Indonesian Journal of Pharmacy

VOL 36 (4) 2025: 592–610 | REVIEW ARTICLE

Bibliometric Analysis of Research on Herbal Medicine for Inflammation From 2004 to 2023

Alfian Syarifuddin[1,5], Arief Nurrochmad[2] and Nanang Fakhrudin[3,4*]

1. Doctorate Program of Pharmacy, Universitas Gadjah Mada, Sekip Utara 5281, Yogyakarta, Indonesia
2. Department of Pharmacology and Clinical Pharmacy, Faculty of Pharmacy Universitas Gadjah Mada, Sekip Utara 5281, Yogyakarta, Indonesia
3. Department of Pharmaceutical Biology, Faculty of Pharmacy Universitas Gadjah Mada, Sekip Utara 5281, Yogyakarta,
4. Indonesia Medicinal Plants and Natural Products Research Center, Faculty of Pharmacy, Universitas Gadjah Mada, Sekip Utara 5281, Yogyakarta, Indonesia
5. Department of Pharmacy, Universitas Muhammadiyah Magelang, Mayjend Bambang Soegeng Street, Km 5, Mertoyudan, Magelang 56172, Central Java, Indonesia

Article Info

Submitted: 13-02-2024
Revised: 10-08-2024
Accepted: 24-09-2024

*Corresponding author
Nanang Fakhrudin

Email:
nanangf@ugm.ac.id

ABSTRACT

Inflammation plays crucial role in the basic pathology of many diseases such as allergies, cardiovascular dysfunction, metabolic syndrome, cancer, and autoimmune diseases. The research on the development of herbal medicine targeting inflammatory processes is increasingly advancing. The study aimed to conduct a bibliometric analysis to examine patterns and trends observed in scientific articles on using herbal anti-inflammatory agents. Data were gathered from the Scopus database. In total, 121 articles on herbal anti-inflammatory drugs were examined through bibliometric analysis using RStudio® and VOSviewer applications. In the Scopus database, 121 articles on using herbal remedies to treat inflammation were included in this study. Moreover, China has produced the most research articles. The Journal of Ethnopharmacology, Molecules, and Evidence-Based Complementary and Alternative Medicine are the three most-read journals. The Journal of Ethnopharmacology demonstrates the highest level of productivity based on its citation count and h-index. Regarding publications on this topic, Li J is regarded as a leading figure. Articles by Li J have received the most citations (143), followed by those published by Li X (134). This study can be used as a reference by researchers when conducting studies on medicinal plants used as anti-inflammatory agents. The findings of this study also make it easier for researchers to locate a substantial global network of academics and promote collaboration in this area.

Keywords: Medicinal plant, Anti-inflammatory, Bibliometric Analysis, Scopus Database

INTRODUCTION

Inflammation is an innate physiological reaction of the body that serves as a defensive mechanism against potentially detrimental stimuli, including allergens or tissue injury. Unregulated inflammatory reactions have been considered a significant contributing factor to various disorders, encompassing allergies, cardiovascular impairment, metabolic syndrome, cancer, and autoimmune conditions (Bagad et al., 2013a; Divya et al., 2009). Prolonged intake of nonsteroidal anti-inflammatory drugs (NSAIDs) has been associated with increased susceptibility to toxicity, predominantly affecting the cardiovascular, gastrointestinal, and renal systems (de Oliveira et al., 2014; Dewanjee et al., 2013; Kumari et al., 2014; Qandil, 2012; Sofidiya et al., 2014). Similarly, corticosteroids can affect health and potentially lead to various issues such as growth inhibition, osteoporosis, hypertension, and hyperglycemia (Gautam & Jachak, 2009). Immunosuppressants are an example of many drugs indicated to regulate and reduce inflammation. The goal of therapy is to achieve high drug effectiveness with minimal side effects. The exploration of anti-inflammatory agents from natural sources as alternative therapies is essential to maximize anti-inflammatory response and minimize unwanted side effects (Sostres et al., 2010; Vogl et al., 2013).

Developing more effective anti-inflammatory agents with safer side effects remains an intriguing topic. To achieve this, a rational and promising strategy is to develop anti-inflammatory drugs from natural sources, including plants (Baumgartner et al., 2011; Fakhrudin et al., 2013, 2017; Gorzalczany et al., 2011; Uddin et al., 2014). Research related to pain and inflammation has grown rapidly. The research update and development on pain and inflammation has been reviewed in previous bibliographic studies from 1981-2019 from the WoS database (2887 articles). Previous bibliographic study showed that neuropathic pain was the most popular topic; whereas European and North American countries contributed the most in the research of inflammation and pain (Xiong et al., 2021).

Bibliometrics is an analytical approach that employs quantitative methods to assess a substantial corpus of scholarly literature within a particular discipline, employing mathematical and statistical correlations. In particular, this bibliometric study aimed to demonstrate the relationship between publication years, citations, authors, institutions, and countries (Van Eck & Waltman, 2010; Zhang et al., 2019). Bibliometric analysis can be applied in various fields; however, its application in herbal research is still quite limited, particularly in herbal anti-inflammatories. Thus, this study conducted a bibliometric analysis of the use of herbal remedies to treat inflammation. Based on all research publications found in the Scopus database, the analysis included articles published between 2004 and 2023. The aim of this study is to show the trends in herbal research on inflammation during this period.

MATERIALS AND METHODS

Data sources

Research data were collected in January 2024 from the Scopus scientific publication database, focusing on articles on the use of medicinal plants as anti-inflammatory agents. The data search period spans from 2004 to 2023. Data were retrieved using the following general keywords: herbs AND anti-inflammatory AND mechanisms AND isolates.

The Scopus database was selected as the primary data source for conducting bibliometric analysis because of its extensive coverage, surpassing that of other academic databases such as WoS. Scopus comprises a comprehensive collection of more than 75 million scholarly papers published by a global network of over 5,000 publishers. Moreover, Scopus possesses a comprehensive database comprising records of approximately 16 million authors while simultaneously monitoring publications originating from approximately 70,000 institutions that are indexed in Scopus journals (Bamel et al., 2020; Khitous et al., 2020) . Moreover, Google Scholar was not used because it does not provide detailed information demanded by network analysis, like the bibliometric approach (Bamel et al., 2020). Bibliometric analysis includes the examination of article attributes, such as authors, titles, abstracts, keywords, citations, and affiliations, to derive meaningful insights. The obtained data are utilized to examine the contemporary significance of the issue (Donthu et al., 2021; Kent Baker et al., 2020). In the article extraction step, filters were used to select only English-language articles of original literature (Figure 1).

Data extraction and analysis

In this study, a bibliometric analysis was performed using the Bibliometrix platform and the BiblioShiny application from RStudio® and VOSviewer (Aria & Cuccurullo, 2017; Yu et al., 2020). This comprehensive tool supports data analysis, including deconstruction and visualization, while simultaneously serving the purpose of knowledge mapping. This literature review aimed to analyze data generated by BiblioShiny, a filter-based tool found within the Bibliometrix package and VOSviewer (Agbo et al., 2021; Fatimah et al., 2022).

RESULTS AND DISCUSSION

Main information

The database retrieved from Scopus was analyzed using RStudio® and VOSviewer. This resulted in key information on the study of herbal medicines for inflammation from 2004 to 2023. The information included source of publication (73 publishers), document (121 documents), annual

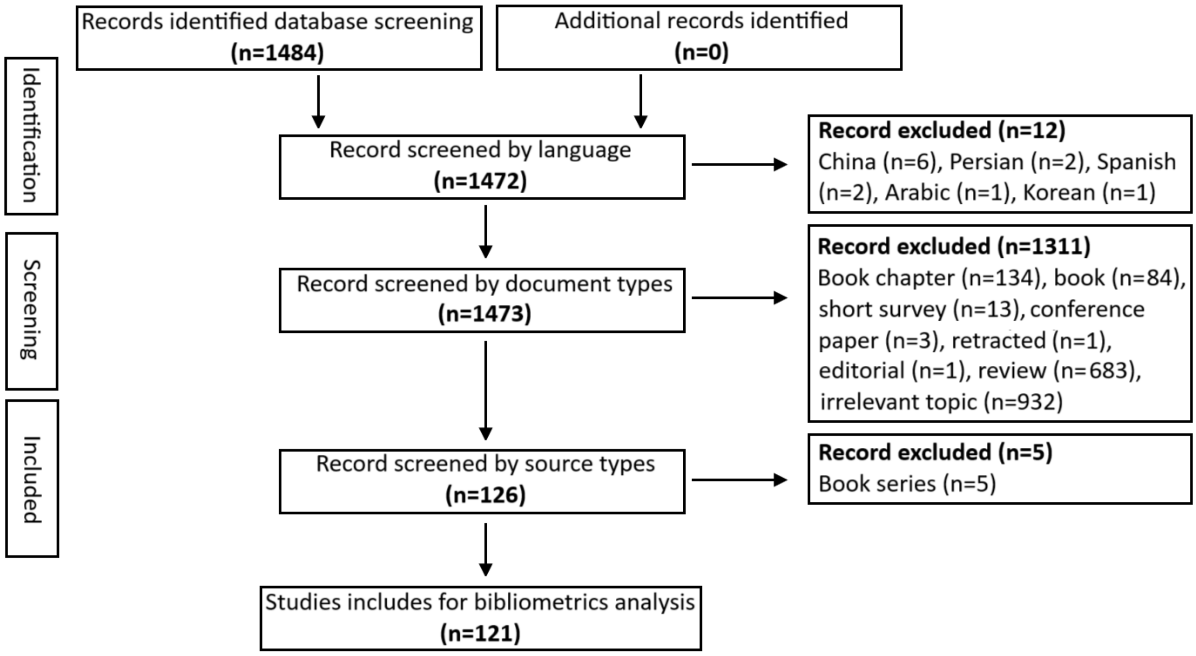

Figure 1. Data collection and selection for the review criteria

growth rate (3.53%), documents average rate (3.85), average citations per document (14.6 citations), the number of references (6272 references), authors who published the studies, authors (808 authors), authors of single-authored docs (1 author), co-authors per document (7.18), and international co-authorship (23.14%) by RStudio®.

