Asian Journal of Medicine and Health Sciences Vol 8 Issue 2, November 2025

REVIEW ARTICLE

A Bibliometric Review of Holy Basil (*Ocimum tenuiflorum*) and its Therapeutic Potential in Dermatological Applications.

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Submitted: 23/09/2025. Revised edition: 15/10/2025. Accepted: 16/10/2025. Published online: 01/11/2025.

Abstract

Ocimum tenuiflorum (*O. tenuiflorum*), commonly recognised as Holy Basil or Tulsi, has garnered growing interest within the scientific and industrial communities due to its extensive phytochemical profile and diverse therapeutic properties. This bibliometric review examines global research trends concerning *O. tenuiflorum* from 2000 to 2024, utilising data from Web of Science (WoS) alongside bibliometric tools including VOSviewer and Biblioshiny. The analysis indicates a consistent increase in publication output, with India leading research contributions and notable inputs from the USA, Thailand, and other nations. Research clusters identify five principal thematic areas: traditional medicine, phytochemistry, pharmacology, nanotechnology applications, and dermatology. The plant's bioactive compounds, such as eugenol, ursolic acid, rosmarinic acid, and luteolin, exhibit significant antioxidant, anti-inflammatory, adaptogenic, anti-diabetic, and dermatological effects. Particularly in dermatology*, O. tenuiflorum* demonstrates promising roles in anti-ageing, skin barrier protection, acne management, and wound healing via mechanisms involving collagen synthesis, cytokine inhibition, and UV protection. This comprehensive bibliometric and phytochemical review underscores the versatile therapeutic potential of *O. tenuiflorum*, thereby supporting its development within cosmeceutical and pharmaceutical sectors, while also highlighting opportunities for further multidisciplinary research.
Keywords: *Bibliometric analysis, dermatology, Ocimum tenuiflorum, skin health, tulsi.*

Introduction

The trend of using natural products for skin health has gained significant momentum in recent years, reflecting a broader shift among consumers towards cleaner, safer, and more environmentally sustainable options. Currently, the natural skin care market revenue has skyrocketed to 28.71 billion USD, with a projected compound annual growth rate (CAGR) of 2.66% [1]. This movement includes a wide range of ingredients sourced from natural compounds, mainly plants, that are valued for their health benefits and therapeutic qualities. Due to their perceived effectiveness and milder characteristics, natural products are becoming increasingly popular compared to synthetic options, especially among health-focused consumers and younger generations who prioritise ethical sourcing and sustainability in their buying choices. Plant-based products such as cannabidiol oil, bakuchiol, marine algae, ginseng, and ashwagandha continue to be highly popular due to their anti-inflammatory, anti-oxidant, anti-microbial, and sebum-regulating properties, which assist in managing conditions such as eczema, psoriasis, and acne [2]. Other examples, like aloe vera, are also making a strong comeback due to their soothing, hydrating, and healing properties, making them ideal for calming irritation and redness without clogging pores [3].

Among the many natural botanicals gaining attention, *Ocimum tenuiflorum* (synonym of *Ocimum sanctum*), commonly known as holy basil or Tulsi, stands out due to its extensive medicinal properties and cultural significance, particularly in Indian traditions [4]. Studies have demonstrated its potential to address various health conditions, including diabetes, cardiovascular diseases, and stress-related disorders, reinforcing its reputation as an essential element of both traditional and modern medicine [4,5].

Traditionally, various parts of the plant have been used to treat skin problems as well as wounds, inflammation, and other ailments. In recent years, dermatological interest has grown in *O. tenuiflorum* adaptogenic, anti-inflammatory, and antioxidant properties, suggesting potential benefits for acne, atopic dermatitis, psoriasis, wound healing, and skin ageing. For example, recent clinical researchers now incorporate *O. tenuiflorum* into botanical nutraceuticals for acne and in cosmeceutical anti-ageing applications. A 2020 study found that an *O. tenuiflorum* extract (rich in rosmarinic acid) delivered by nanocarriers significantly enhanced skin retention by 27.1 ± 1.8%, with sustained release of rosmarinic acid over 24 hours while inducing no irritation and not permeating deeply through the skin [6]. A recent review by Bhattacharjee and colleagues highlighted that the nanotherapeutic delivery of ursolic acid from *O. tenuiflorum* represents a paradigm shift in skincare, bringing forth a promising molecular strategy to combat skin ageing [7]. Similarly, pre-clinical models show that the plant extracts accelerate wound closure and increase collagen and antioxidant enzymes in healing tissue [8]. Furthermore, studies also highlighted its effectiveness in treating common skin problems like acne, irritation, and early ageing, making it a popular ingredient in cosmetic products [2,9,10]. The plant's ability to fight skin pathogens, especially *C. acnes*, along with its potential to improve wound healing, highlights its importance in dermatological uses [9].

Studies concerning *O. tenuiflorum* have been growing over the years, demonstrating the rising interest in this plant in multiple industries. Some review articles have been recently published regarding this plant, focusing on the phytochemicals and their numerous pharmacological activities, including its therapeutic potential against COVID-19 [5,11]. However, a document that collates the most important and relevant studies, as well as demonstrates the main trends and developments concerning *O. tenuiflorum,* is necessary. Bibliometric analysis has now become widely popular for researchers as a statistical method to quantify, analyse and evaluate scientific publications [12]. This methodology facilitates the identification of various principles, including the research trends within a specific domain [12,13]. Researchers are able to discern notable research gaps, emerging topics, and influential studies through the analysis of publication patterns and citation networks. This review will focus on the research trends of *O. tenuiflorum* and its potential application in the skin care industry.

Materials and methods

Research design and data collection procedure

A bibliometric analysis was performed using the Web of Science© (WoS) databases (www.webofknowledge.com) to investigate the worldwide literature concerning *O. tenuiflorum*. Web of Science (WoS) was selected for its selective coverage and is considered a scholarly source for measuring scientific output, identifying scope, coverage, and data volume [13]. The terms 'holy basil', OR 'ocimum sanctum', OR '*ocimum tenuiflorum'*, OR Tulasi, OR Tulsi, were used in the "topic item", which includes the title, abstract, keywords, and keywords plus of articles indexed in the databases. As shown in Figure 1, a search was performed to include the last 24 years (2000–2024), with a total of 4,210 scientific articles being retrieved (WoS = 1,491). From the data, we extracted the number of publications, categories, the top ten most cited papers, the top ten most productive authors, countries, and the 50 most frequent keywords. Additionally, the data of the most productive countries were processed using the VOSViewer software (Java version build 1.8.0_461-b11) in order to gather information concerning international collaborations among nations, and the 50 most frequent keywords were processed to evaluate the research focus on *O. tenuiflorum*.

Additionally, Biblioshiny was used to identify the topic trends over the 24 years. Specifically, the visualisation of keyword trends and thematic evolution plots reveals the trajectory and importance of certain topics within the dataset. Then the users can interpret thematic maps that categorise topics by their maturity and significance in the domain, gaining insights into the dynamic development of the field.

Bibliometric review of *O. tenuiflorum* from the past 24 years

Global paper publication trend and categories

The annual number of publications serves as an intuitive indicator of the pace of development and change within specific fields [14]. The statistics pertaining to *O. tenuiflorum*-related articles demonstrate that the annual volume has remained comparatively modest, with all years reporting fewer than 200 articles. The trend exhibited a gradual increase from 2000 to 2005. Subsequently, the annual number of publications experienced steady growth, rising from 17 articles in 2006 to 69 in 2019. Following this period, there was a marked increase in publication numbers from 2020 to 2024, with a publication count exceeding 125 articles annually after 2020. As of December 2024, a total of 154 articles have been published (see Figure 2). The observed upward trend clearly indicates a growing scholarly interest in *O. tenuiflorum*.

