias derived from daily update of the database. For processing and bibliometric analysis, the acquired data were extracted in a value format with commas separated.

Bibliometric analyses and visualization

The annual publications, total number of citations, and publication type were all calculated using Microsoft Office Excel 365. A study of trends in the scientific literature was analyzed and visualized using the latest version of the Visualization of Similarities (VOSviewer 1.6.20) (www.vosviewer.com).[8] The retrieved articles were loaded into VOSviewer to conduct the cluster analysis and network visualization mapping. Relationships between nations, authors, cited authors, journals, and keywords were shown visually. Furthermore, the distribution of terms was shown using cluster density maps. Author keywords were further examined using biblioshiny software, a component of the bibliometrix package.[9] By examining trends in author keyword usage, this method provided information to identify focus areas and commonalities. All the retrieved words were manually reviewed during the author keyword analysis process, and a thesaurus file was used to combine synonymous or related keywords into a single related word. VOSviewer and biblioshiny could perform such an alteration, which could improve the precision and validity of the analysis. The flowchart methodology is provided in Figure 1.

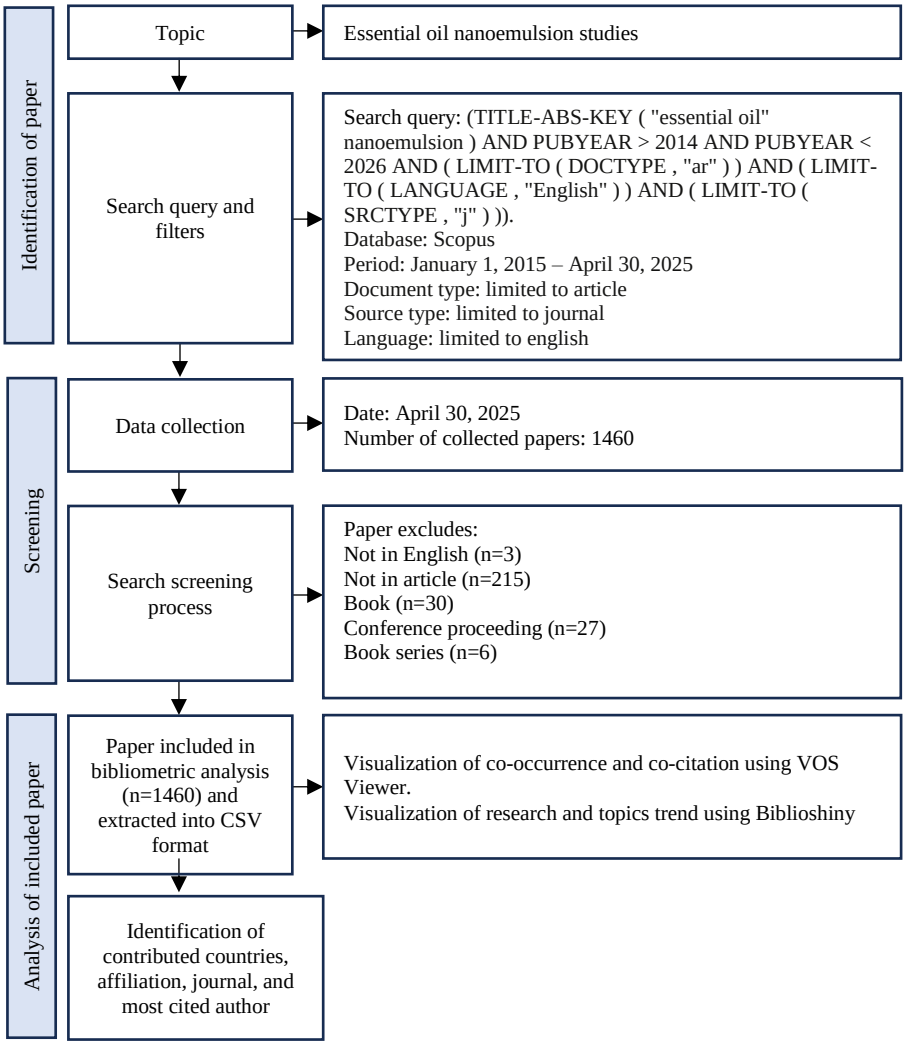

Figure 1: Flowchart of study methodology

Results and Discussion

Essential oils are complex volatile mixtures commonly found in aromatic plants. Their composition varies depending on the species of plant extracted.[1] Due to their many applications, main constituents, and unique qualities, essential oils have become increasingly popular in a variety of sectors in recent years, including aromatherapy, food flavouring, and natural pharmaceutical treatments.[10,11] As a result, numerous properties have been investigated, including their antioxidant,[12] antiviral,[13] antibacterial,[14] antifungal,[15] antitumor,[16] and anti-inflammatory qualities.[17] Essential oils typically consist of around 20 to 60 constituents in varying quantities, while some can contain over 300 distinct chemicals. However, 2 or 3 compounds are usually present in large proportions (20−70%).[18] For instance, myristicin is the major constituent of *Myristica fragrans* (32.00%) and L-borneol (20.34%) of *Lavandula dentata.*[19] The primary constituents of essential oils are often those that confer their biological activities. However, minor substances can also be crucial for bioactivity, either by enhancing the actions of predominant components or through additive or antagonistic effects.[18] Essential oils present certain problems, including hydrophobicity, instability, high volatility, and toxicity risks, which can be obstacles to