Publication trends

Between 2004 and 2023, the number of research publications has noticeably increased. This significant increase in scientific publications occurred after 2022, which was likely due to the growing research interest in the anti-inflammatory activities of herbal plants. Synthetic drugs currently available have side effects, making it necessary to develop new drugs that have equal or better effectiveness with fewer side effects. However, the goal of drug therapy is to use drugs at lower concentrations with high efficacy and safety levels to maximize the drug's activity and minimize undesirable side effects. Therefore, research on natural agents with anti-inflammatory properties that can be used as alternatives is necessary (Bagad et al., 2013b; Djunarko et al., 2022; Fakhrudin et al., 2015; Jo et al., 2010; Sostres et al., 2010).

The oldest/first article published in 2004 in the Archives of Pharmacal Research explores the Nitric Oxide (NO) inhibitory activity of curcuminoids and two sesquiterpenes of *Curcuma zedoaria* in vitro on activated macrophages (Jang et al., 2004). Before 2016, there were relatively few publications related to the use of medicinal herbs as anti-inflammatories. However, the number of publications increased steadily over the years, with the highest total of 25 published articles recorded in 2022. Research conducted between 2004 and 2023 focused on isolating compounds with potential anti-inflammatory properties, resulting in the identification of 25 isolates. Among these isolates are notable compounds such as 1,7-bis(4-hydroxyphenyl)-1,4,6-heptatrien-3-one, procurcumenol, and epiprocurcumenol (Jang et al., 2004). Another significant isolate, spilanthol, was extracted from *Spilanthes acmella* (Wu et al., 2008). *Pyrus bretschneideri* has been found to contain isolates with notable anti-inflammatory potential. Among these constituents are β-sitosterol, daucosterol, oleanolic acid, and ursolic acid (Huang et al., 2010). Isolates of compounds are also derived from aerial parts of *Melastoma dodecandrum*, yielding a total of 18 isolates. Among these, four isolates have demonstrated activity as anti-inflammatory agents.

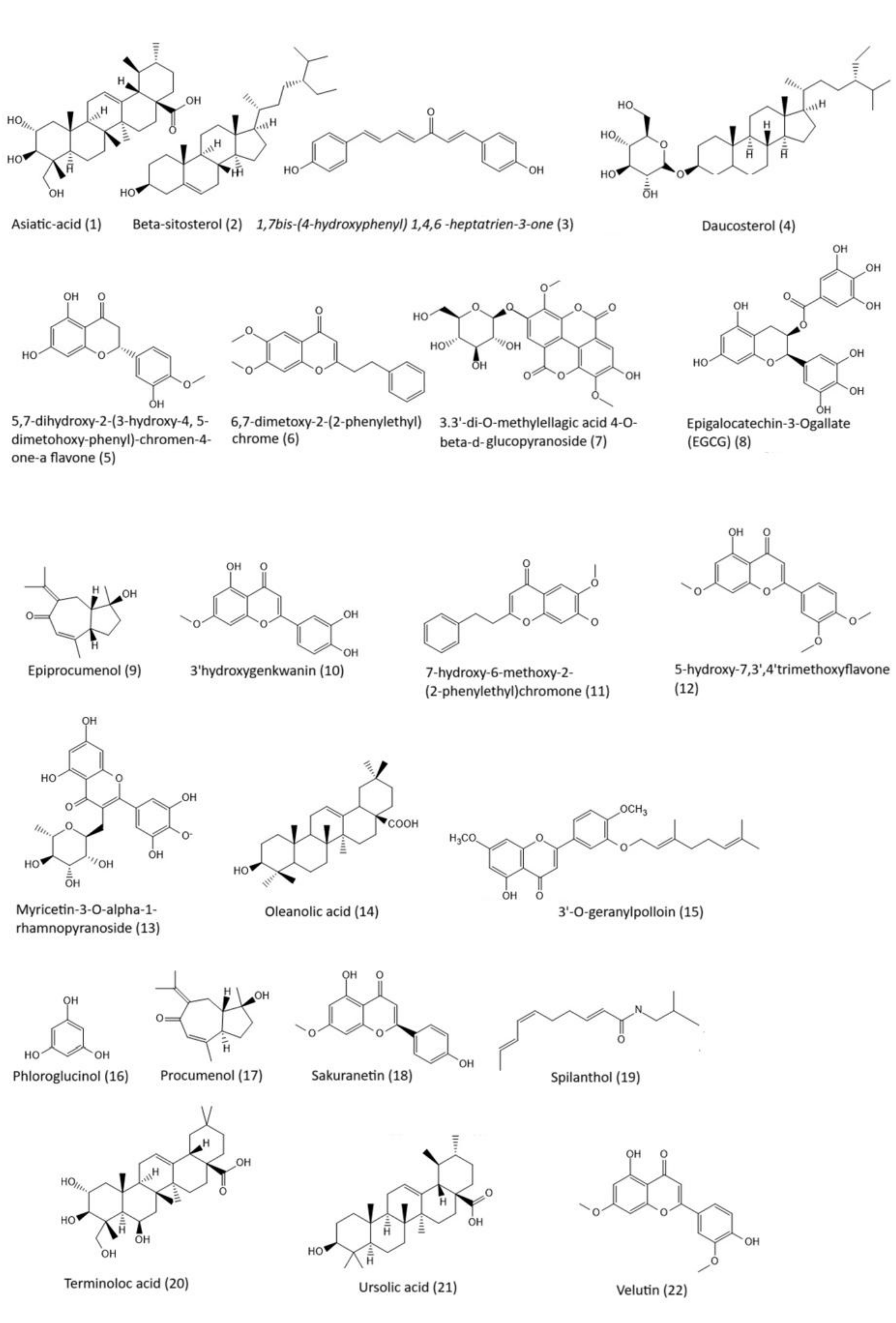

Figure 2. Structure of some anti-inflammatory compounds identified from plants published in the literature

These include pentacyclic triterpenoids such as ursolic acid, asiatic acid, and terminolic acid, as well as tannin groups, notably casuarinin (Yang et al., 2014). Phloroglucinol, specifically 1-(2,6-dihydroxy-4-methoxyphenyl)-3-methylbutan-1-one, has been effectively isolated from the flower extract of *Callistemon citrinus* (Radulović et al., 2015). In the stem bark of *Aquilaria sinensis*, several new flavone compounds have been isolated, showing potential in inhibiting inflammation. These compounds include 3'-O-geranylpolloin, 7-hydroxy-6-methoxy-2-(2-phenylethyl)chromone, 5-hydroxy-7,3',4'-trimethoxyflavone, velutin, 3'-hydroxygenkwanin, sakuranetin, and 6,7-dimethoxy-2-(2-phenylethyl) chromone (Wang et al., 2015). Compounds isolated from *Bruguiera gymnorrhiza* include: 5,7-dihydroxy-2-(3-hydroxy-4,5-dimethoxy-phenyl)-chromene-4-one-flavone, 3,3′-di-O-methylelagic acid 4-O-β-d-glucopyranoside, epigallocatechin-3-O-galate (EGCG), and myricetin-3-O-α-l-rhamnopyranoside (Nualkaew et al., 2017). The structures of anti-inflammatory natural compounds isolated from plants published in 2004-2017 (Figure 2).