The analysis of research areas serves as a valuable instrument for identifying gaps within the scholarly domain [12,13]. An examination of the WoS database reveals that, at present, the articles are associated with a total of 139 entries within the WoS Categories. Figure 3 illustrates the leading categories, namely Pharmacology & Pharmacy (198), Plant Sciences (197), Food Science & Technology (135), Medicinal Chemistry (113), and Multidisciplinary Chemistry (98). This distribution indicates that research concerning *O. tenuiflorum* encompasses multiple disciplines, underscoring its multidisciplinary and interdisciplinary characteristics. According to these research areas and grouped publications, it was concluded that the predominant topics are linked to extensive investigations in medicinal chemistry and molecular biology, thereby reflecting a robust multidisciplinary engagement in both traditional uses and contemporary biomedical applications.

Authors and affiliations publication

Within the domain of *O. tenuiflorum*, the WoS has documented a total of 5,285 authors and 1,731 affiliated institutions. Among these top three authors, Shanmugam Rajeshkumar emerges as a leading figure with 11 publications and 73 citations, indicative of sustained scholarly output, although with a moderate citation rate (**Table 1**). The consistent contributions imply ongoing engagement in investigating various biological or pharmacological aspects of *O. tenuiflorum* [15–17]. Similarly, Balaji Raju also exhibits significant academic productivity, with 9 publications and 49 citations, reflecting a focused yet potentially less widely cited body of research. In contrast, Kusindarta Dwi Liliek, despite matching Balaji in publication count (9 records), stands out because of a significantly higher citation count (255 citations), indicating a strong impact in research. This high citation-to-publication ratio suggests that Kusindarta's work may have tackled a notably novel or clinically relevant aspect of *O. tenuiflorum*, possibly in immunological or therapeutic fields [17,18]. Such a pattern highlights the importance of both publication volume and research significance in progressing scientific discussion.

On an institutional level, the Council of Scientific and Industrial Research (CSIR) India stands out as the most active and influential organisation, with 89 publications and a total of 2,868 citations (Table 1). This showcases CSIR's key contribution to India's phytopharmaceutical and ethnobotanical fields, supported by its extensive network of research centres across the country [19,20]. The Indian Council of Agricultural Research (ICAR) follows closely with 57 publications and 1,232 citations, underlining its vital role in agricultural research and plant-based therapies, including the cultivation, genetic improvement, and analysis of bioactive compounds in *O. tenuiflorum* [21–23]. The third leading institution, CSIR–Central Institute of Medicinal and Aromatic Plants (CIMAP), has contributed 48 publications with 1,128 citations, highlighting the importance of India's national research agencies in producing high-impact work. As a dedicated branch of CSIR, CIMAP has likely made significant strides in standardising, profiling bioactivity, and supporting industrial applications of *O. tenuiflorum*. The impressive citation counts from both CSIR and CIMAP emphasise their crucial role in not only basic research but also in translating traditional knowledge into modern pharmacology.

These findings collectively emphasise the geographical and institutional clustering of *O. tenuiflorum* research within India, driven by a combination of prolific individual researchers and government-supported institutions. The strong output and impact from these authors and affiliations reflect both national interest and the global significance of *O. tenuiflorum* as a medicinal plant with considerable therapeutic potential.

National publication and collaboration analysis

According to Table 2, the global research landscape on *O. tenuiflorum* is prominently shaped by contributions from three leading countries, India, the United States, and Thailand, each demonstrating distinct strengths in publication volume and citation impact. Unsurprisingly, India leads the field with an impressive 1,074 publications and 23,896 citations, firmly establishing itself as the centre of *O. tenuiflorum* research. This dominance reflects India's deep-rooted cultural, medicinal, and scientific engagement with the herb, widely known in the region as Tulsi. Indian research covers a broad range, from pharmacological and agronomic studies to clinical and therapeutic applications, largely driven by major national research organisations such as the Council of Scientific and Industrial Research (CSIR) and the Indian Council of Agricultural Research (ICAR). The high citation count indicates that Indian research is both fundamental and widely referenced internationally, making a significant contribution to the global knowledge base.

The United States, despite producing a comparatively smaller number of publications (89 records), has amassed 1,899 citations, reflecting a high citation-per-publication ratio. This suggests that American research, although more selective, tends to exert greater influence and frequently focuses on specific therapeutic mechanisms, clinical applications, and the incorporation of *O. tenuiflorum* into nutraceuticals, stress management strategies, and functional foods [24–26]. The United States presumably plays a crucial role in translating traditional knowledge into evidence-based health solutions compatible with Western healthcare systems. Thailand occupies the third position with 81 publications and 1,547 citations, highlighting Southeast Asia's active contribution to the advancement of research on *O. tenuiflorum*. Thai research often seeks to bridge traditional herbal practices with contemporary scientific validation, with particular emphasis on anti-microbial, anti-oxidant, and dermatological applications [27–29]. The country's research initiatives are further supported by national policies aimed at herbal medicine development and biodiversity conservation, with *O. tenuiflorum* frequently featured in integrated healthcare and cosmeceutical studies.

Apart from the country's publication and citation count, the collaboration network between countries is also analysed (Figure 4). The VOSviewer co-authorship network visualisation illustrates the international collaboration landscape in *O. tenuiflorum* research. The size of each node reflects a country's total publication output, while the thickness of connecting lines (edges) indicates the strength of collaborative links [30]. The colour groupings represent clusters of countries that frequently co-publish together [30].

Consistent with its predominant role in *O. tenuiflorum* research, India occupies the central and most prominent position within the network. Its extensive and numerous co-authorship connections, particularly with the United States of America (USA), Thailand, Saudi Arabia, and South Korea, underscore its significance as a collaborative hub. The substantial linkages among India, Saudi Arabia, the USA, and South Korea indicate a notably robust bilateral research relationship. Thailand also exhibits strong collaborative ties, notably with India and the USA, demonstrating active engagement in international research networks, often centred on anti-microbial and cosmetic applications. Although the United States has a smaller volume of publications, it sustains strong co-authorship relations with principal nations such as India, Thailand, and South Korea. Additionally, Saudi Arabia, Pakistan, Bangladesh, and Malaysia form a dense cluster with moderate link strengths among other countries, reflecting regional collaboration patterns potentially driven by shared ethnobotanical interests and institutional partnerships. Overall, the network highlights India's central coordinating role, with Saudi Arabia, the USA, and South Korea serving as key nodes in promoting international collaboration. This structure indicates a collaborative environment that integrates traditional knowledge, regional biodiversity, and modern scientific methods to enhance the global understanding of *O. tenuiflorum's* health benefits.

Publication citation and research field

Table 3 shows the citation profile of the ten most frequently cited papers in *O. tenuiflorum* research, underscoring significant themes and the evolving scientific interest in this medicinal plant. A noteworthy observation from this selection is the predominance of studies related to nanotechnology, which constitute six of the top ten publications, thereby indicating a robust connection between green synthesis methodologies and the biomedical applications of *O. tenuiflorum* [31–33]. The most frequently cited investigation, titled "Biosynthesis of silver nanoparticles using *Ocimum sanctum* (Tulsi) leaf extract and screening its anti-microbial activity" (with 483 citations, published in 2011), along with the second most cited publication (with 476 citations, published in 2010), both underscore the green synthesis of silver nanoparticles (AgNPs)

[33,34]. These research works highlight the attractiveness of *O. tenuiflorum* as a sustainable, plant-derived reducing and capping agent possessing robust anti-microbial properties. The consistent publication of such scholarly articles in esteemed journals such as the Journal of Nanoparticle Research and Colloids and Surfaces B-Biointerfaces exemplifies this interdisciplinary focus, bridging botany, materials science, and microbiology.