their utilization.[4] Therefore, essential oils need to be formulated into a more stable preparation form, such as the nanoemulsions increasingly used in drug delivery systems.[3]

Publication trend

Since their discovery, essential oil nanoemulsions have been the subject of a growing number of scientific publications every year. Using the selected search terms, from January 1, 2015 to April 30, 2025, a total of 1460 publications on the subject of essential oil nanoemulsions were found. The number of articles published each year was increasing steadily. The peak in publication output occurred in 2024, signifying a period of heightened study activity (Figure 2). Nanoemulsions are currently the subject of many investigations because of their potential thermodynamic stability. Investigators have begun to examine their special characteristics, such as their nanoscale droplet size, which usually ranges from 20 to 200 nm. This era signals a change in perspective toward the possible use of nanoemulsions, specifically in the food and pharmaceutical sectors. Drug delivery systems using nanoemulsions have developed into an advanced and important technology for effectively delivering medications to a specific physiological location. They also offer better distribution and protection through bioactive constituent encapsulation compared to the majority of traditional dosage forms.[5]

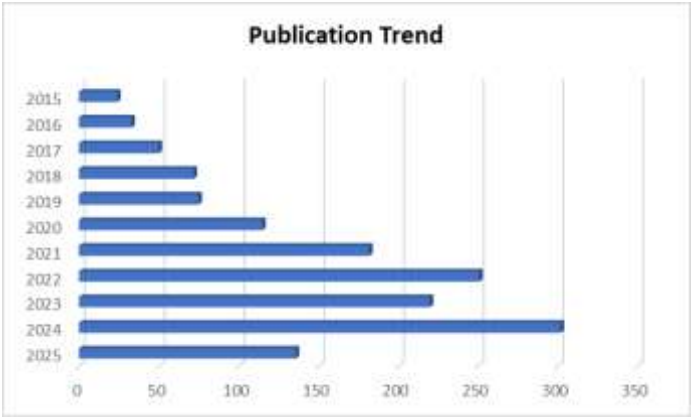

Figure 2: Number of essential oil nanoemulsion articles.

Distribution of articles by country and affiliation

More than 150 institutions participated in this study, and the institutions with the most participants were the National Research Centre, with 62 publications, followed by the Agricultural Study Center, with 39, and Fasa University of Medical Sciences, with 38 (Figure 3B). All the countries with the most productive affiliations were located in the Middle East. According to the study of the regional distribution of publications retrieved, investigators from Iran contributed the most papers, with 279 documents (19.3%), followed by China (16.2%) and India (14.2%). Other notable contributors were Brazil and Middle Eastern countries like Egypt and Saudi Arabia (Figure 3A). This global distribution indicates widespread scientific interest in essential oil nanoemulsions across diverse economic and academic regions.