Inflammatory pathways play a pivotal role in the pathogenesis of numerous chronic diseases involving inflammatory mediators. Exposure to inflammation can activate intracellular signaling pathways, which subsequently stimulate the production of inflammatory mediators (Suwandi et al., 2021). The primary triggers of inflammation encompass microbial products and cytokines, notably interleukin-1β (IL-1β), interleukin-6 (IL-6), and tumor necrosis factor-α (TNF-α). Additionally, inhibiting the formation of Nitric oxide (NO) plays a significant role in the mechanism (Colombini et al., 2022; McLeish et al., 2017; Tanaka & Kishimoto, 2014), mediators that modulate inflammation interact with Toll-like receptors (TLRs), including IL-1 receptor (IL-1R), IL-6 receptor (IL-6R), and TNF receptor (TNFR). These interactions are crucial for regulating the inflammatory response (Kaminska, 2005). Activation of receptors initiates intracellular signaling cascades, such as the Mitogen-Activated Protein Kinase (MAPK), Nuclear Factor Kappa-B (NF-κB), and Janus Kinase (JAK) pathways, as well as the Signal Transducers and Activators of Transcription (STATs) (Hendrayani et al., 2106; Henríquez-Olguín et al., 2015; Kyriakis & Avruch, 2001). MAPKs (Mitogen-Activated Protein Kinases) are serine/threonine protein kinases that orchestrate cellular responses to diverse stimuli, including osmotic stress, mitogens, heat induction, and inflammatory cytokines (such as IL-1, TNF-α, and IL-6). They play a crucial role in regulating cell proliferation, differentiation, cell survival, and apoptosis (Kaminska, 2005; Pearson et al., 2001). The NF-κB pathway plays a pivotal role in regulating a wide range of biological processes within cells (Oeckinghaus et al., 2011). NF-κB has subsequently been identified as a signal-responsive transcription factor, modulating the expression of genes involved in diverse biological processes, including immune response, cell growth, and inflammation (Girard et al., 2009; Hayden & Ghosh, 2012; Vallabhapurapu & Karin, 2009). The NF-κB family comprises five related transcription factors, namely: P50 (NF-κB1), p52 (NF-κB2), RelA (p65), RelB, and c-Rel. These factors share significant homology within a region called the Rel homology domain (Hayden & Ghosh, 2012). IKK regulates activation of the NF-κB pathway through phosphorylation of IκB (Lawrence, 2009).

Phosphorylation of IκB causes degradation by the proteasome, which subsequently allows release of NF-κB for translocation to the nucleus and transcriptional gene activation (Hayden & Ghosh, 2012). This pathway plays a crucial role in regulating the production of pro-inflammatory cytokines and the recruitment of inflammatory cells. The anti-inflammatory compounds extracted from the database of the articles published from 2004 to 2023 along with their mechanisms of action (Table I). The published anti-inflammatory compounds from the articles ranging from 2004 to 2023 alongside with their mechanism of actions are presented in the (Table I).

Analysis of contributing country and institution dissemination of publications

The publication distribution based on geographical locations was analyzed, taking into account the countries of the authors and institutions involved. The most productive institutions and countries regarding the NP (Table II). In addition, this analysis measures other aspects, including multiple-country publications (MCP), multiple-country publication ratio (MCPR), TC, and average citations. Shenyang Pharmaceutical University is one of the noteworthy institutions in terms of publications, with 12 publications, among all the involved institutions. Southwest Medical University ranks second in publication contributions with 12 publications.

Table I. The list of anti-inflammatory compounds and their mechanism of actions

No.	Plants	Isolate	Mechanisms	References
1	*Isodon ternifolius* (D. Don) Kudô (Lamiaceae)	Six phenyl-naphthalene lignans, ternifoliuslignan A, ternifoliuslignan B, ternifoliuslignan C, ternifoliuslignan D, ternifoliuslignan E and 3-carboxy-6,7-dihydroxy-1-(3′,4′-dihydroxyphenyl) -naphthalene	inhibit nitric oxide (NO), PGE2 and TNF-α, COX-2 and NF-κB/p65 protein expression	(Zhang et al., 2018)
2	*Lindera aggregata* (Sims) Kosterm	kaempferol-7-O-α-l-rhamnopyranoside, quercetin-3-O-β-D-glucoside, and quercetin-5-O-β-D-glucoside"	inhibit ROS	(Zou et al., 2023)
3	*Salvia plebeia*	epieudebeiolide C	inhibit nitric oxide (NO), iNOS, COX-2, IL-1β, and TNF-α.	(Jang et al., 2017)
4	*Kleinia odora*	lupeol acetate, lupenone	inhibit NFκB p65 content, TNF-α IL-6, and IL-1β levels	(Shehata et al., 2018)
5	*Scolymus hispanicus* L	iso-japonicolactone, oleanolic acid	inhibit NFκB p65 content, TNF-α IL-6, and IL-1β levels	(Kandil et al., 2020)
6	*Nelumbo nucifera*	Bisbenzylisoquinolines, liensinine, isoliensinine, neferine	inhibit NF-kB, IL-1β, IL-6, and TNF-α	(Xie et al., 2023)
7	*Curcuma kwangsiensis*	curcumenol, dihydroprocurcumenol, curcuminol G, souliene A	inhibit COX-2, IL-1β, and TNF-α	(Yuan et al., 2020)
8	*Nyctanthes arbor-tristis* Linn	arborside A, arborside C	inhibit nitric oxide (NO), TNF-α, ROS, and PMNs	(Sana et al., 2024)
9	*Dendrobium nobile*	4,5,4′-trihydroxy-3-methoxybibenzyl; 4,5-dihydroxy-3,3′-dimethoxybibenzyl; and nobilin B	inhibit nitric oxide (NO)	(D.-S. Guo et al., 2023)
10	*Physalis angulata* L.	Physagulin A, physagulin C, and physagulin H	inhibit nitric oxide (NO), NF-κB, PGE2, IL-6 and TNF-α, iNOS and COX-2	(Wang et al., 2021)
11	*Baeckea f rutescens*	Frutescone O	inhibit NF-κB p65, TNF-α and IL-6	(Hou et al., 2017)
12	*Salvia plebeia*	salviplenoid A	inhibit nitric oxide (NO), NF-κB and Erk1/2, TNF-α, iNOS, and COX-2	(Zou et al., 2018)
13	*Zygophyllum simplex*	myricitrin, luteolin-7- O-β-D-glucoside	inhibit IL-6, IL-1β and TNF-α	(Abdallah & Esmat, 2017)
14	*Heritiera littoralis*	Heritiera B	inhibit nitric oxide (NO)	(Liang et al., 2023)
15	*Hypecoum erectum*	Invivo: protopine, cryptopine, allcryptopine, oxyhydrastinin; Invitro: protopine, oxyhydrastinin	inhibit COX-2, IL-1β, and TNF-α	(Yuan et al., 2021)

Continue of table I.

No.	Plants	Isolate	Mechanisms	References
16	Licorice.	Glycyrrhetinic acid (GA)	inhibit IL-1β, and TNF-α	(Guo et al., 2023)
17	Warburgia ugandensis	Neolignanamides	inhibit COX-2, 5-LOX, interleukin-1β (IL-1β), interleukin-2 inhibit IL-2, granulocyte-macrophage colony stimulating factor (GM-CSF), and TNF-α	(Zhuang et al., 2021)
18	Aster tataricus	achnophyllol acetate	inhibit nitric oxide (NO), IL-6, IL-1β, NF-κB, MAPK (COX-2, PGE-2)	(Su et al., 2019)
19	Nepeta bracteata B	nepetabrates B dan nepetabrates D	inhibit nitric oxide (NO)	(Zhang et al., 2021)
20	Callicarpa nudiflora	6′-O-trans-feruloyl-8-epiloganic acid	inhibit nitric oxide (NO)	(Wang et al., 2022)
21	Aster tataricus	achnophyllol acetate, Isoacteoside	inhibit nitric oxide (NO), IL-6, IL-1β, NF-κB, MAPK (COX-2, PGE-2)	(Gao et al., 2017b)
22	Jing-Fang	JFNE-C	inhibit TNF-a, IL-6, IL-1β	(Li et al., 2023)
23	Patrinia heterophylla	Heterophdoid A	inhibit iNOS and COX-2	(Wu et al., 2020)
24	Streblus ilicifolius	streblusoamides A, moracin M 6-b-D-glucopyranoside, moracin M 30-(b-D-glucopyranoside)	inhibit nitric oxide (NO)	(Huang et al., 2022)
25	Rosa multiflora Thunb	a,19adihydroxyurs-3-O-acetyltormentic acid, 1a,2a,3a,20b-tetrahydroxyurs-13(18)-en-28-oic acid, 2a,3a,20b, 24-tetrahydroxyurs-13(18)-en-28-oic acid	inhibit nitric oxide (NO)	(Jiang et al., 2020)

Globally, China leads in scientific production in the study of herbal use for anti-inflammation, with 44 publications. It is followed by India, which has a significant contribution with 8 publications. However, the global ranking changes when considering the collaboration production ratio. Egypt ranks first among countries having the highest MCPR, with 0,667. Meanwhile, China has the highest MCP, with 5, followed by Egypt with 4 and then India with 2.

Analysis of contribution journals

The results of the analysis outlined information regarding publications and scholarly articles that play a significant role in developing herbal treatments for anti-inflammation. It presents a compilation of the top 10 journals ranked based on their credibility, as indicated by the average citations per publication from the initial year to the present. The table also reports the h-index. The Journal of Ethnopharmacology has made the most significant contribution, with the highest NP since 2004, publishing 21 articles, with h-index of 12 and a TC of 383, and an average citation per publication of 72. Followed by Molecules (NP=7, H-index= 5, TC= 149), next Evidence-Based Complementary and Alternative Medicine, Natural Product Research, Bioorganic Chemistry, Food Research International, Frontiers in Pharmacology, Journal of Agricultural and Food Chemistry, Journal of Herbal Medicine, and Journal of Natural Product (Supplementary File Table III).