Further articles like the 2015 Journal of Saudi Chemical Society and 2017 Scientific Reports continue to affirm that green nanotechnology remains central in *O. tenuiflorum's* high-impact research [35,36]. Beyond nanoscience, traditional pharmacology is well represented. The 2003 Journal of Ethnopharmacology study (327 citations) compares the hypoglycaemic activity of *O. tenuiflorum* with other Indian medicinal plants in diabetic rats, showing ongoing interest in its metabolic role [37]. The 2000 Phytomedicine study (261 citations) identifies cyclooxygenase-inhibitory and anti-oxidant compounds, unveiling anti-inflammatory mechanisms [26]. Another significant study (260 citations, Plant Science, 2004) investigates the effect of heavy metal stress (chromium) on the physiological and biochemical parameters of *O. tenuiflorum*, including eugenol biosynthesis [20]. This reflects interests in ecological and agricultural research concerning how environmental conditions impact the plant's phytochemical profile and therapeutic potential. Further broadening the metabolic application theme, the 2011 BMC Complementary and Alternative Medicine paper (235 citations) assesses α-amylase inhibition, positioning *O. tenuiflorum* as a promising anti-diabetic agent through enzyme inhibition pathways [38]. A 2017 article concerning carbon dots synthesised from Tulsi for the purposes of detecting Pb^{2+} ions and live-cell imaging (Sensors and Actuators B: Chemical, cited 324 times) highlights *O. tenuiflorum's* increasing significance in bioimaging and environmental sensing, further extending its applications beyond conventional phytotherapy [35]. Notably, while all highly cited studies encompass diverse fields, they consistently emphasise *O. tenuiflorum's* biochemical richness, ecological resilience, and compatibility with contemporary scientific methodologies. These attributes have positioned it not merely as a medicinal plant but also as a valuable bioresource platform for nanoscience, pharmacology, and environmental biotechnology.

Keywords and trends analysis

To better understand researchers' current interests, a keyword analysis was also employed as a strategy to gain an overview of the trends related to *O. tenuiflorum*. The WoS database categorises keywords into two fields, author keywords (AKs) and keywords plus (KP), both of which are significant in bibliometrics [12]. Here, we focus only on the most cited AKs to identify the key trends highlighted by authors (Figure 5).

The co-occurrence network of author keywords in *O. tenuiflorum* research, visualised through VOSviewer, reveals a rich and interconnected thematic landscape shaped by both traditional and modern scientific approaches [30]. The most prominent terms, *Ocimum sanctum*, *Ocimum tenuiflorum*, antioxidant, Tulsi, holy basil, eugenol, and essential oil, highlight the centrality of the plant's identity, phytochemical composition, and its widely studied anti-oxidant properties.

The network reveals five major thematic clusters with strong interconnections. Red Cluster (traditional medicine & bioactivity) connects keywords such as medicinal plants, Ayurveda, molecular docking, phytochemicals, diabetes, and COVID-19. It highlights research linking *O. tenuiflorum* to traditional medicine and modern applications like computational pharmacology, anti-diabetic effects, and COVID-19. The combination of conventional uses with molecular studies shows active exploration of *O. tenuiflorum* for therapeutic leads through in silico modelling and ethnomedicine-based drug development. Green Cluster (phytochemistry & essential oils), centred around holy basil, eugenol, essential oil, *Lamiaceae*, methyl eugenol, and rosmarinic acid, this cluster highlights the chemical profiling and bioactivity screening of specific phytoconstituents. The strong link between phytochemicals and bioactivity highlights ongoing efforts to isolate compounds responsible for anti-oxidant, anti-inflammatory, and anti-microbial effects.

With keywords like silver nanoparticles, green synthesis, anti-bacterial activity, anti-microbial activity, plant extract, and nanoparticles, Blue Cluster (Nanotechnology & Antimicrobial Research) is aligned with the green nanotechnology trend. The prominence of green synthesis shows ongoing interest in *O. tenuiflorum* as a biogenic source for metal nanoparticle production, used in anti-microbial therapies and biosensing. Meanwhile, Purple Cluster (oxidative stress & cellular mechanisms) represents studies probing the cellular and biochemical mechanisms underlying the plant's therapeutic effects, with terms like oxidative stress, apoptosis, cytotoxicity, and anti-oxidant. Lastly, the Yellow Cluster (anti-microbial phytotherapy) suggest a focus on comparative anti-microbial studies across species in the Ocimum genus and their nanoparticle-enhanced bioactivity, with keywords like anti-bacterial, anti-fungal, *Ocimum gratissimum*, and AGNPs (silver nanoparticles).

Figure 6 shows the Biblioshiny topic visualisation, which shows research evolution on *O. tenuiflorum*, reflecting shifts in focus over time. Early trends (2007–2015) centred on diabetes, antioxidants, oxidative stress, immunomodulation, and traditional medicine terms like *Curcuma longa* and *Tinospora cordifolia*, highlighting its role in metabolic and immune health, in combination with or without other natural products. Later, research shifted toward mechanistic and molecular studies, with terms like apoptosis, GC-MS, and eugenol, demonstrating increased interest in bioactive compounds and biochemical mechanisms.

By the mid to late 2010s, research focus shifted to phytochemicals and pharmacology, with keywords like rosmarinic acid, essential oils, anti-bacterial, and anti-oxidant activity gaining prominence. Attention increased on *Ocimum sanctum* L., *Ocimum basilicum,* and *Withania somnifera*, showing broader interspecies studies. After 2020, research expanded into green synthesis, silver nanoparticles, cytotoxicity, molecular docking, and COVID-19 applications. These themes reflect *O. tenuiflorum's* role in nanotech, drug discovery, and public health crises. The latest trending terms like phytochemicals, Tulsi, plant extract, green synthesis, and molecular docking indicate a merging of traditional knowledge with modern science, focusing on natural therapeutics, sustainable methods, and in silico validation. Research on *O. tenuiflorum* has shifted from ethnopharmacology to molecular pharmacology and nanotechnology, maintaining its core while embracing new scientific approaches. In summary, the bibliometric insights show that *Ocimum tenuiflorum* research has expanded significantly in scope and complexity. It has evolved from ethnobotanical validation into an interdisciplinary field involving molecular pharmacology, nanotechnology, and computational modelling, while retaining its foundation in traditional health applications.

Phytochemical constituents of *O. tenuiflorum*

O. tenuiflorum originates from the Indian subcontinent and adjacent tropical regions of Asia, including India, Nepal, Sri Lanka, and Malaysia, with a range extending to tropical areas of Australia and the western Pacific. This short-lived and small perennial herb is extensively cultivated and has also become naturalised in other tropical regions, including the Caribbean and parts of Africa, owing to its medicinal, culinary, and religious importance. Nowadays, the plant is recognised for its rich phytochemical profile, which contributes to its therapeutic properties. The plant contains a variety of bioactive compounds, including phenolic compounds (flavonoids & phenolic acids), terpenoids, steroids, monoterpenes and sesquiterpenes, esters, aldehydes and ketones, which play significant roles in its health benefits (Table 4).

Flavonoids & phenolic acids

Flavonoids and phenolic acids are the most common secondary metabolites with low molecular weight polyphenol structures, recognised for their diverse biological activities, including anti-oxidant properties [39,40]. *O. tenuiflorum* contains various flavonoids and phenolic acids, which are responsible for the plant's therapeutic effects. Some flavonoids commonly found in *O. tenuiflorum* include apigenin, luteolin, kaempferol, quercetin, vicenin, eupalitin, esculetin, isoorientin, orientin, galuteolin, genkwanin, vitexin, isovitexin, cirsimaritin, chrysoeriol, cirsilineol, isothymusin, molludistin, demethylnobiletin, salvigenin, luteolin-7-O-glucuronide, apigenin-7-O-glucuronide, kaempferide, chrysoeriol, isosakuranetin, luteolin-5-glucoside, esculin, robinetintrimethyl ether, and xanthomicrol [5]. *O. tenuiflorum* is also well-known for its anti-oxidant properties owing to the presence of several phenolic acids. Some of these include rosmarinic acid, (E)-p-coumaroyl 4-O-β-D-glucoside, chlorogenic acid, caffeic acid, vanillin, methylisoeugenol, vanillic acid, sinapic acid, p-coumaric acid, 3-(3,4-dihydroxyphenyl) lactic acid, protocatechuic acid, 3,4-dimethoxycinnamic acid, p-hydroxybenzoic acid, ferulic acid, and bieugenol [4,5,41].