Document by subject area

The distribution of documents on essential oil nanoemulsions by subject area, as indexed in the Scopus database between 2015 and 2025, is presented in Figure 4. The majority of publications fell under "Agricultural and Biological Science" (43.36%), reflecting the natural origin of essential oils and their primary association with botanical, ecological, and agricultural studies. A substantial proportion of documents also originated from "Pharmacology, Toxicology, and Pharmaceutics" (19.38%), underscoring the growing interest in translating essential oil nanoemulsions into viable drug delivery systems through advanced formulation techniques and optimization processes. Essential oils have been studied for more than 60 years, but significant interest has emerged in recent decades due to a desire to rediscover natural medicines. Essential oils have been used for millennia, even in prehistoric times, because of their therapeutic qualities and for ceremonial and medicinal purposes. These oils were produced from plant raw materials using a range of techniques that were honed over centuries.[4]

Names of authors and number of publications

Among the published authors, a total of 7 authors each published at least 20 articles on the subject of essential oil nanoemulsion. The most productive author with the most articles (36 publications) was M. Osanloo from Fasa University of Medical Science in Iran. Nanotechnology and nanoscience were the main focus of the studies. However, D. J. McClements of the University of Massachusetts Amherst in the United States was the author most frequently mentioned in this field (Table 1).

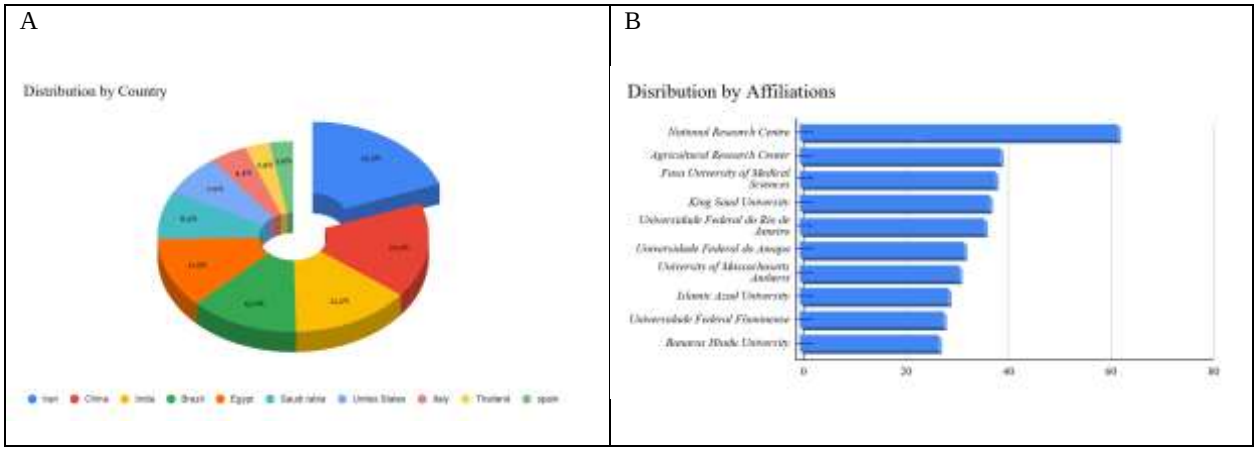

Figure 3: Distribution of articles by (A) country and (B) institutional affiliation

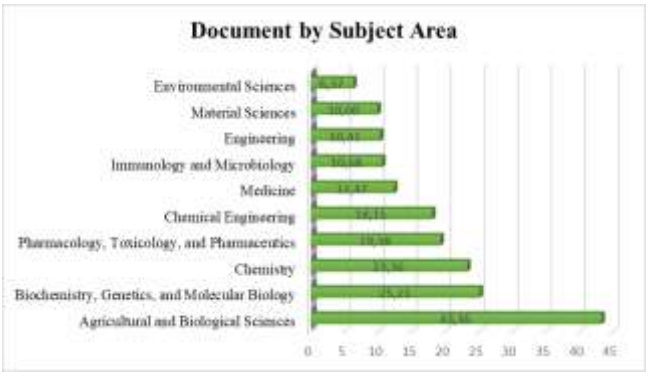

Figure 4: Subject area classification of publications.