Table II. Top 5 most productive institutions and countries on the research of anti-inflammatory activity of herbal medicines

Rank	Institution affiliations		Corresponding author's country				Most cited countries		
	Institutions	NP*	Country	NP	MCP*	MCPR*	Country	TC*	AC*
1	Shenyang Pharmaceutical University	12	China	44	5	0,114	China	832	18,90
2	Southwest Medical University	12	India	8	2	0,250	Korean	131	18,71
3	Heilongjiang University of Chinese Medicine	11	Korean	7	0	0,000	Egypt	115	19,16
4	Kaohsiung Medical University	11	Egypt	6	4	0,667	Brazil	71	14,20
5	Nankai University	11	Brazil	5	1	0,200	Saudi Arabia	64	12,80

Note(s): *AC, average citations; *MCP, multiple-country publications; *MCPR, multiple-country publication ratio; *NP, number of productions; *TC, total citations

Analysis of authors and their bibliographical coupling network

Identifying the most prolific authors in a discipline can indeed provide insight into researchers who have made significant contributions to the exploration and development of the field. Additionally, understanding the key figures in a particular scientific domain can help in making informed policy decisions and addressing institutional challenges within that field (Bamel et al., 2020). Out of the 121 selected documents, a total of 808 authors contributed to research on the anti-inflammatory properties of herbal medicines. The most productive authors, defined as those with at least three documents, were evaluated based on various factors, including NP (Number of Publications), TC (Total Citations), and AC (Average Citations). The top 5 authors displayed varying results for each of these parameters, highlighting the diversity and impact of their contributions to the field. As illustrated in (Supplementary File Table IV), the primary author Li J. holds the highest number of publications with six documents, accumulating 143 citations (Gao et al., 2017; X. Li et al., 2023; A. Wang et al., 2016). Following Li J., we have Li X with four documents (Gao et al., 2017; Li et al., 2023; Wang et al., 2016), Li N. (Chen et al., 2018; Mazzio et al., 2016; Zhuang et al., 2021), Esmat A (Abdallah & Esmat, 2017; Kandil et al., 2020; Shehata et al., 2018), and Li Y each with three documents (Giribabu et al., 2017; Güran et al., 2019; Jang et al., 2017; Wu et al., 2008; Zou et al., 2018). The most prolific authors hail from institutions in China (Guangxi Normal University, Macau University of Science and Technology) and Egypt (King Abdulaziz University, Saudi Arabia, and Ain Shams University). These five authors have conducted exploratory studies on anti-inflammatory compounds derived from various plants and have investigated their mechanisms of action. Their names, affiliated institutions, and countries serve as valuable references for potential collaborations among researchers working on similar topics. In the conducted study, an author network analysis was performed, revealing that two authors cite the same article in papers published by both authors. This finding suggests a potential collaborative relationship or shared interest between these authors, as indicated by their mutual referencing of the same article (Ma, 2012). A high value in bibliographic merging indicates that there is a significant overlap or similarity in topics between the analyzed documents (Chang et al., 2015). The method used in the calculation utilizes fractional counting to develop the bibliographic coupling network. This approach offers a more specific perspective compared to full counting, which could potentially lead to misinterpretation by overemphasizing certain connections or relationships (Perianes-Rodriguez et al., 2016; Van Eck & Waltman, 2014).

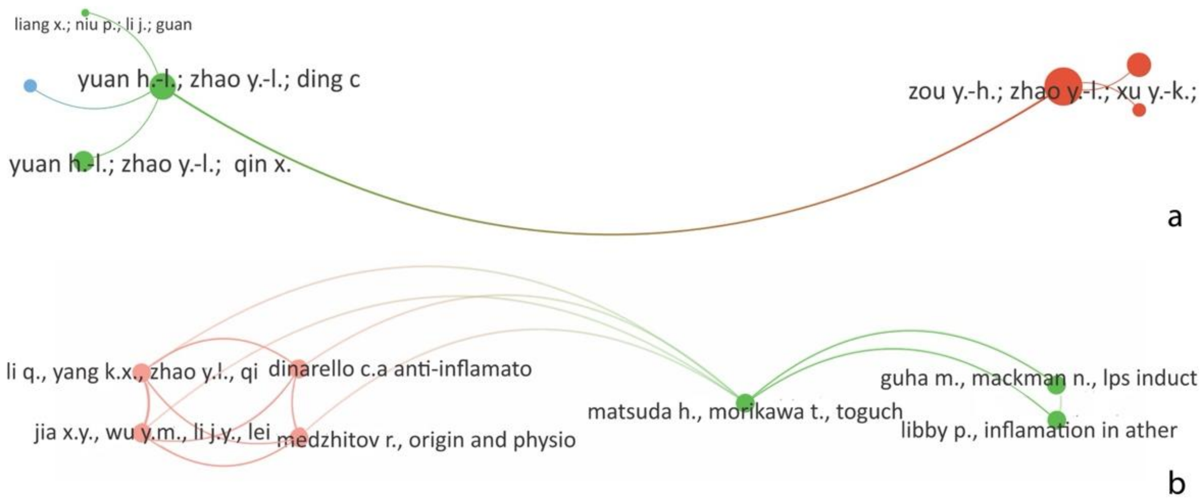

Figure 3a. The bibliographic coupling network (author based) analysed using VOSviewer. The criteria for the bibliography analysis were: minimum of 1 document and 1 citation per author, maximum of 25 authors per document. In total, 122 authors out of 808 authors were included in this study. b. The co-citation network of cited references analyzed using VOSviewer. The size of the nodes and the distance between the two nodes represent the number of citations and the level of similarity between nodes. The co-citation network analysis shows two clusters expressed in two different colors, red and green, with each color representing a different group of research topics

Analysis of the most influential papers and their co-citation network

The most influential papers were assessed based on the total citations of each document. The analysis revealed the top 10 papers with more than 40 citations. (Supplementary File Table V) The paper with the highest total citations was authored by Wu and team in 2008, titled "Anti-inflammatory effect of spilanthol from *Spilanthes acmella* on murine macrophage by down-regulating LPS-induced inflammatory mediators," published in the Journal of Agricultural and Food Chemistry. The top 10 most productive papers discussed the anti-inflammatory activity of isolates, compound combinations, and extracts from medicinal plants. These papers explored various mechanisms of anti-inflammatory action, including downregulation of the MAPK and NF-κB pathways (El Gizawy et al., 2021; Gao et al., 2017; Luo et al., 2016), inhibition of NF-κB (Giribabu et al., 2017; Güran et al., 2019; Jang et al., 2017; Wu et al., 2008; Zou et al., 2018)and Erk1/2 signaling pathways (Zou et al., 2018), and antioxidant effects (Abdallah & Esmat, 2017; Huang et al., 2010). Co-citation network analysis is used to analyze and manage the knowledge structure and topic bases of a particular scientific field (Shiau et al., 2017). Co-citation network is the concept of two documents being cited by another document, called "Co-cited" (Bamel et al., 2020; Shiau et al., 2017). Two documents are strongly correlated if they are cited intermittently by other documents (Bamel et al., 2020; Shiau et al., 2017). Co-citation network helps identify the most influential published articles to determine thematic clusters (Donthu et al., 2021). The co-citation network was analyzed based on unit analysis of the cited references. Fractional counting was used for this calculation. Co-authored publications were counted fractionally for each author, with the overall weight of the publications equal to one (Bamel et al., 2020; Perianes-Rodriguez et al., 2016; Van Eck & Waltman, 2014). Indeed, in fractional counting, each publication is assigned the same overall weight, ensuring balance, consistency, and precision in bibliometric measurement. This approach aims to provide a fair and accurate representation of the contributions of each publication within the analysis, regardless of factors such as the number of authors or citations (Sivertsen et al., 2019).

By setting a criterion of a minimum of two citations, 20 documents out of 6.256 references cited met the threshold. However, if the criterion is lowered to a minimum of one citation, all 6.256