Esters, aldehydes, and ketones

O. tenuiflorum contains various esters, aldehydes, and ketones that exhibit significant biological activities. Some of them are methyl isovalerate, ethyl isovalerate, pentanal, hexane-3-one, 4-methyl-4-hepten-3-one, and octyl ester [4,5].

Sesquiterpenes and monoterpenes

Sesquiterpenes and monoterpenes are important secondary metabolites with significant pharmaceutical values. Both metabolites are mostly found in the essential oils of the plant, contributing to the plant's flavour and aroma, and play a significant role in various biological applications. The plant *O. tenuiflorum* contains a variety of sesquiterpenes, including copaene, zingiberene, bourbonene, guaiene, bergamotene, sesquiphellandrene, farnesene, sesquisabinene, humulene, bicyclogermacrene, germacrene, bisabolene (Z), δ-cadinene, α-bisabolene, amorphene, caryophyllene oxide, c-muurolene, α-muurolene, α-cadinol, c-cadinene, α-caryophyllene, β-caryophyllene, germacrene D, β-guaiene, α-longipinene, α-panasinsen, selina-6-en-4-ol, nerolidol, spathulenol, aromadendrene oxide, α-calacorene, 1,4-cadinadiene, β-bisabolene, alloaromadendrene, β-gurjunene, β-cubebene, β-elemene, and c-eleneme [5]. Some important monoterpenes reported in *O. tenuiflorum* are α-pinene, camphene, sabinene, β-pinene, 1,8-cineole, β-trans-ocimene, camphor, borneol, tricyclene, myrcene, phellandrene, terpinene, limonene, ocimene, terpinolene, sabinene hydrate, carene, fenchone, linalool, camphenehydrate, terpinen-4-ol, terpineol, estragole, and eugenol [5].

Triterpenoids

Triterpenoids are a large group of natural products, mostly derived from squalene, that have significant pharmaceutical importance. *O. tenuiflorum* contains multiple triterpenoids, which hold important therapeutic value. Studies have identified various triterpenoids such as β-sitosterol, stigmasterol, campesterol, ocimic acid, ursolic acid, trihydroxyursolic acid, β-sitosterol-3-Oβ-D-glucopyranoside, oleanolic acid (OA), urs-12-en-3β,6β,20β-triol-28-oic acid, and 16-hydroxy-4,4,10,13-tetramethyl-17-(4-methyl-pentyl)-hexadecahydrocyclopenta [α] phenanthrene -3-one [4,5,41].

Therapeutic properties of *O. tenuiflorum* and its potential in dermatological applications

Established health benefits of *O. tenuiflorum*

One of the most prominent effects of *O. tenuiflorum* is its adaptogenic capacity, particularly in reducing stress and improving mental well-being [42,43]. Clinical trials have shown that standardised extracts of *O. tenuiflorum* can significantly lower perceived stress levels, decrease cortisol production, and enhance sleep quality in healthy adults [44,45]. These benefits are linked to the plant's ability to modulate the hypothalamic-pituitary-adrenal (HPA) axis and its influence on neurotransmitter regulation, especially through bioactive compounds such as eugenol and ursolic acid. In addition to its psychological advantages, *O. tenuiflorum* has demonstrated promising potential in managing blood sugar levels [46,47]. Both clinical and animal studies report that holy basil supplementation can reduce fasting and postprandial blood glucose levels and improve overall glycaemic control. The mechanisms behind this include increased insulin secretion, better pancreatic β-cell function, and the modulation of key metabolic enzymes. These effects make it a valuable complementary option for individuals with type 2 diabetes or metabolic syndrome.

A further well-established therapeutic property of *O. tenuiflorum* is its anti-oxidant and anti-inflammatory activity. Rich in phenolic compounds such as rosmarinic acid, apigenin, and eugenol, the plant strongly inhibits pro-inflammatory cytokines and oxidative stress markers. Laboratory and *in vivo* research confirm its ability to suppress pathways such as NF-κb and COX-2, while boosting the activity of natural anti-oxidant enzymes like superoxide dismutase and catalase [48–50]. Studies demonstrate that bioactive compounds from *O. tenuiflorum*, such as eugenol and ursolic acid, inhibit NF-κb signalling by modifying residues of IKKβ (inhibitor of κB kinase β), preventing the phosphorylation and degradation of IκB proteins that normally sequester NF-κB in the cytoplasm [51]. These actions block NF-κB nuclear translocation and subsequent inflammatory gene transcription, and help protect cells and are relevant in preventing or managing inflammatory and oxidative stress-related conditions.

Cardiovascular advantages also constitute a significant part of *O. tenuiflorum's* therapeutic profile. Supplementation with the plant has been linked to improved lipid profiles, including reductions in total cholesterol, LDL, and triglycerides, alongside increases in HDL levels. Clinical trials indicate it can modestly lower blood pressure, likely through vasodilatory and anti-oxidant mechanisms [52–54]. These findings support its use in promoting heart health and reducing risk factors associated with cardiovascular disease. Moreover, *O. tenuiflorum* has shown immunomodulatory and anti-microbial properties. Human studies have revealed that supplementation can boost immune function by increasing natural killer (NK) cell activity and the production of key cytokines that help regulate T-helper cell differentiation, such as interferon-gamma (IFN-γ), that promotes the development of Th1 cells (involved in cell-mediated immunity), and interleukin-4 (IL-4) which promotes Th2 cells (involved in allergic responses and parasitic infections) [55]. Additionally, its essential oils exhibit broad-spectrum anti-microbial effects against various bacterial and fungal pathogens, including resistant strains like *S. aureus* (MRSA) and *E. coli* [56,57]. These combined immunological and anti-microbial mechanisms highlight *O. tenuiflorum's* significance in supporting host defences and combating infections.

O. tenuiflorum **emerging potential in skin health applications**

Antimicrobial activity for skin infections

As previously noted, *O. tenuiflorum* exhibits significant potential in the treatment of skin infections through its broad-spectrum anti-microbial properties. The essential oil constituents, notably eugenol, have been shown to be effective against skin pathogens such as *S. aureus, E. coli,* and *P. aeruginosa*, major causative agents of skin and soft tissue infections [16,57]. This anti-microbial efficacy, coupled with the herb's anti-inflammatory attributes, renders it especially beneficial for the management of infected wounds and the prevention of secondary infections.

Prevention and treatment of acne

The anti-bacterial and anti-inflammatory properties of *O. tenuiflorum* make it highly effective in treating acne. Eugenol and other bioactive compounds neutralise bacteria that cause acne while reducing inflammation and redness linked to breakouts [58,59]. Besides, traditional formulations combining *O. tenuiflorum* with honey show promising effectiveness in reducing acne lesions and preventing scars, however, limited studies have been conducted to support this claim. *O. tenuiflorum* essential oil-regulating properties may help to keep sebum production balanced, addressing one of the main causes of acne [60,61].

Anti-ageing and collagen enhancement

O. tenuiflorum exhibits considerable anti-ageing properties via various mechanisms. Ursolic acid, an important triterpenoid, fosters collagen synthesis and improves skin elasticity [62,63]. Studies suggested that ursolic acid could be a promising candidate for treating skin fibrosis due to its dual effects on collagen homeostasis, inhibiting collagen production and promoting collagen degradation [62]. Apart from that, the anti-oxidant substances help guard against free radical damage, thereby preventing premature ageing and supporting skin firmness [64].

Wound healing and tissue repair

The wound healing properties of *O. tenuiflorum* are well-documented in preclinical studies. The herb accelerates epithelialization, increases wound breaking strength, and enhances the formation of granulation tissue [65–67]. These effects are attributed to the combined action of eugenol, ursolic acid, and other bioactive compounds that stimulate cellular repair mechanisms [64]. Studies demonstrate that *O. tenuiflorum*-treated wounds show faster healing rates and improved cosmetic outcomes compared to controls [67,68]. The anti-microbial properties provide additional protection against wound infections, making *O. tenuiflorum* valuable for both acute and chronic wound management.