With 179 papers that were cited 21,437 times, the authors published the most articles in 2024. Also studied were food nanotechnology, oral delivery systems, gastrointestinal destiny of nutrients and nutraceuticals, natural ingredients, food biopolymers and colloids, and plant-based foods. Among the publications was an article entitled "Potato Protein-based Nanoemulsion of Oregano (*Origanum vulgare*) Essential Oil: A Promising Strategy Against Escherichia coli O157:H7". In this study, McClements's team successfully developed nanoemulsions with distinct physicochemical properties using potato protein to encapsulate essential oils.[20]

Distribution of the number of articles in journals

In addition to high-impact generalist journals frequently cited in the field, Table 2 presents journals that specifically published the highest number of original study articles on essential oil nanoemulsions, with the International Journal of Biological Macromolecules leading in output (8.06% cited), followed by Industrial Crops and Products (4.83% cited), and Food Chemistry (3.76% cited).

Table 1: Top 10 most productive authors

Rank	Name of Author	Documents	Citations	Total Link Strength
1st	Osanloo, M.	36	1,550	233
2nd	Das, S.	25	2,489	425
3th	Fernandes, C.P.	24	1,547	7
4th	Dubey, N.K.	23	15,304	409
5th	Rafati, H.	22	1,310	218
6th	Maggi, F.	21	16,369	16
7th	McClements, D.J.	21	147,440	273
8th	Chaudari, A.K.	19	1,666	326
9th	Carvalho, C.J.T.	17	5,692	14
10th	Dwivedy, A.K.	17	2,194	332

These journals primarily focus on the interface of food science, biopolymers, and natural product applications. Journals like Journal of Drug Delivery Science and Technology and Pharmaceutics reflect the pharmaceutical and delivery system aspect of the topic, while Scientific Reports and Molecules represent broader multidisciplinary contributions. This pattern of journal distribution confirmed the interdisciplinary nature of essential oil nanoemulsion studies, with outputs concentrated in both domain-specific journals and broader scientific platforms, depending on the intended audience, application focus, and study maturity.

The majority of essential oil nanoemulsion reports were published in molecular, food, and pharmaceutical publications. With 90 publications, the International Journal of Biological Molecules was the most active in the subject of essential oil nanoemulsion (Impact Factor (IF) 2023 = 7.7). The journals with the second-highest number of publications were Industrial Crops and Products (IF = 5.6), and Food Chemistry (IF = 8.5) (Table 2). On the subject of essential oil nanoemulsions, the study articles published in this journal had a significant scientific impact. Reports in the field of food and pharmaceuticals are developing rapidly because, among other reasons, nanoemulsions enable more efficient delivery and protection of essential oils, allowing bioactive constituents to reach their site of action more effectively.[21]

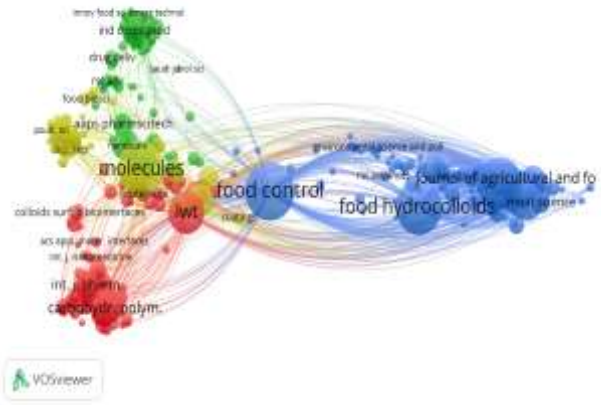

Figure 5: Co-citation network of journals.