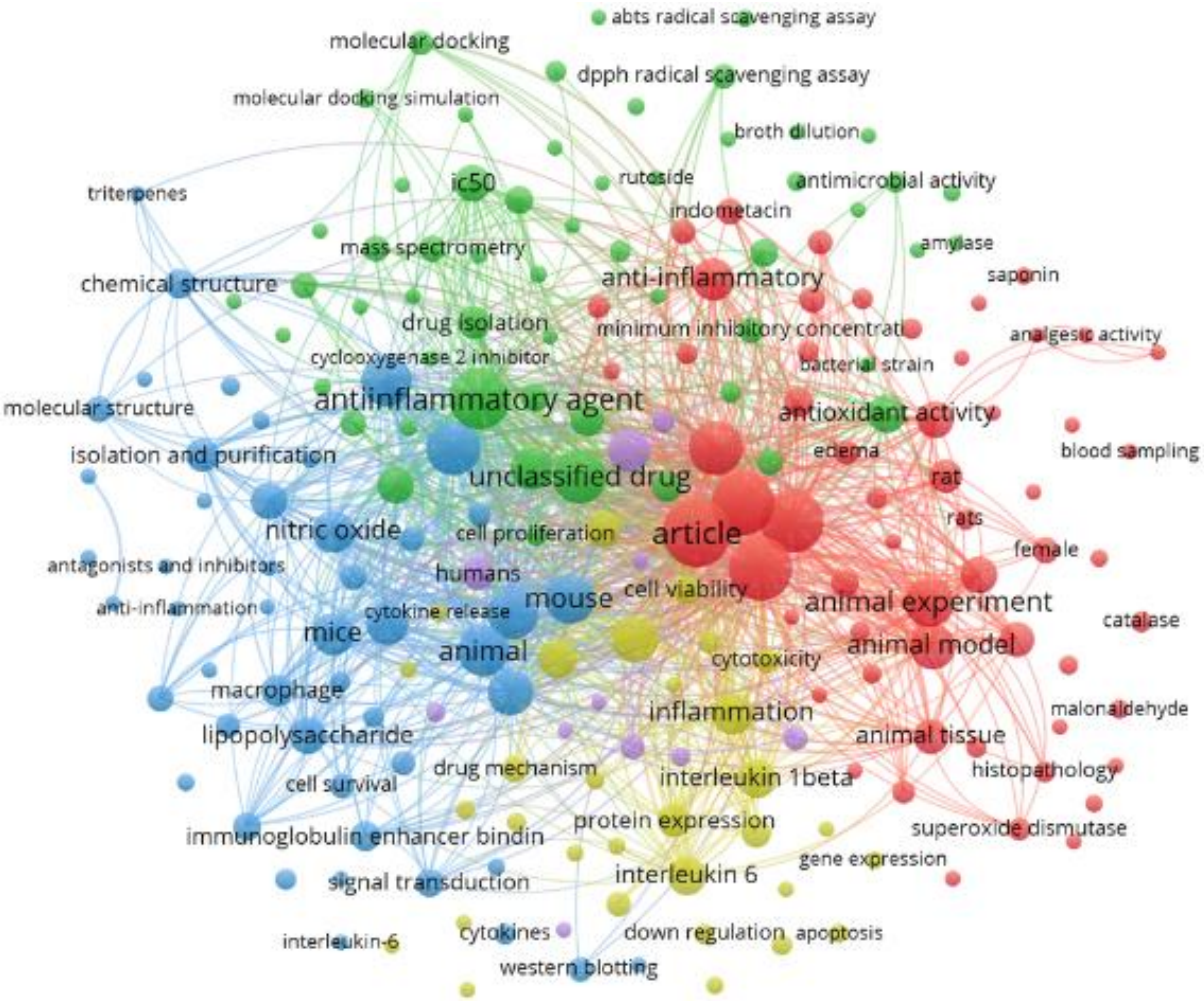

Figure 4. Keyword co-occurrence network analyzed using VOSviewer. The visualization revealed that there are 2481 keywords extracted from the 121 selected documents. Due to limitation in the visualization, the program only selected 1000 keywords. Therefore, two keywords were applied and resulted in 633 keywords that met the criteria. After exclusion of the irrelevant terms, five clusters were identified within the Keyword co-occurrence network (Supplementary File Table VI).

documents meet the threshold. When creating a co-citation network from these 6.256 documents, the program selects only 1.000 documents but removes some items that are not connected in the network visualization based on the greatest total link strength. This criterion results in a network consisting of 124 items with the highest item linkage. Therefore, to ensure the creation of a meaningful and interpretable network, despite only 20 items having the greatest item linkage, a minimum of two citations criterion was used. This decision was made to maintain the quality and relevance of the co-citation network visualization. The results of the co-citation analysis (Figure 3b) indicated by the color of the nodes. Cluster 1 (red nodes) focuses on discussions related to anti-inflammatory agents that have been discovered and developed (Dinarello, 2010), physiology of inflammation (Medzhitov, 2008), anti-inflammatory activity of alkaloid compounds from the plant *Veratrum taliense* (Jia et al., 2020), and analgesic and anti-inflammatory potential of steroidal alkaloids from *Veratrum taliense* (Q. Li et al., 2016). Cluster 2 (green nodes) focuses on gene expression in LPS-induced human monocytes (Guha & Mackman, 2001), the search process of anti-inflammatory drug compounds in atherosclerosis (Libby, 2013), and the inhibitory activity on NO production of new compounds, including sesquiterpenes such as zedoarofuran, 4-epicurcumenol, neocurcumenol, gajutsulactones A and B, and zedoarolides A and B, extracted from *Zedoariae Rhizoma* (Matsuda et al., 2001). The two clusters provide further direction for exploring new plant-derived compounds with anti-inflammatory activity and their mechanisms of action.

Keyword co-occurrence network and overlay

Keyword co-occurrence networks and overlays were utilized to identify the most frequently used and influential terms. The interpretation of this data offers valuable insights into key research topics within a specific field. This approach provides a quick, objective, and actionable method for understanding current research trends and guiding future research directions (Bamel et al., 2020; Grames et al., 2019). The calculation method employed is full counting, meaning that the number of occurrences of a keyword included in the analysis represents the total occurrence of that keyword in all documents. All keywords are categorized into author keywords ("article titles," "abstracts," and "full texts") and indexed keywords for comprehensive coverage and analysis (Bamel et al., 2020; Grames et al., 2019; Zhang et al., 2019b). The keyword co-occurrence network is represented by the appearance of each node (Grames et al., 2019). The calculation method uses fractional counting, to create co-occurrences of keywords as the network level can normalize the relative weight of links and present more realistic results. This approach explains the structure in the network (Vargas-Quesada et al., 2017). This analysis encompasses three analysis options: author keywords, indexed keywords, and all keywords (which include both author and indexed keywords). In this analysis, all keywords are utilized to ensure comprehensive coverage. Author keywords and indexed keywords offer valuable insights into the authorship and content interpretation, respectively (Vargas-Quesada et al., 2017). Previous research indicates that author keywords are effective for exploring the structure of scientific fields in bibliometric analysis. However, it's important to acknowledge the potential for bias, as some researchers may strategically use certain keywords to enhance the visibility of their articles. On the other hand, indexed keywords are highly comprehensive and provide a robust means of visualizing the content of the article (Bonaccorsi, 2008; Vargas-Quesada et al., 2017; Zhang et al., 2016).

Keyword co-occurrence and the results are divided into 3 (Figure 4). From the figure, cluster 1 (Red nodes) contains 58 detected keywords. This cluster reveals *in vivo* analgesic and anti-inflammatory tests of secondary metabolites from traditional medicinal plants on rat test animals. The tests cover various parameters related to analgesic and anti-inflammatory effects, and the cluster extends to other related diseases, supporting scientific fields beyond these specific tests. Cluster 2 (Green Nodes/ 56 keywords), This cluster highlights the isolation and identification of phytochemical compounds utilizing various instruments. It encompasses a range of anti-inflammatory tests conducted both in vitro and in vivo, along with other related tests. Cluster 3 (Blue Nodes/ 49 keywords), This cluster illustrates in vitro and in vivo anti-inflammatory testing, along with various molecular mechanism assays. Cluster 4 (Yellow Nodes/ 31 keywords), This cluster focuses on testing several parameters related to inflammatory mediators and markers of associated diseases. Additionally, it includes testing of the molecular mechanisms underlying these processes. Cluster 5 (Purple Nodes/ 11 keywords), This cluster unveils plant tests alongside supporting tests related to the microbial causes of inflammation.

Conclusion and implication

This study aimed to provide academics with a better understanding of how research on herbal anti-inflammatory remedies has evolved. Through bibliometric analysis, which considers trends in publications such as writing styles, citations, sources used, countries active in this research, highly influential authors, international collaborations between countries or authors, and development of research topics, the study also desires to identify emerging concepts in this field. The analysis, which spans from 2004 to 2023, provides an in-depth understanding of the conceptual, intellectual, and social underpinnings of research issues in this area.

In this study, 121 articles were collected from Scopus and evaluated using the BiblioShiny platform in RStudio® and VOSviewer. According to the findings of the analysis, from 2004 to 2023, publications discussing the use of herbal anti-inflammatory remedies grew steadily. The number of publications notably increased in 2021.

This descriptive study shows a marked rise in publications that advance our understanding of herbal innovation for anti-inflammation and mechanisms. According to TC, China is not only the largest producer but also the most influential nation in this field. China had a higher NP than other countries. Moreover, Southwest Medical University is the second-most productive institution in terms of scientific publications, after Shenyang Pharmaceutical University. The analysis emphasizes the importance of institutions and cross-border cooperation in demonstrating a global interest in this subject. Based on the TC, total publication, and h-index, the *Journal of Ethnopharmacology* is the most productive journal. The most prolific author and the most citation is Li J, receiving 143 in total. Furthermore, the involvement of Indonesian researchers in this topic is still limited, presenting an opportunity for further research in the field of herbal anti-inflammatory and molecular mechanisms from Indonesian plants.

Practical Implication

This study has four significant implications. **First**, the research findings facilitate better collaboration among researchers, enabling them to establish research partnerships based on the results of the analysis. **Second**, this study can serve as a valuable guide for researchers specializing in herbal remedies as anti-inflammatory agents, helping them identify the most relevant studies in the field. **Third**, the study reveals gaps in existing research that can serve as a foundation for making decisions regarding further research based on evidence. **Fourth**, this study can be a monitoring tool for tracking progress in herbal remedies for use as anti-inflammatory agents over time, aiding researchers in determining research topics for future funding applications.