Photoprotection and skin brightening

Research reveals that *O. tenuiflorum* possesses natural sun protection properties [69,70]. The phenolic compounds and flavonoids in *O. tenuiflorum* extracts demonstrate UV absorption capabilities, with studies showing Sun Protecting Factor (SPF) values ranging from 2.87 to 13.29 depending on concentration and extraction method [71,72]. While these values are moderate compared to commercial sunscreens, they provide valuable supplementary protection when combined with other photoprotective agents. The photoprotective effects extend beyond UV absorption to include anti-oxidant protection against UV-induced free radical damage. This dual mechanism helps prevent both immediate sun damage and long-term photoaging effects. Apart from that, vitamin C and rosmarinic acid from *O. tenuiflorum can* contribute to its skin-brightening properties, helping to reduce melanin production and fade dark spots, promoting a more even skin tone [73–75].

Key bioactive compound and the potential mechanism

Studies suggest natural phytochemicals help protect skin cells from oxidative stress, inflammation, and UV damage, supporting wound healing, anti-ageing, and skin barrier health [76,77]. This profile highlights five main compounds from *O. tenuiflorum*, such as eugenol, ursolic acid, rosmarinic acid, apigenin, and luteolin. Focusing on their chemical compound, anti-oxidant actions, and skin benefits like anti-ageing, anti-inflammatory effects, and UV protection.

Eugenol

Eugenol, or 4-allyl-2-methoxyphenol ($C_{10}H_{12}O_2$), is a key phenolic in *O. tenuiflorum* essential oil [20,78]. It exhibits potent anti-oxidant activity via its hydroxyl group, donating hydrogen to neutralise free radicals and inhibiting oxidative enzymes like lipoxygenase, reducing oxidative stress [79]. In skin applications, eugenol offers anti-inflammatory, anti-microbial, and local anaesthetic benefits, aiding wound healing and skin barrier repair [80]. It reduces inflammation by downregulating pro-inflammatory mediators like TNF-α and IL-6 and supports tissue regeneration by boosting collagen. Studies show eugenol lessens UVB-induced inflammation and accelerates tissue recovery [58,81]. Formulations with eugenol from *O. tenuiflorum* effectively prevent chemically-induced skin cancer, mainly through anti-oxidant and anti-inflammatory pathways like NF-κb [82]. Overall, eugenol enhances *O. tenuiflorum* skin protection, healing, and anti-ageing properties in context.

Ursolic acid

Ursolic acid ($C_{30}H_{48}O_3$), found in *O. tenuiflorum* leaves, is a pentacyclic triterpenoid with strong anti-oxidant and anti-inflammatory properties, valuable in dermatology [83,84]. It scavenges reactive oxygen species (ROS) and activates the Nrf2 pathway, boosting enzymes like superoxide dismutase (SOD) and catalase (CAT) [85,86]. It also inhibits NF-κB and TLR4 pathways, reducing cytokine production and skin inflammation [87,88]. Studies show ursolic acid alleviates atopic dermatitis symptoms by lowering oxidative stress and inflammation, decreasing redness, swelling, and itching. It promotes collagen synthesis, inhibits Matrix Metalloproteinases (MMPs), and maintains skin elasticity, supporting anti-ageing and skin rejuvenation [86,89,90]. Overall, ursolic acid enhances *O. tenuiflorum* skin benefits by protecting against oxidative damage, inflammation, and ageing.

Rosmarinic acid

Rosmarinic acid ($C_{18}H_{16}O_8$) is a polyphenolic compound found in *O. tenuiflorum* leaves, recognised for its anti-oxidant and skin-protective properties [5,91]. It has hydroxyl groups on aromatic rings, enabling it to neutralise free radicals through hydrogen donation and metal ion chelation [92,93]. This process inhibits lipid peroxidation, reduces DNA damage, and maintains redox balance [93]. It activates the Nrf2 pathway, boosting protective enzymes such as HO-1 [94,95]. In dermatology, it inhibits skin-ageing enzymes like collagenase, elastase, and hyaluronidase, thereby preserving skin elasticity [96–98]. It also suppresses NF-κB signalling, leading to a reduction in pro-inflammatory cytokines such as IL-1β [99]. Studies demonstrate that it protects skin cells from UV damage, decreasing UVB-induced apoptosis and inflammation by downregulating NLRP3 inflammasome and enhancing Nrf2/HO-1 activity [100]. These effects improve *O. tenuiflorum's* anti-ageing, photoprotective, and anti-inflammatory potential.

Apigenin

Apigenin ($C_{15}H_{10}O_5$) is a natural flavonoid in *O. tenuiflorum*, known for its anti-oxidant and anti-inflammatory benefits in skin health [101]. As a flavone, it scavenges reactive oxygen species (ROS) via hydroxyl groups, maintaining oxidative balance in skin cells [102,103]. It inhibits inflammatory pathways like NF-κB, MAPK, and COX-2, which are often upregulated in chronic skin conditions [104,105]. Studies suggest apigenin can treat inflammatory skin issues like dermatitis and psoriasis by reducing cytokines such as IL-1β, IL-6, IL-31, TNF-α, and IL-33, easing inflammation [106,107]. It also promotes barrier repair by increasing proteins like filaggrin and involucrin, which are essential for hydration and integrity, supports skin homeostasis by enhancing epidermal differentiation, and reduces pruritus signals [108]. Combining anti-oxidant, anti-inflammatory, and barrier-enhancing effects, apigenin from *O. tenuiflorum* is a promising ingredient for soothing sensitive skin, eczema, psoriasis, and overall skin health.

Luteolin

Luteolin ($C_{15}H_{10}O_6$), a flavonoid in *O. tenuiflorum*, exhibits strong anti-oxidant and anti-inflammatory properties, relevant for dermatology [5]. Its hydroxyl groups enable it to scavenge reactive oxygen species (ROS) and inhibit lipid peroxidation, protecting skin cells from oxidative stress [109]. Luteolin also modulates inflammatory pathways like NF-κB, AP-1, and JAK/STAT, reducing cytokines IL-1β, IL-6, and TNF-α [110,111]. It has notable anti-photoaging effects, diminishing UVB-induced erythema, wrinkles, and collagen breakdown by inhibiting MMPS, stimulating collagen, and activating the SIRT3/ROS/MAPK axis [112–114]. It supports dermal cell survival under oxidative stress, preventing premature ageing and UV damage. This broad activity makes luteolin valuable in skincare for photoprotection, wrinkle prevention, and calming inflammation.

Conclusion

O. tenuiflorum illustrates that the traditional botanical knowledge aligns with modern scientific validation. Its well-documented properties of adaptogenic, anti-microbial, anti-inflammatory, and antioxidant, thanks to its various bioactive compounds including eugenol, ursolic acid and rosmarinic acid, support a wide range of therapeutic uses, from overall health to emerging dermatological treatments. These activities support traditional uses for acne, eczema, wounds, and ageing skin, with recent studies confirming their potential, such as improved wound healing and photoprotection. However, the literature regarding the application of *O. tenuiflorum* in clinical trials is limited, and standardised formulations are still under development. Future research should focus on rigorous clinical trials for acne, dermatitis, and skin repair, as well as mechanistic studies on *O. tenuiflorum* effects. Overall, *O. tenuiflorum* is a bioactive herb with potential benefits for skin health, deserving more research in dermatologic treatments.

Conflict of Interest

The authors have no conflicts of interest to declare.

Author's Contribution

M.F.Z.: Formal analysis, Writing, Review & Editing, M.H.Z: Writing, Review, & Editing, N.S.I.M: Writing, Review, & Editing, S.H: Writing, Review, & Editing, P.M.R.: Project Administration, Writing, Review, & Editing,

Acknowledgement

I would like to extend my deepest appreciation and heartfelt thanks to many individuals. Firstly, I am profoundly grateful to the YouBaby Million research team and the CeSBTech (Cell Signalling and Biotechnology Research Group), Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, Faculty of Health Sciences Universiti Teknologi MARA Cawangan Pulau Pinang, Kampus Bertam, Kepala Batas for their invaluable cooperation in enabling the successful completion of this study.