Frequency of keywords

Keywords are crucial in academic publications because they represent study hotspots and trends across all study areas. In the current study, two different bibliometric techniques were used to examine the co-occurrence of author keywords in the retrieved papers. The keywords most often used were nanoemulsion (20.03%), followed by essential oil (16.62%), antibacterial activity (2.49%), and antimicrobial activity (2.32%) (Table 3). Based on this data, the pharmacological activities explored most frequently were antibacterial and antimicrobial. Some of the antibacterial activity studies focused on essential oils from the *Origanum* species. *O. majorana* L. was found to reduce the formation of bacterial clusters in *Haemophilus influenzae* and *H. parainfluenzae* biofilms analyzed by scanning electron microscopy.[22] Due to their hydrophobic nature, essential oils probably affect the lipids of the mitochondria or bacterial plasma membrane, functionally impairing these structures by promoting proton permeability, as determined by membrane electrical conductivity tests.[23] Finger citron essential oil induced alterations in the morphology of *Escherichia coli* and *Staphylococcus aureus*.[24] Mustard essential oil resulted in damage to the bacterial cell membranes of *Salmonella enterica* serovar Typhi and *Escherichia coli*, resulting in loss of the cellular structures necessary for the microorganism's survival through ATP depletion and decreased intracellular pH.[25] Thymol-loaded nanoemulsions showed significant free-radical scavenging activity, which could reduce the tissue damage caused by oral infections.[26] *E. coli* and Thymol were included in the author keyword analysis, and this was an emerging theme based on biblioshiny visualization analysis (Figure 6D).