CONFLICT OF INTEREST

The authors declare no conflict of interest

ACKNOWLEDGEMENT

The authors would like to thank the Center for Higher Education Funding (BPPT) and Indonesia Endowment Fund for Education (LPDP) for the financial support through a Doctoral Scholarship Scheme with Number 00751/J5.2.3/BPI.06/9/2022 obtained by the first author.

REFERENCES

Abdallah, H. M., & Esmat, A. (2017). Antioxidant and anti-inflammatory activities of the major phenolics from *Zygophyllum simplex* L. *Journal of Ethnopharmacology*, *205*, 51–56. Scopus. https://doi.org/10.1016/j.jep.2017.04.022

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2021). Scientific production and thematic breakthroughs in smart learning environments: A bibliometric analysis. *Smart Learning Environments*, *8*(1), 1. https://doi.org/10.1186/s40561-020-00145-4

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Bagad, A. S., Joseph, J. A., Bhaskaran, N., & Agarwal, A. (2013a). Comparative evaluation of anti-inflammatory activity of curcuminoids, turmerones, and aqueous extract of *Curcuma longa*. *Advances in Pharmacological Sciences*, *2013*, 1–7. https://doi.org/10.1155/2013/805756

Bamel, U. K., Pandey, R., & Gupta, A. (2020). Safety climate: Systematic literature network analysis of 38 years (1980-2018) of research. *Accident Analysis & Prevention*, *135*, 105387. https://doi.org/10.1016/j.aap.2019.105387

Baumgartner, L., Sosa, S., Atanasov, A. G., Bodensieck, A., Fakhrudin, N., Bauer, J., Favero, G. D., Ponti, C., Heiss, E. H., Schwaiger, S., Ladurner, A., Widowitz, U., Loggia, R. D., Rollinger, J. M., Werz, O., Bauer, R., Dirsch, V. M., Tubaro, A., & Stuppner, H. (2011). Lignan derivatives from *Krameria lappacea* roots inhibit acute inflammation in vivo and pro-inflammatory mediators in vitro. *Journal of*

Natural Products, *74*(8), 1779–1786. https://doi.org/10.1021/np200343t

Bonaccorsi, A. (2008). Search regimes and the industrial dynamics of science. *Minerva*, *46*(3), 285–315. https://doi.org/10.1007/s11024-008-9101-3

Chang, Y.-W., Huang, M.-H., & Lin, C.-W. (2015). Evolution of research subjects in library and information science based on keyword, bibliographical coupling, and co-citation analyses. *Scientometrics*, *105*(3), 2071–2087. https://doi.org/10.1007/s11192-015-1762-8

Chen, G., Wu, J., Li, N., & Guo, M. (2018). Screening for anti-proliferative and anti-inflammatory components from *Rhamnus davurica* Pall. Using bio-affinity ultrafiltration with multiple drug targets. *Analytical and Bioanalytical Chemistry*, *410*(15), 3587–3595. Scopus. https://doi.org/10.1007/s00216-018-0953-6

Colombini, A., Libonati, F., Cangelosi, D., Lopa, S., De Luca, P., Coviello, D. A., Moretti, M., & De Girolamo, L. (2022). Inflammatory priming with IL-1β promotes the immunomodulatory behavior of adipose derived stem cells. *Frontiers in Bioengineering and Biotechnology*, *10*, 1000879. https://doi.org/10.3389/fbioe.2022.1000879

de Oliveira, R. G., Mahon, C. P. A. N., Ascêncio, P. G. M., Ascêncio, S. D., Balogun, S. O., & Martins, D. T. de O. (2014). Evaluation of anti-inflammatory activity of hydroethanolic extract of *Dilodendron bipinnatum* Radlk. *Journal of Ethnopharmacology*, *155*(1), 387–395. https://doi.org/10.1016/j.jep.2014.05.041

Dewanjee, S., Dua, T. K., & Sahu, R. (2013). Potential anti-inflammatory effect of *Leea macrophylla* Roxb. leaves: A wild edible plant. *Food and Chemical Toxicology*, *59*, 514–520. https://doi.org/10.1016/j.fct.2013.06.038

Dinarello, C. A. (2010). Anti-inflammatory agents: Present and Future. *Cell*, *140*(6), 935–950. https://doi.org/10.1016/j.cell.2010.02.043

Divya, T., Latha, P., Usha, K., Anuja, G., Suja, S., Shyamal, S., Shine, V., Sini, S., Shikha, P., & Rajasekharan, S. (2009). Anti-inflammatory, analgesic and anti-lipid peroxidative properties of *Wattakaka volubilis* (Linn.f.) Stapf. *8*.

Djunarko, I., Fakhrudin, N., Nurrochmad, A., & Wahyuono, S. (2022). In vivo Anti-Inflammatory Activity of *Coleus atropurpureus* leaves extract and fractions. *Tropical Journal of Natural Product Research*, *6*(1), 40–43. https://doi.org/10.26538/tjnpr/v6i1.8

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

El Gizawy, H. A., Boshra, S. A., Mostafa, A., Mahmoud, S. H., Ismail, M. I., Alsfouk, A. A., Taher, A. T., & Al-Karmalawy, A. A. (2021). *Pimenta dioica* (L.) merr. Bioactive constituents exert anti-sars-cov-2 and anti-inflammatory activities: Molecular docking and dynamics, in vitro, and in vivo studies. *Molecules*, *26*(19). Scopus. https://doi.org/10.3390/molecules26195844

Fakhrudin, N., Dwi Astuti, E., Sulistyawati, R., Santosa, D., Susandarini, R., Nurrochmad, A., & Wahyuono, S. (2017). N-hexane insoluble fraction of *Plantago lanceolata* exerts anti-inflammatory activity in mice by inhibiting cyclooxygenase-2 and reducing chemokines levels. *Scientia Pharmaceutica*, *85*(1), 12. https://doi.org/10.3390/scipharm85010012

Fakhrudin, N., Hastuti, S., Andriani, A., Widyarini, S., & Nurrochmad, A. (2015). Study on the antiinflammatory activity of *Artocarpus altilis* leaves extract in mice. *International Journal of Pharmacognosy and Phytochemical Research*, *7*(6), 1080–1085.

Fakhrudin, N., Putri, P. S., & Wahyuono, S. (2013). Antiinflamatory activity of methanolic extract of *Mangifera casturi* in thioglycollate-induced leukocyte migration on mice. *Traditional Medicine Journal*, *18*(3), 151–156. https://doi.org/10.22146/tradmedj.8217

Fatimah, S. F., Lukitaningsih, E., Martien, R., & Nugroho, A. K. (2022). Bibliometric analysis of articles on nanoemulsion and/or in-situ gel for ocular drug delivery system published during the 2011–2021 period. *Pharmacia*, *69*(2), 467–484. https://doi.org/10.3897/pharmacia.69.e82847

Fernández, M. I. E., Barbosa, P. L., & Guerrero, A. P. (2010). Web of science vs. scopus: Un estudio cuantitativo en ingeniería química. *Anales de Documentación*, 13, 159-175.

Gao, H., Cui, Y., Kang, N., Liu, X., Liu, Y., Zou, Y., Zhang, Z., Li, X., Yang, S., Li, J., Wang, C., Xu, Q.-M., & Chen, X. (2017). Isoacteoside, a dihydroxyphenylethyl glycoside, exhibits anti-inflammatory effects through blocking toll-like receptor 4 dimerization. *British Journal of Pharmacology*, *174*(17), 2880–2896. Scopus. https://doi.org/10.1111/bph.13912

Gautam, R., & Jachak, S. M. (2009). Recent developments in anti-inflammatory natural products. *Medicinal Research Reviews*, *29*(5), 767–820. https://doi.org/10.1002/med.20156

Girard, S., Kadhim, H., Roy, M., Lavoie, K., Brochu, M.-E., Larouche, A., & Sébire, G. (2009). Role of perinatal inflammation in cerebral palsy. *Pediatric Neurology*, *40*(3), 168–174. https://doi.org/10.1016/j.pediatrneurol.2008.09.016

Giribabu, N., Karim, K., Kilari, E. K., & Salleh, N. (2017). *Phyllanthus niruri* leaves aqueous extract improves kidney functions, ameliorates kidney oxidative stress, inflammation, fibrosis and apoptosis and enhances kidney cell proliferation in adult male rats with diabetes mellitus. *Journal of Ethnopharmacology*, *205*, 123–137. Scopus. https://doi.org/10.1016/j.jep.2017.05.002

Gorzalczany, S., López, P., Acevedo, C., & Ferraro, G. (2011). Anti-inflammatory effect of Lithrea molleoides extracts and isolated active compounds. *Journal of Ethnopharmacology*, *133*(3), 994–998. https://doi.org/10.1016/j.jep.2010.11.031

Grames, E. M., Stillman, A. N., Tingley, M. W., & Elphick, C. S. (2019). An automated approach to identifying search terms for systematic reviews using keyword co-occurrence networks. *Methods in Ecology and Evolution*, *10*(10), 1645–1654. https://doi.org/10.1111/2041-210X.13268

Guha, M., & Mackman, N. (2001). LPS induction of gene expression in human monocytes. *Cellular Signalling*, *13*(2), 85–94. https://doi.org/10.1016/S0898-6568(00)00149-2