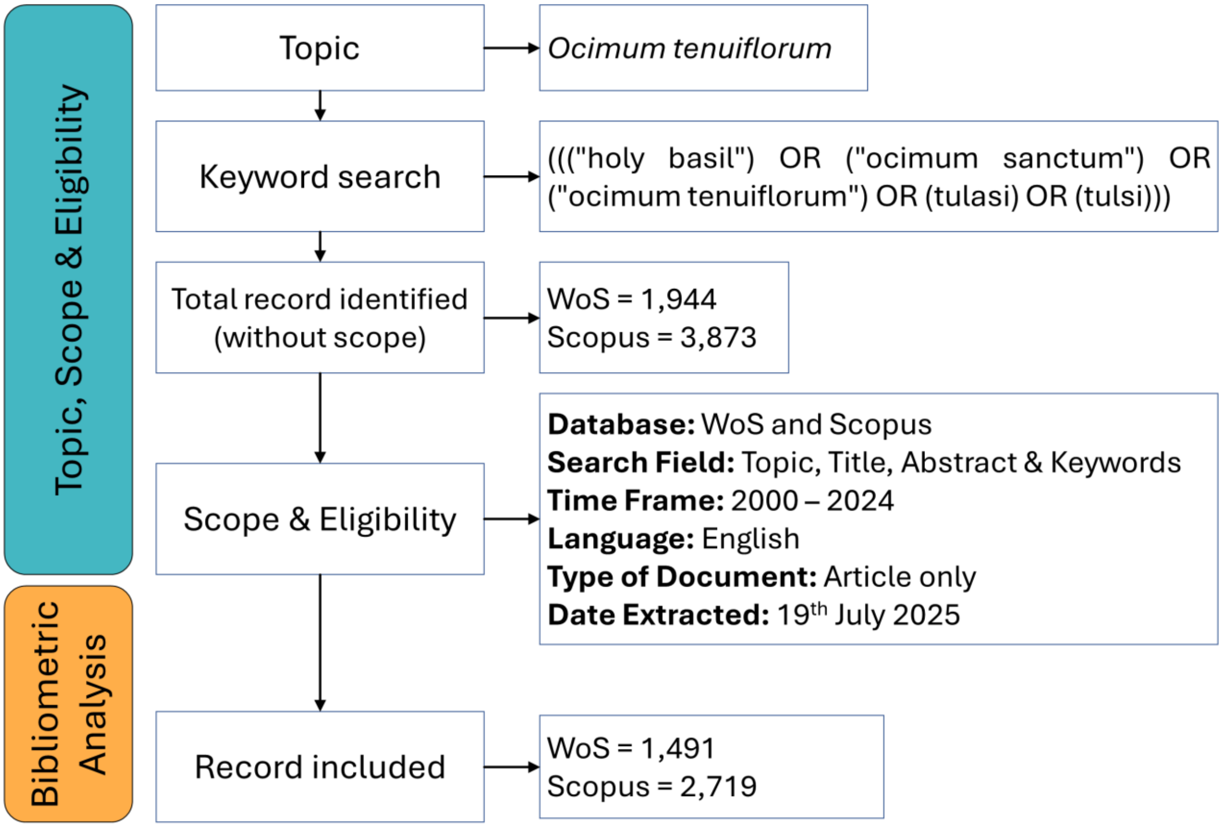

Figure 1. PRISMA flow diagram of the search strategy. (WoS = Web of Science)

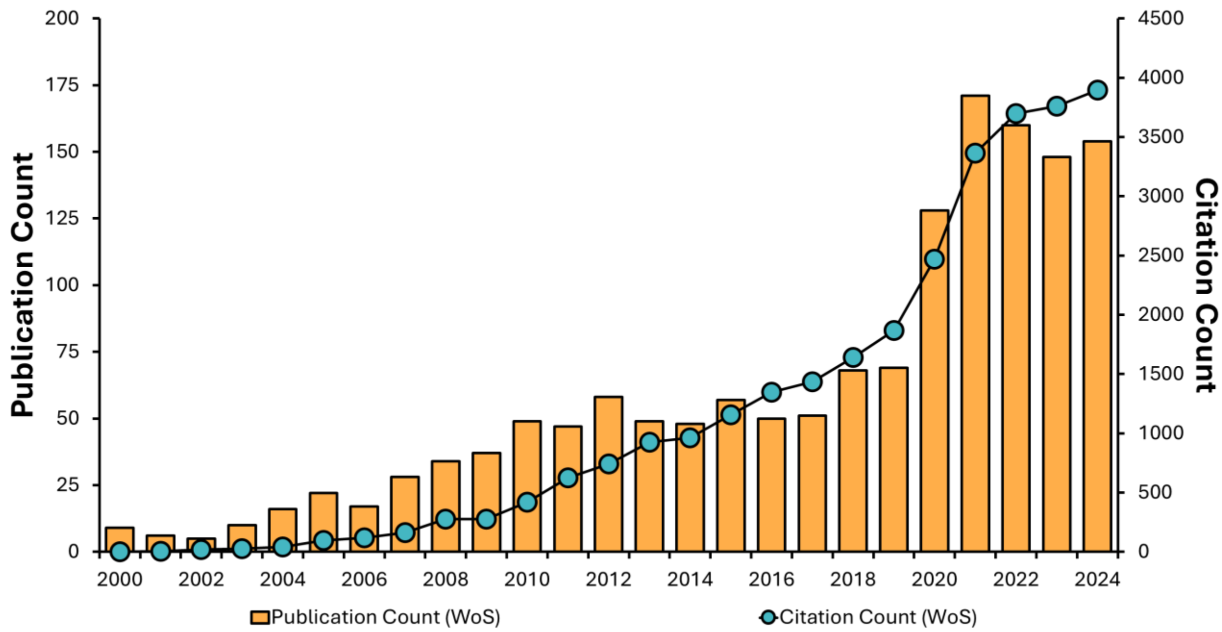

Figure 2. The evolution of publication and citation count of *O. tenuiflorum* during the period 2000 – 2024. (WoS = Web of Science)

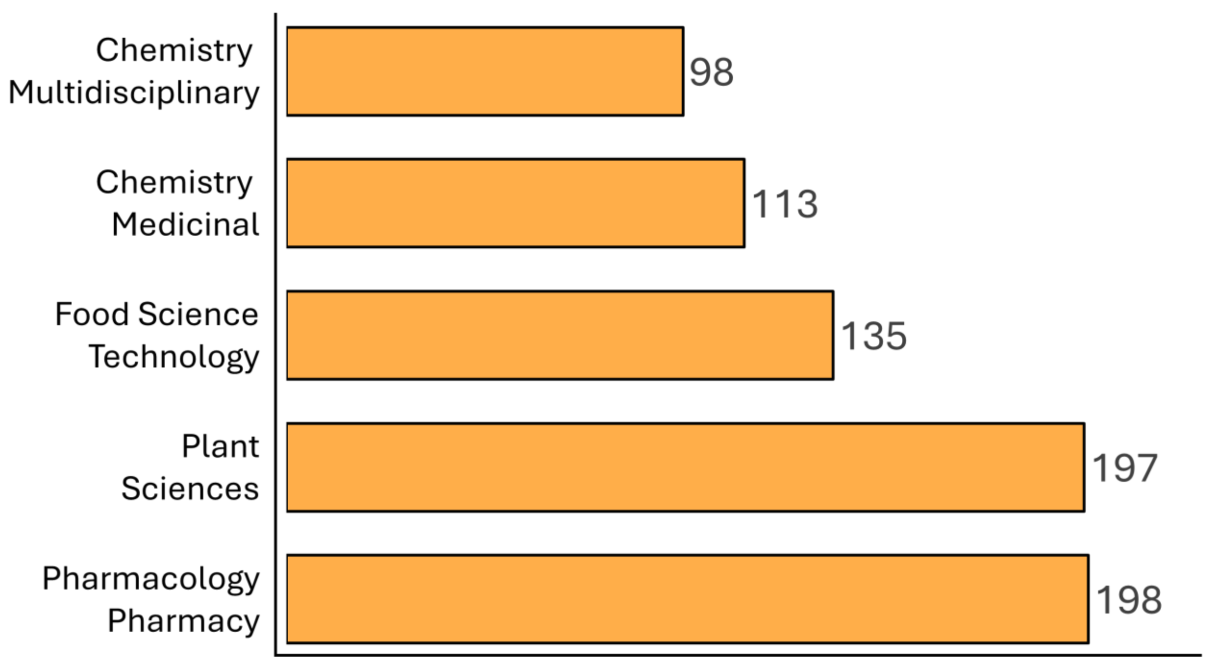

Figure 3. Top WoS categories based on the publication count over the last 24 years.