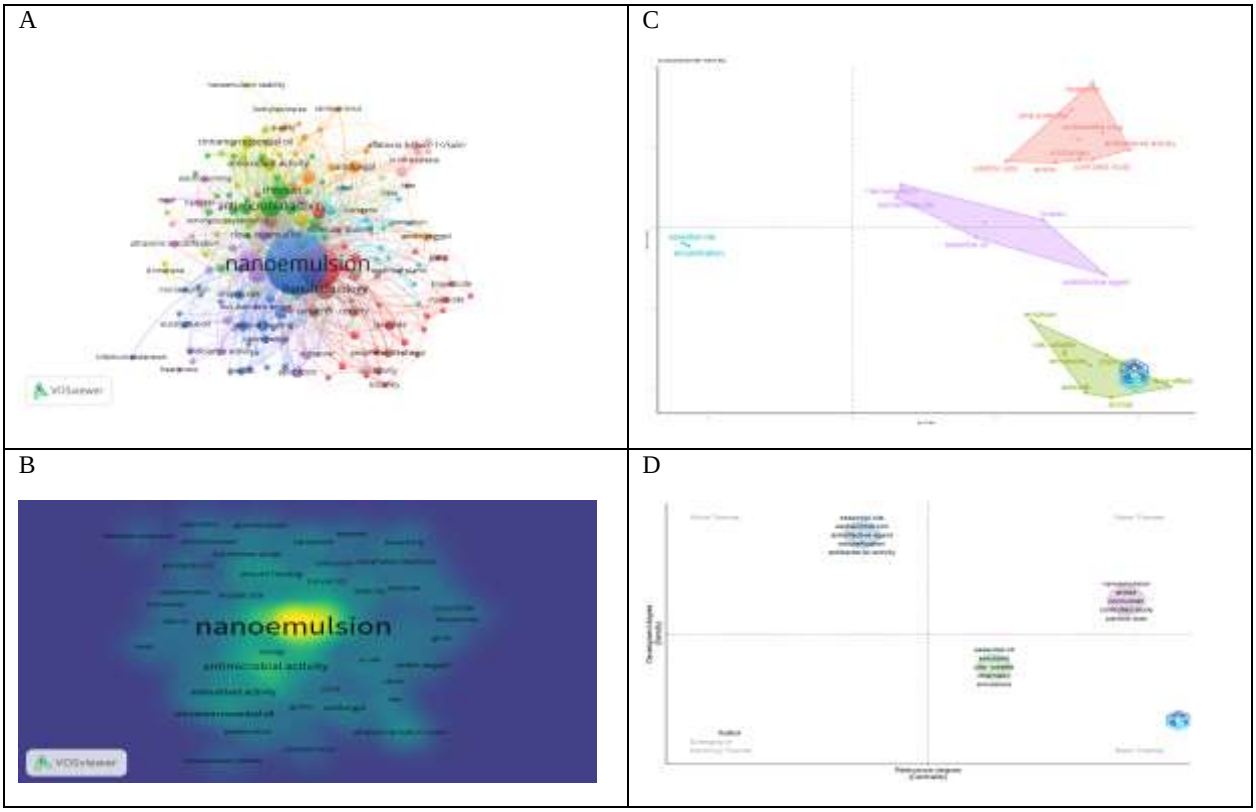

Figure 6: Keyword analysis through co-occurrence mapping (A), density visualization (B), conceptual structuring (C), and thematic mapping showing thematic depth and topic evolution (D).

Analysis of the co-citation network

The identified co-citation networks were grouped by VOSviewer into 4 main clusters (Figure 5) corresponding to dominant study areas such as food science, forming the backbone of the studies on nanoemulsions as food delivery vehicles and bioactive carriers. Nanoemulsions can be used to improve the quality and shelf life of various foods, as well as for packaging, biodegradable coating, and antibacterial coating. A review of the nanotechnology, materials, and methods used for creating and manufacturing food and nutrition-related nanoemulsions also provided the analytical methods used for characterizing nanoemulsions, followed by a discussion of the uses and restrictions of nanoemulsions in the food sector.[27]

Keyword co-occurrence network

VOSviewer analysis grouped the identified author keywords into 12 clusters reflecting the primary study interest and focus of the recovered documents (Figure 6A). The node highest frequency keyword, nanoemulsion was located and highlighted in the middle of density map (Figure 6B). The selected keywords were grouped into four conceptual groups (Figure 6C). Nanoemulsion, controlled study, and particle size were clustered together (Figure 6D). This showed the formulation strategies, delivery system design, and polymeric stabilization techniques used in pharmaceutical applications of essential oil nanoemulsions. There is a growing demand for essential oils due to their many health benefits, and essential oil nanoemulsions are among the most dependable and environmentally friendly technologies. However, because essential oils are so volatile, investigators still find it difficult to formulate essential oil-based nanoemulsions. During the different stages of formulation, these oils can lose part of their beneficial constituents due to their sensitivity to heat and mechanical stress. Therefore, when developing essential oil nanoemulsion synthesis conditions, it is important to choose the appropriate emulsifier, oil-to-surfactant ratio, processing duration, and temperature, among other factors. In addition, high-energy procedures require less surfactant and shorter processing times than low-energy processes. High-energy techniques also offer excellent stability and smaller droplets, but their disadvantages include high energy requirements, high cost, inability to scale for commercial use, and loss of bioactivity.

Table 2: Top 10 most active publishing journals

Rank	Source Title	CiteScore*	Citations	Documents	%Cited
1st	International Journal of Biological Macromolecules	13.7	191,042	90	8.06
2nd	Industrial Crops and Products	9.5	48,754	54	4.83
3th	Food Chemistry	16.3	167,849	42	3.76
4th	LWT	11.8	77,348	40	3.58
5th	Molecules	7.4	228,683	34	3.04
6th	Journal of Drug Delivery Science and Technology	8.0	27,031	28	2.51
7th	Journal of Food Measurement and Characterization	6.0	10,968	27	2,41
8th	Food Control	12.2	33,786	24	2.42
9th	Pharmaceutics	7.9	70,829	23	2.15
10th	Scientific Reports	7.5	661,612	22	2.06

*CiteScore 2023 is based on the number of citations to peer-reviewed papers over a 4-year period (2020−2023).