Güran, M., Şanlıtürk, G., Kerküklü, N. R., Altundağ, E. M., & Süha Yalçın, A. (2019). Combined effects of quercetin and curcumin on anti-inflammatory and antimicrobial parameters in vitro. *European Journal of Pharmacology*, *859*. Scopus. https://doi.org/10.1016/j.ejphar.2019.172486

Hayden, M. S., & Ghosh, S. (2012). NF-κB, the first quarter-century: Remarkable progress and outstanding questions. *Genes & Development*, *26*(3), 203–234. https://doi.org/10.1101/gad.183434.111

Hendrayani, S.-F., Al-Harbi, B., Al-Ansari, M. M., Silva, G., & Aboussekhra, A. (2106). The inflammatory/cancer-related IL-6/STAT3/NF-κB positive feedback loop includes AUF1 and maintains the active state of breast myofibroblasts. *Oncotarget*, *7*(27), 41974–41985. https://doi.org/10.18632/oncotarget.9633

Henríquez-Olguín, C., Altamirano, F., Valladares, D., López, J. R., Allen, P. D., & Jaimovich, E. (2015). Altered ROS production, NF-κB activation and interleukin-6 gene expression induced by electrical stimulation in dystrophic mdx skeletal muscle cells. *Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease*, *1852*(7), 1410–1419. https://doi.org/10.1016/j.bbadis.2015.03.012

Huang, L.-J., Gao, W.-Y., Li, X., Zhao, W.-S., Huang, L.-Q., & Liu, C.-X. (2010). Evaluation of the in vivo anti-inflammatory effects of extracts from *Pyrus bretschneideri* Rehd. *Journal of Agricultural and Food Chemistry*, *58*(16), 8983–8987. Scopus. https://doi.org/10.1021/jf101390q

Jang, H.-J., Lee, S., Lee, S.-J., Lim, H.-J., Jung, K., Kim, Y. H., Lee, S. W., & Rho, M.-C. (2017). Anti-inflammatory Activity of eudesmane-type sesquiterpenoids from *Salvia plebeia*. *Journal of Natural Products*, *80*(10), 2666–2676. Scopus. https://doi.org/10.1021/acs.jnatprod.7b00326

Jang, M. K., Lee, H. J., Kim, J. S., & Ryu, J.-H. (2004). A curcuminoid and two sesquiterpenoids from *Curcuma zedoaria* as Inhibitors of nitric oxide synthesis in activated macrophages. *Archives of Pharmacal Research*, *27*(12), 1220–1225. Scopus. https://doi.org/10.1007/BF02975885

Jia, X.-Y., Wu, Y.-M., Li, J.-Y., Lei, C., & Hou, A.-J. (2020). Alkaloid constituents of *Ficus hispida* and their antiinflammatory activity. *Natural Products and Bioprospecting*, *10*(1), 45–49. https://doi.org/10.1007/s13659-020-00233-5

Jo, W. S., Yang, K. M., Choi, Y. J., Jeong, C. H., Ahn, K. J., Nam, B. H., Lee, S. W., Seo, S. Y., & Jeong, M. H. (2010). In vitro and in vivo anti-inflammatory effects of pegmatite. *Molecular & Cellular Toxicology*, *6*(2), 195–202. https://doi.org/10.1007/s13273-010-0027-0

Kaminska, B. (2005). MAPK signalling pathways as molecular targets for anti-inflammatory therapy—From molecular mechanisms to therapeutic benefits. *Biochimica et Biophysica Acta (BBA) - Proteins and Proteomics*, *1754*(1–2), 253–262. https://doi.org/10.1016/j.bbapap.2005.08.017

Kandil, Z. A., Esmat, A., El-Din, R. S., & Ezzat, S. M. (2020). Anti-inflammatory activity of the lipophilic metabolites from *Scolymus hispanicus* L. *South African Journal of Botany*, *131*, 43–50. Scopus. https://doi.org/10.1016/j.sajb.2020.01.022

Kent Baker, H., Pandey, N., Kumar, S., & Haldar, A. (2020). A bibliometric analysis of board diversity: Current status, development, and future research directions. *Journal of Business Research*, *108*, 232–246. https://doi.org/10.1016/j.jbusres.2019.11.025

Khitous, F., Strozzi, F., Urbinati, A., & Alberti, F. (2020). A systematic literature network analysis of existing themes and emerging research trends in circular economy. *Sustainability*, *12*(4), 1633. https://doi.org/10.3390/su12041633

Kumari, K. D. K. P., Weerakoon, T. C. S., Handunnetti, S. M., Samarasinghe, K., & Suresh, T. S. (2014). Anti-inflammatory activity of dried flower extracts of *Aegle marmelos* in Wistar rats. *Journal of Ethnopharmacology*, *151*(3), Article 3. https://doi.org/10.1016/j.jep.2013.12.043

Kyriakis, J. M., & Avruch, J. (2001). Mammalian mitogen-activated protein kinase signal transduction pathways activated by stress and inflammation. *Physiological Reviews*, *81*(2), 807–869. https://doi.org/10.1152/physrev.2001.81.2.807

Lawrence, T. (2009). The Nuclear Factor NF- B Pathway in Inflammation. *Cold Spring Harbor Perspectives in Biology*, *1*(6), a001651–a001651. https://doi.org/10.1101/cshperspect.a001651

Li, Q., Yang, K.-X., Zhao, Y.-L., Qin, X.-J., Yang, X.-W., Liu, L., Liu, Y.-P., & Luo, X.-D. (2016). Potent anti-inflammatory and analgesic steroidal alkaloids from *Veratrum taliense*. *Journal of Ethnopharmacology*, *179*, 274–279. https://doi.org/10.1016/j.jep.2015.12.059

Li, X., Qi, H., Zhang, X., Liang, H., & Zeng, N. (2023). Jing-Fang n-butanol extract and its isolated JFNE-C inhibit ferroptosis and inflammation in LPS induced RAW264.7 macrophages via STAT3/p53/SLC7A11 signaling pathway. *Journal of Ethnopharmacology*, *316*. Scopus. https://doi.org/10.1016/j.jep.2023.116689

Libby, P. (2013). History of discovery: inflammation in atherosclerosis. *Arterioscler Thromb Vasc Biol 32*(9), 2045–2051. https://www.ahajournals.org/doi/10.1161/ATVBAHA.108.179705

Luo, J., Kong, J.-L., Dong, B.-Y., Huang, H., Wang, K., Wu, L.-H., Hou, C.-C., Liang, Y., Li, B., & Chen, Y.-Q. (2016). Baicalein attenuates the quorum sensing-controlled virulence factors of *Pseudomonas aeruginosa* and relieves the inflammatory response in *P. aeruginosa*-infected macrophages by downregulating the MAPK and NFκB signal-transduction pathways. *Drug Design, Development and Therapy*, *10*, 183–203. Scopus. https://doi.org/10.2147/DDDT.S97221

Ma, R. (2012). Author bibliographic coupling analysis: A test based on a chinese academic database. *Journal of Informetrics*, *6*(4), 532–542. https://doi.org/10.1016/j.joi.2012.04.006

Matsuda, H., Morikawa, T., Toguchida, I., Ninomiya, K., & Yoshikawa, M. (2001). Medicinal Foodstuffs. XXVIII. Inhibitors of nitric oxide production and new sesquiterpenes, zedoarofuran, 4-epicurcumenol, neocurcumenol, gajutsulactones a and b, and zedoarolides a and b, from *Zedoariae rhizoma*. *Chemical and Pharmaceutical Bulletin*, *49*(12), 1558–1566. https://doi.org/10.1248/cpb.49.1558

Mazzio, E. A., Li, N., Bauer, D., Mendonca, P., Taka, E., Darb, M., Thomas, L., Williams, H., & Soliman, K. F. A. (2016). Natural product HTP screening for antibacterial (*E. coli* 0157:H7) and anti-inflammatory agents in (LPS from E. coli O111:B4) activated macrophages and microglial cells; focus on sepsis. *BMC Complementary and Alternative Medicine*, *16*(1). Scopus. https://doi.org/10.1186/s12906-016-1429-x

McLeish, K. R., Merchant, M. L., Creed, T. M., Tandon, S., Barati, M. T., Uriarte, S. M., & Ward, R. A. (2017). Frontline Science: Tumor necrosis factor-α stimulation and priming of human neutrophil granule exocytosis. *Journal of Leukocyte Biology*, *102*(1), 19–29. https://doi.org/10.1189/jlb.3HI0716-293RR

Medzhitov, R. (2008). Origin and physiological roles of inflammation. *Nature*, *454*(7203), 428–435. https://doi.org/10.1038/nature07201

Nualkaew, S., Thongpraditchote, S., Wongkrajang, Y., Umehara, K., & Noguchi, H. (2017).