Table 1. Ranking of the 10 top authors and affiliations based on the number of publications and citations over the last 24 years of bibliometric analysis.

Author's Name	Record Count	Citation Count
Shanmugam, Rajeshkumar	11	73
Balaji, Raju	9	49
Kusindarta, Dwi Liliek	9	255
Wihadmadyatami, Hevi	9	168
Varghese, Remmiya Mary	8	204
Kumar, S. Aravind	6	116
Kustiati, Ulayatul	6	77
Ledwani, Lalita	5	252
Singh, Mumal	5	338
Vajpayee, Mona	5	372
Affiliations	**Record Count**	**Citation Count**
Council of Scientific Industrial Research (CSIR) India	89	2,868
Indian Council of Agricultural Research (ICAR)	57	1,232
CSIR Central Institute of Medicinal Aromatic Plants (CIMAP)	48	1,128
Indian Institute of Technology System (IIT) System	38	1,684
Saveetha Institute of Medical Technical Science	36	179
All India Institute of Medical Sciences (AIIMS), New Delhi	31	1,233
National Institute of Technology (NIT) System	30	579
Saveetha Dental College Hospital	30	161
Banaras Hindu University Bhu	29	727
King Saud University	23	258

Table 2. Top 10 countries with the highest record count in the *O. tenuiflorum* research over the last 24 years.

Countries	Record Count	Citation Count
India	1074	23,896
United States of America (USA)	89	1,899
Thailand	81	1,547
Saudi Arabia	65	899
Pakistan	48	548
Bangladesh	33	529
South Korea	31	1,322
Malaysia	27	383
People's Republic of China	27	523
Indonesia	21	172

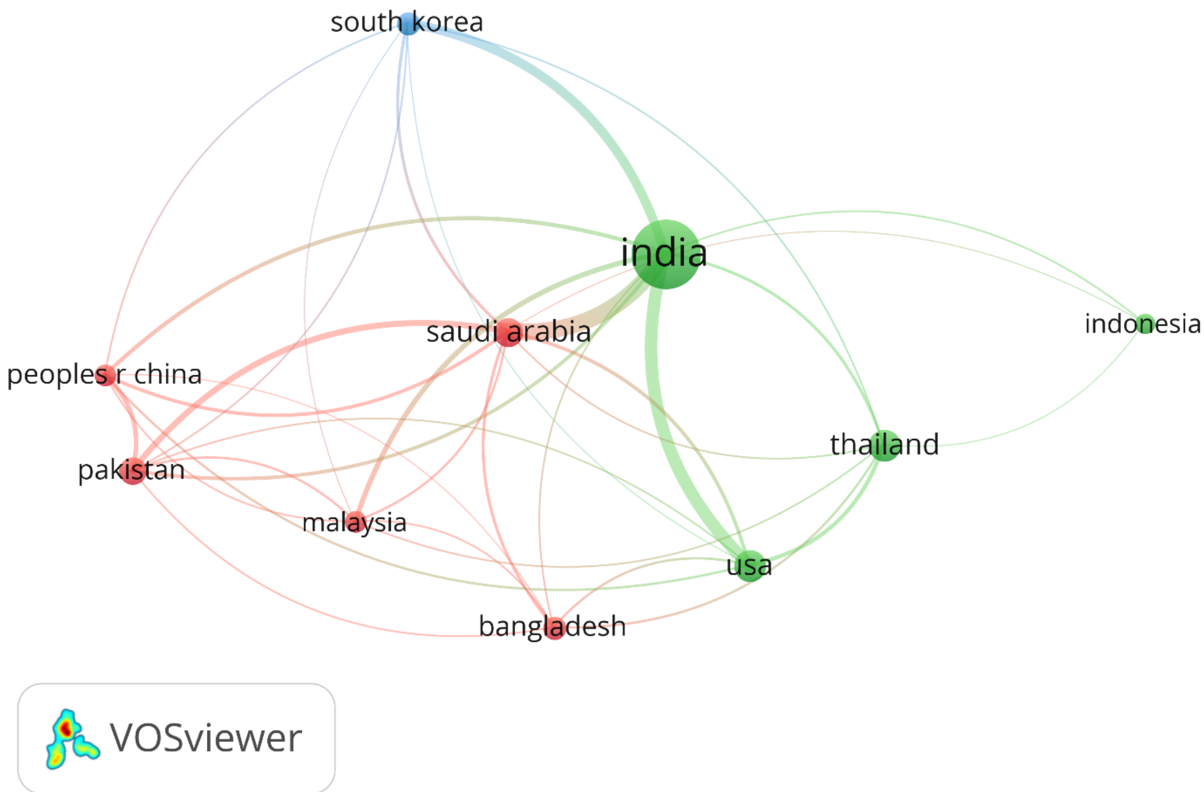

Figure 4. Collaborations among the 10 most prolific *O. tenuiflorum* research countries, as shown by co-authorship analysis (Network visualisation map).

Table 3. Top 10 most cited articles in the *O. tenuiflorum* research over the last 24 years.

Rank	Title	Citation Count	Year	Journal (IF)	Ref
1	Biosynthesis of silver nanoparticles using *Ocimum sanctum* (Tulsi) leaf extract and screening its antimicrobial activity	483	2011	Journal of Nanoparticle Research (2.6)	[33]
2	Rapid synthesis of silver nanoparticles using dried medicinal plant of basil	476	2010	Colloids and Surfaces B-Biointerfaces (5.6)	[34]
3	Synthesis of silver nanoparticles using plant extract and analysis of their antimicrobial property	373	2015	Journal of Saudi Chemical Society (5.8)	[36]
4	Comparative evaluation of hypoglycaemic activity of some Indian medicinal plants in alloxan diabetic rats	327	2003	Journal of Ethnopharmacology (5.4)	[37]
5	Green synthesis of carbon dots from *Ocimum sanctum* for effective fluorescent sensing of Pb2+ ions and live cell imaging	324	2017	Sensors and Actuators B-Chemical (7.7)	[35]
6	Antioxidant and cyclooxygenase inhibitory phenolic compounds from *Ocimum sanctum Linn.*	261	2000	Phytomedicine (8.2)	[26]
7	Effect of chromium accumulation on photosynthetic pigments, oxidative stress defence system, nitrate reduction, proline level and eugenol content of *Ocimum tenuiflorum L*.	260	2004	Plant Science (4.1)	[20]
8	Potent α-amylase inhibitory activity of Indian Ayurvedic medicinal plants	235	2011	BMC Complementary and Alternative Medicine (3.4)	[38]
9	Green Synthesis of Silver Nanoparticles Using Ocimum Leaf Extract and Their Characterisation	233	2011	Digest Journal of Nanomaterials and Biostructures (1.3)	[115]
10	Medicinal Plant Leaf Extract and Pure Flavonoid Mediated Green Synthesis of Silver Nanoparticles and their Enhanced Antibacterial Property	226	2017	Scientific Reports (3.9)	[31]