Table 3: Top 10 most-used author keywords

Rank	Study Area	Documents	%Publication
1st	Nanoemulsion	587	20.03
2nd	Essential oil	487	16.62
3th	Antibacterial activity	73	2.49
4th	Antimicrobial activity	68	2.32
5th	Nanotechnology	64	2.18
6th	Stability	46	1.57
7th	Chitosan	45	1.54
8th	Antioxidant	43	1.47
9th	Active packaging	29	0.99
10th	Cinnamon essential oil	27	0.92

Low-energy techniques are not regarded as environmentally friendly. Therefore, when formulating essential oil nanoemulsions, a thorough analysis of processing factors and their impact on overall stability and performance must be taken into consideration.[28]

Various types of biopolymers, including proteins, lipids, and carbohydrates, are well-known wall materials used as surfactants and emulsifiers in the creation of nanoemulsions. Functional oils have been successfully encapsulated using wall materials like small-molecule surfactants (such as Tweens and Spans), phospholipids (such as lecithins), proteins (such as whey proteins), polysaccharides (such as chitosan), and/or their mixtures. Biopolymers are generally regarded as safe (GRAS) and are recognized as ecologically friendly biomaterials that also play important structural and nutritional roles in humans. These are therefore very popular in the production of numerous innovative functional foods. As emulsifiers or wall materials, carbohydrates, lipids, and other biodegradable food-grade biopolymers have generally achieved great success in the food and pharmaceutical industries. Among these biopolymers, polysaccharides, lipids, and proteins are widely used biomaterials due to their abundance in nature, reasonable price, excellent biodegradability and biocompatibility, and non-toxic and non-reactogenic character.[29] Multidisciplinary studies, serving as a thematic intersection between the pharmaceutical and food fields, show the translational nature of essential oil nanoemulsion studies in specialized or regional applications, but the relatively sparse and peripheral nature of this cluster suggests context-specific study streams.

Trend Topics

The essential nanoemulsion trend topic in 2025 was nanoclays (Figure 7). One of the studies used acoustic cavitation-based probe ultrasonication to create nanoclay-essential oil hybrid nanostructures

for controlled release antibacterial action. These studies shed light on the possible use of nanoclay as an adsorbent or nanocarrier and on the combination of nanoclay with essential oils for efficient drug delivery.[30] Other studies in the field of food packaging focused on the incorporation of nanoclay with a mixture of clove essential oil, which led to a significant change in the mechanical properties of the bionanocomposites and an increase in their antimicrobial activity against the bacteria *Lactobacillus sakei*, *Listeria monocytogenes*, and *E. coli*.[31]