Isolation of a new compound, 2-butanone 4-glucopyranoside 6′-O-gallate and other 8 compounds from the anti-inflammatory leave extracts of *Memecylon edule* Roxb. *Natural Product Research*, *31*(12), 1370–1378. Scopus. https://doi.org/10.1080/14786419.2016.1253074

Oeckinghaus, A., Hayden, M. S., & Ghosh, S. (2011). Crosstalk in NF-κB signaling pathways. *Nature Immunology*, *12*(8), 695–708. https://doi.org/10.1038/ni.2065

Pearson, G., Robinson, F., Gibson, T. B., Xu, B.-E., Karandikar, M., Berman, K., & Cobb, M. H. (2001). Mitogen-activated protein (MAP) Kinase pathways: Regulation and physiological functions. *Endocrine Reviews*, *22*(2), 153-183. https://doi.org/10.1210/edrv.22.2.0428

Perianes-Rodriguez, A., Waltman, L., & Van Eck, N. J. (2016). Constructing bibliometric networks: A comparison between full and fractional counting. *Journal of Informetrics*, *10*(4), 1178–1195. https://doi.org/10.1016/j.joi.2016.10.006

Qandil, A. (2012). Prodrugs of nonsteroidal anti-inflammatory drugs (NSAIDs), more than meets the eye: A Critical Review. *International Journal of Molecular Sciences*, *13*(12), Article 12. https://doi.org/10.3390/ijms131217244

Radulović, N. S., Randjelović, P. J., Stojanović, N. M., Cakić, N. D., Bogdanović, G. A., & Živanović, A. V. (2015). Aboriginal bush foods: A major phloroglucinol from Crimson Bottlebrush flowers (*Callistemon citrinus*, Myrtaceae) displays strong antinociceptive and anti-inflammatory activity. *Food Research International*, *77*, 280–289. Scopus. https://doi.org/10.1016/j.foodres.2015.02.023

Shehata, I. A., El-harshany, E., Abdallah, H. M., Esmat, A., & Abdel-sattar, E. A. (2018). Anti-inflammatory activity of Kleinia odora. *European Journal of Integrative Medicine*, *23*, 64–69. Scopus. https://doi.org/10.1016/j.eujim.2018.10.005

Shiau, W.-L., Dwivedi, Y. K., & Yang, H. S. (2017). Co-citation and cluster analyses of extant literature on social networks. *International Journal of Information Management*, *37*(5), 390–399. https://doi.org/10.1016/j.ijinfomgt.2017.04.007

Sivertsen, G., Rousseau, R., & Zhang, L. (2019). Measuring scientific contributions with modified fractional counting. *Journal of Informetrics*, *13*(2), 679–694. https://doi.org/10.1016/j.joi.2019.03.010

Sofidiya, M. O., Imeh, E., Ezeani, C., Aigbe, F. R., & Akindele, A. J. (2014). Antinociceptive and anti-inflammatory activities of ethanolic extract of Alafia barteri. *Revista Brasileira de Farmacognosia*, *24*(3). https://doi.org/10.1016/j.bjp.2014.07.013

Sostres, C., Gargallo, C. J., Arroyo, M. T., & Lanas, A. (2010). Adverse effects of non-steroidal anti-inflammatory drugs (NSAIDs, aspirin and coxibs) on upper gastrointestinal tract. *Best Practice & Research Clinical Gastroenterology*, *24*(2), 121–132. https://doi.org/10.1016/j.bpg.2009.11.005

Suwandi, D. W., Rostnawati, T., Muchtaridi, M., & Subarnas, A. (2021). In vitro evaluation of selligueain A effects on the proinflammatory mediators production in RAW264.7 murine macrophages. *Journal of Herbmed Pharmacology*, *10*(3), 313–318. https://doi.org/10.34172/jhp.2021.36

Tanaka, T., & Kishimoto, T. (2014). The Biology and Medical Implications of Interleukin-6. *Cancer Immunology Research*, *2*(4), 288–294. https://doi.org/10.1158/2326-6066.CIR-14-0022

Uddin, G., Rauf, A., Siddiqui, B. S., Muhammad, N., Khan, A., & Shah, S. U. A. (2014). Anti-nociceptive, anti-inflammatory and sedative activities of the extracts and chemical constituents of Diospyros lotus L. *Phytomedicine*, *21*(7), 954–959. https://doi.org/10.1016/j.phymed.2014.03.001

Vallabhapurapu, S., & Karin, M. (2009). Regulation and Function of NF-κB Transcription Factors in the Immune System. *Annual Review of Immunology*, *27*(1), 693–733. https://doi.org/10.1146/annurev.immunol.021908.132641

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds), *Measuring Scholarly Impact* (pp. 285–320). Springer International Publishing. https://doi.org/10.1007/978-3-319-10377-8_13

Vargas-Quesada, B., Chinchilla-Rodríguez, Z., & Rodriguez, N. (2017). Identification and visualization of the intellectual structure in graphene research. *Frontiers in Research Metrics and Analytics*, *2*, 7. https://doi.org/10.3389/frma.2017.00007

Vogl, S., Picker, P., Mihaly-Bison, J., Fakhrudin, N., Atanasov, A. G., Heiss, E. H., Wawrosch, C., Reznicek, G., Dirsch, V. M., Saukel, J., & Kopp, B. (2013). Ethnopharmacological in vitro studies on Austria's folk medicine—An unexplored lore in vitro anti-inflammatory activities of 71 Austrian traditional herbal drugs. *Journal of Ethnopharmacology*, *149*(3), 750–771. https://doi.org/10.1016/j.jep.2013.06.007

Wang, A., Xiao, Z., Zhou, L., Zhang, J., Li, X., & He, Q. (2016). The protective effect of atractylenolide I on systemic inflammation in the mouse model of sepsis created by cecal ligation and puncture. *Pharmaceutical Biology*, *54*(1), 146–150. Scopus. https://doi.org/10.3109/13880209.2015.1024330

Wang, S.-L., Hwang, T.-L., Chung, M.-I., Sung, P.-J., Shu, C.-W., Cheng, M.-J., & Chen, J.-J. (2015). New flavones, a 2-(2-phenylethyl)-4H-chromen-4-one derivative, and anti-inflammatory constituents from the stem barks of *Aquilaria sinensis*. *Molecules*, *20*(11), 20912–20925. Scopus. https://doi.org/10.3390/molecules201119736

Wu, L.-C., Fan, N.-C., Lin, M.-H., Chu, I.-R., Huang, S.-J., Hu, C.-Y., & Han, S.-Y. (2008). Anti-inflammatory effect of spilanthol from Spilanthes acmella on murine macrophage by down-regulating LPS-induced inflammatory mediators. *Journal of Agricultural and Food Chemistry*, *56*(7), 2341–2349. Scopus. https://doi.org/10.1021/jf073057e

Xiong, H.-Y., Zhang, Z.-J., & Wang, X.-Q. (2021). Bibliometric analysis of research on the comorbidity of pain and inflammation. *Pain Research and Management*, *2021*, 1–13. https://doi.org/10.1155/2021/6655211

Yang, G.-X., Zhang, R.-Z., Lou, B., Cheng, K.-J., Xiong, J., & Hu, J.-F. (2014). Chemical constituents from *Melastoma dodecandrum* and their inhibitory activity on interleukin-8 production in HT-29 cells. *Natural Product Research*, *28*(17), 1383–1387. Scopus. https://doi.org/10.1080/14786419.2014.903480

Yu, Y., Li, Y., Zhang, Z., Gu, Z., Zhong, H., Zha, Q., Yang, L., Zhu, C., & Chen, E. (2020). A bibliometric analysis using VOSviewer of publications on COVID-19. *Annals of Translational Medicine*, *8*(13), 816–816. https://doi.org/10.21037/atm-20-4235

Zhang, D., Zhang, Z., & Managi, S. (2019a). A bibliometric analysis on green finance: Current status, development, and future directions. *Finance Research Letters*, *29*, 425–430. https://doi.org/10.1016/j.frl.2019.02.003

Zhang, D., Zhang, Z., & Managi, S. (2019b). A bibliometric analysis on green finance: Current status, development, and future directions. *Finance Research Letters*, *29*, 425–430. https://doi.org/10.1016/j.frl.2019.02.003

Zhang, J., Yu, Q., Zheng, F., Long, C., Lu, Z., & Duan, Z. (2016). Comparing keywords plus of WOS and author keywords: A case study of patient adherence research. *Journal of the Association for Information Science and Technology*, *67*(4), 967–972. https://doi.org/10.1002/asi.23437

Zhuang, X.-C., Zhang, Y.-L., Chen, G.-L., Liu, Y., Hu, X.-L., Li, N., Wu, J.-L., & Guo, M.-Q. (2021). Identification of anti-inflammatory and anti-proliferative neolignanamides from *Warburgia ugandensis* employing multi-target affinity ultrafiltration and LC-MS. *Pharmaceuticals*, *14*(4). Scopus. https://doi.org/10.3390/ph14040313

Zou, Y.-H., Zhao, L., Xu, Y.-K., Bao, J.-M., Liu, X., Zhang, J.-S., Li, W., Ahmed, A., Yin, S., & Tang, G.-H. (2018). Anti-inflammatory sesquiterpenoids from the traditional chinese medicine salvia plebeia: regulates pro-inflammatory mediators through inhibition of NF-κB and Erk1/2 signaling pathways in LPS-induced raw264.7 cells. *Journal of Ethnopharmacology*, *210*, 95–106. Scopus. https://doi.org/10.1016/j.jep.2017.08.034