*IF = Impact Factor

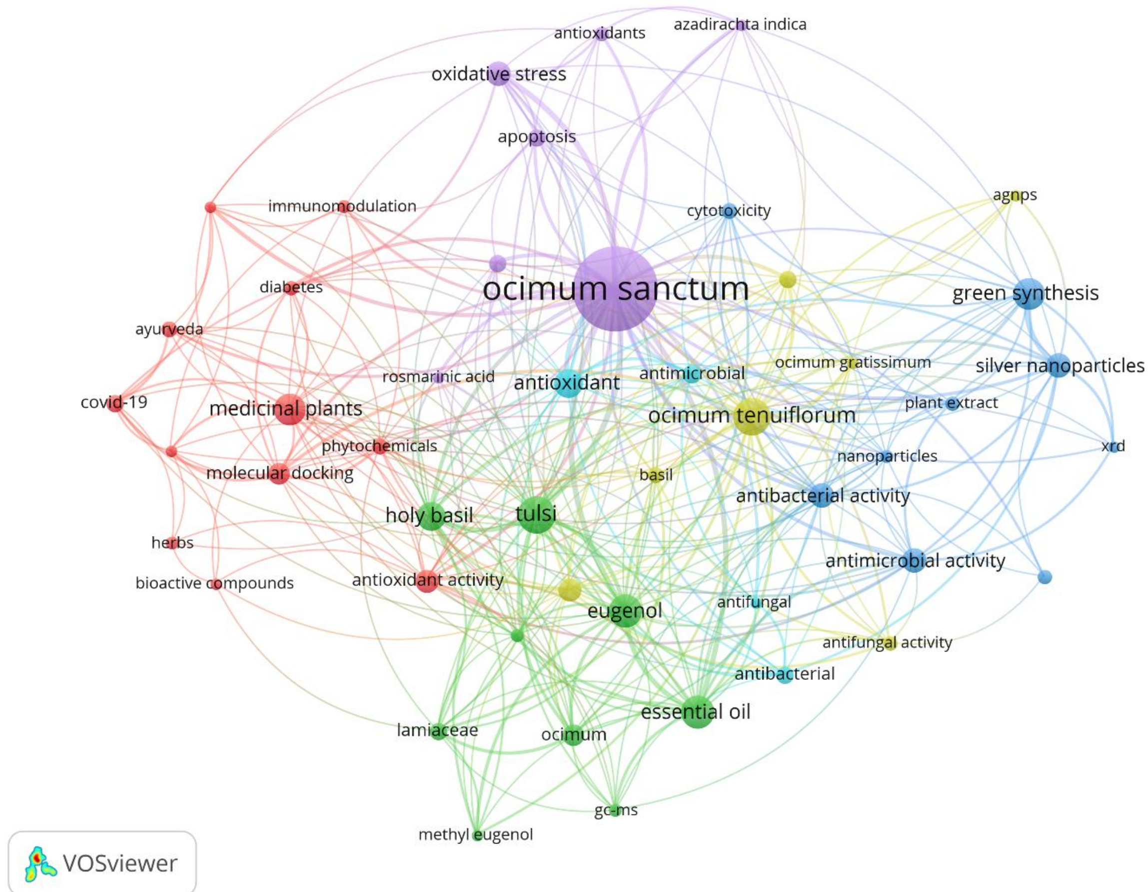

Figure 5. Co-occurrences of author keywords map with 50 of the most occurring words (Network visualisation map).

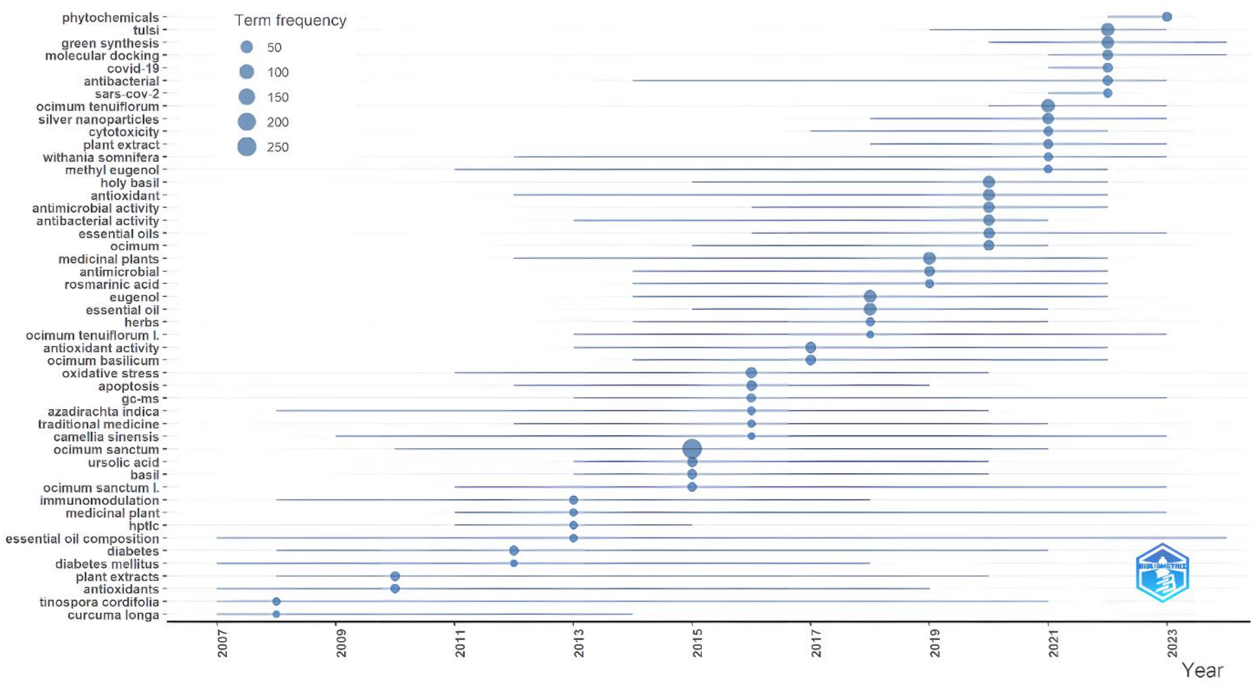

Figure 6. The trend topic visualisation from Biblioshiny highlights the evolving research focus on *O. tenuiflorum* over time (24 years).

Table 4. The biological activities of each compound group that is present in *O. tenuiflorum*

Compound Group	Biological Activities
Flavonoids	Anti-oxidant activity, anti-bacterial activity, anti-inflammatory activity, anti-proliferative, anti-cancer activity, anti-diabetic activity, anti-asthmatic activity, anti-convulsant effects, anti-depressant effects, anti-hypoxia / ischemia injury activity, enhances lipid metabolism, vasodilatation effects, antinociceptive effects, immunomodulatory activity, anti-atherosclerosis activity, and anti-thrombotic activity.
Phenolic Acids	Anti-oxidant activity, anti-microbial activity, anti-cancer activity, anti-proliferative on colon cancer cells, restores cognitive functions, anti-hepatitis B virus, regulation of carbohydrate and lipid metabolism, protects liver and kidney, protects the nervous system, protective effects against Huntington's disease, anti-sickling agent, anti-necrotic and anti-cholestatic effects against liver injury, anti-amoebic activity, hypo-pigmenting agent, anti-osteoporotic, analgesia, anti-wrinkle properties, hepatoprotective, anti-ageing properties, and angiogenic agent.
Triterpenoids	Anti-oxidant, anxiolytic effects and sedative effects, anti-bacterial activity, anti-inflammatory, anti-diabetic, wound-healing effect, neuroprotective activity, herbicidal activity, anti-hypertensive activity, and hepatoprotective effect.
Sesquiterpenes and Monoterpenes	Anti-oxidant effect, anti-bacterial activity, anti-fungal activity, anti-leishmanial activity, anti-inflammatory activity, neuroprotective activity, anti-apoptotic activity, anti-tumour activity, insecticidal activity, anti-diabetic activity, gastroprotective effect, anti-stress effect, anti-convulsant activity, insecticidal activity, and anti-ulcer activity.

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