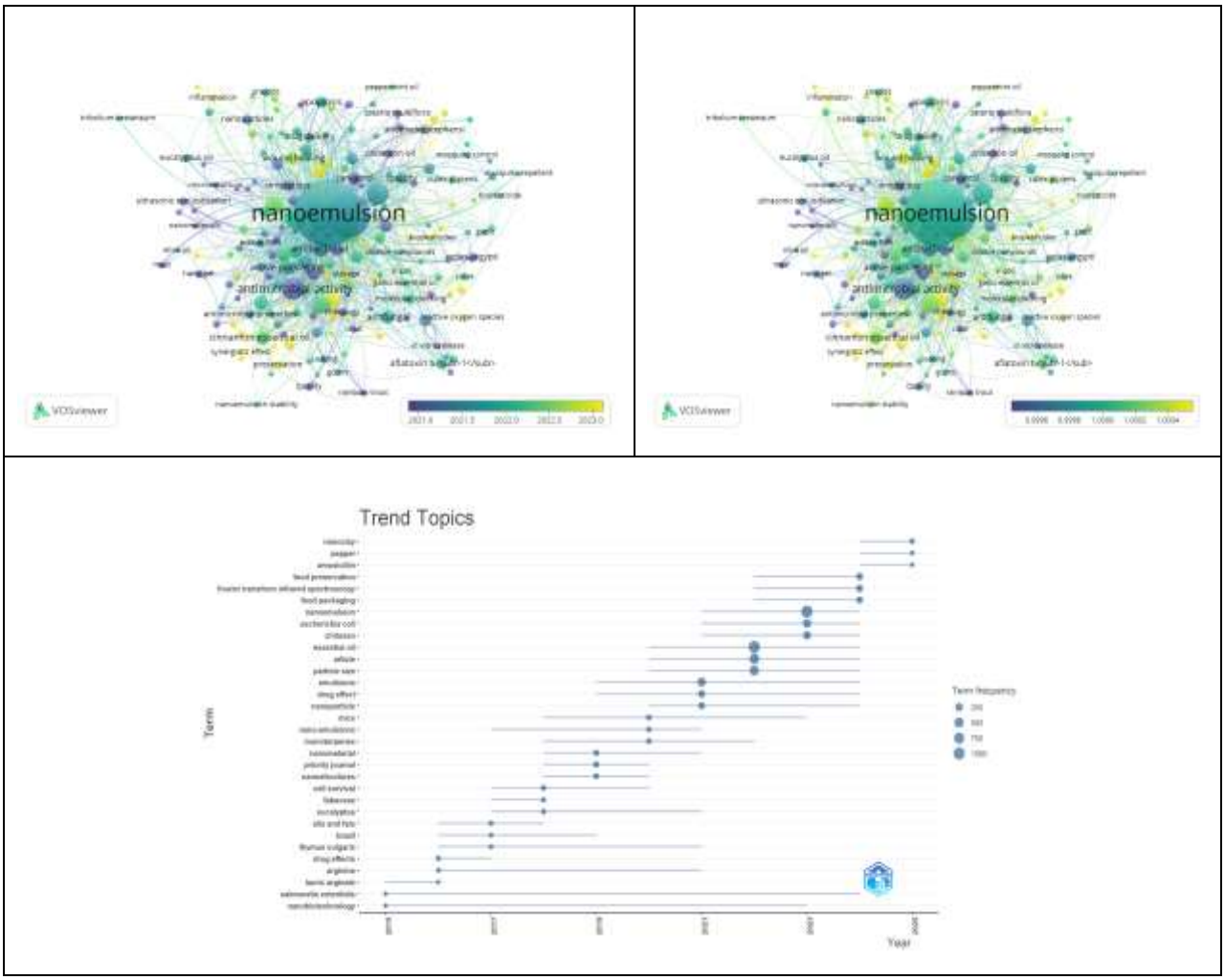

Figure 7: Trend topic visualizations.

The current study is the first to examine the study trends in the field of essential oils and nanoemulsions, despite the small number of published bibliometric analyses regarding essential oil nanoemulsions. The examination of these papers in the PubMed core collection database was the primary focus of earlier investigations. In this study, the authors took into account Scopus, the largest reliable database that offers sophisticated search capabilities, together with abstracts and citations of peer-reviewed literature. Additionally, this study used 2 bibliometric methods to examine the documents obtained, and the linked keywords were merged into a VOSviewer thesaurus file. By preventing repetition of the same terms in the visualization map and by standardizing the results, this method could produce thorough and reliable results.

Conclusion

In conclusion, a Scopus data search of essential oil nanoemulsion found 1460 published documents and was followed by a bibliometric analysis using VOSviewer and biblioshiny software. This provided a bibliometric analysis of the reviews and papers published in this field, including citations, publishing journals, regional distributions, contributing authors, and the year of publication. The number of publications on this topic increased yearly, and the majority of these publications were study articles showing a strong interest in molecular, food, and pharmaceutical studies. The authors are confident that the analysis will aid academics in gaining a more systematic understanding of the distribution of scholarly resources, collaboration patterns, and study hot spots within the discipline.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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