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Evolution of research on medicinal plants for non-alcoholic fatty liver disease (NAFLD): A two-decade bibliometric analysis from 2005 to 2024

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ABSTRACT

Non-alcoholic fatty liver disease (NAFLD) has become a major public health concern, affecting an estimated 20-30% of the global population. While statins are commonly prescribed for NAFLD patients, their use is often linked to adverse effects. Consequently, medicinal plants have attracted interest due to their potential therapeutic benefits. This study aimed to evaluate the research landscape on medicinal plants and NAFLD from 2005 to 2024. We retrieved 1,126 articles from the Scopus database and included only those published in English. Bibliometric analysis was performed using Microsoft Office Excel to collect and organise data, Harzing's Publish and Perish for citation analysis, and VOSviewer for data visualisation and cluster analysis. The analysis covered publication growth, citation metrics, leading countries, research areas, organizations, journals, and the most cited papers. Among the 63 countries contributing to this field, China was the predominant contributor, accounting for over half of the total publications (792 of 1,126). The top research area was 'Medicine', reflecting the fact that NAFLD is a significant global health issue requiring extensive medical research to develop effective treatments. Keywords such as NAFLD, animal model, and lipid dominated the literature. The most cited article received 1,442 citations, which related to the pathogenesis of liver disease involves oxidative stress. This bibliometric analysis highlights the growing research interest in medicinal plants for the treatment of NAFLD, underscoring a global effort to explore alternative and complementary therapies. It also provides an evidence-based framework to guide future NAFLD research priorities and inform health policy on the clinical and public health integration of medicinal plant–based interventions.

Keywords: *NAFLD; medicinal plant; bibliometric; Harzing's Publish or Perish and VOSviewer*

INTRODUCTION

Non-alcoholic fatty liver disease (NAFLD) is a spectrum of chronic liver disease characterized by excessive fat accumulation in the liver, in the absence of secondary causes, including excessive alcohol consumption (Pouwels et al., 2022). In 2020, Eslam et al. proposed a new terminology as 'Metabolic dysfunction-associated fatty liver disease' (MAFLD), defined by hepatic steatosis in addition to one of three metabolic criteria: overweight/obesity, type 2 diabetes mellitus (T2DM), or metabolic dysregulation (Eslam et al., 2020).

NAFLD is a complex, multisystem disease involving interactions among organs such as the gut and heart (Yang & Song, 2023). If left untreated, it may progress to complications such as liver cirrhosis and hepatocellular carcinoma (Chua et al., 2022). Dyslipidemia, an unhealthy lifestyle, and metabolic syndrome have also been linked to the development of this disease (Rinella, 2015). Globally, NAFLD affects approximately 20–30% of the world population (Chan et al., 2022). This disease has become a significant public health issue, driven by the worldwide increase in obesity, diabetes, and metabolic syndrome.

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The pathogenesis of NAFLD is multifactorial and not yet fully understood. Elevated triglyceride (TG) levels and reduced high-density lipoprotein cholesterol (HDL-C) concentrations are highly prevalent in this disease (Tzanaki et al., 2022). Previous studies suggest that high glucose, insulin resistance, inflammation, and oxidative stress are key drivers in the pathogenesis of NAFLD, which is further characterized by increased reactive oxygen species (ROS) production and reduced antioxidant enzyme activity in liver tissue (Marra & Lotersztajn, 2013; Rahman et al., 2017). Moreover, accumulating evidence indicates that insulin resistance, endothelial dysfunction, and systemic inflammation in NAFLD may play a role in elevating the risk of cardiovascular disease (CVD). NAFLD may progress to simple steatosis, steatohepatitis, advanced fibrosis, cirrhosis, and eventually hepatocellular carcinoma and death (Srivastava et al., 2019; Kucera & Cervinkova, 2014).

Despite increasing prevalence, effective treatment options for NAFLD remain limited. Medicinal plants have emerged as having potential hepatoprotective properties, with numerous studies highlighting their role in preventing and managing liver diseases, including NAFLD. The World Health Organization (WHO) reports that 80% of populations in developing countries rely on medicinal plants for disease treatment (Duraipandiyan et al., 2006). WHO has also cataloged 21,000 species with medicinal value out of 300,000 species available worldwide (Pandita et al., 2021). The use of medicinal plants for therapeutic applications has a long history, with knowledge of their properties being preserved and transmitted across generations (Caballero-Serrano et al., 2019).

Bibliometric analysis is a quantitative approach that utilizes mathematical and statistical tools to evaluate the relationships and impact of publications within a specific research area (Ellegaard & Wallin, 2015). It helps researchers identify research hotspots and emerging trends in a given field. This method focuses on the literature system and bibliometric characteristics, enabling the assessment of contributions from various entities, such as organizations, countries, and authors. Although research on NAFLD and medicinal plants has expanded considerably, comprehensive bibliometric studies specifically examining global publication trends, collaboration networks, and emerging research themes in this field remain scarce. Existing analyses have largely focused on NAFLD in general or on specific regions, with limited attention to the integration of medicinal plant-based approaches. Therefore, this study aims to address this gap by providing a systematic bibliometric and visual analysis of global research on medicinal plants in NAFLD.

Thus, the objective of this study was to assess the current landscape of research in the field of medicinal plants and NAFLD by employing bibliometric and visual analysis. Scopus database was used to retrieve the data on the growth of publications, citation metrics, top-research areas, country contribution, most active organizations, top-cited articles and journals, relevant keywords, and collaboration between countries from 2005 to 2024.

METHODOLOGY

Data acquisition and search strategy

A retrospective bibliometric study was conducted to analyze research on medicinal plants in the treatment of NAFLD. The publications were retrieved on July 31, 2025, from the Scopus database. We chose Scopus as our data source due to its extensive bibliographic coverage, offering a broader range of literature compared to other databases (Pranckute, 2021). Furthermore, the Scopus database is a comprehensive collection of over 24,000 indexed publications spanning multiple scientific disciplines and equipped with extensive metric analysis tools. Most recently, Shakhsir et al. and Vaisha et al. also used the Scopus database only for their bibliometric analysis of NAFLD (Shakhshir & Sa'ed, 2024; Vaishya et al., 2024). The search terms included “Medicinal plant’’ OR “Traditional medicine” OR “Traditional herb” OR “Herbal medicine’’ AND “NAFLD” OR “non-alcoholic fatty liver” OR “non-alcoholic steatohepatitis’’ OR “MAFLD” OR “Metabolic dysfunction-associated fatty liver” OR “Metabolic-associated fatty liver”. The search was within the article title, abstract, and keywords [TITLE-ABS-KEY]. A total of 1,518 articles were obtained, but we exclusively focused on original articles and reviews. Duplicate records, conference papers, and book chapters were excluded to ensure data quality and consistency for bibliometric analysis. Additionally, we only included articles published in English. Hence, the total number of publications included in this study was 1126. Figure 1 depicts the PRISMA flowchart for the study selection process.

Search period

Our data collection was extracted on 31 July 2025, spanning the period from 2005 to 2024, which covers twenty years of publications. This two-decade span was selected to establish a comprehensive framework for understanding the evolution of research on medicinal plants as treatment for NAFLD.

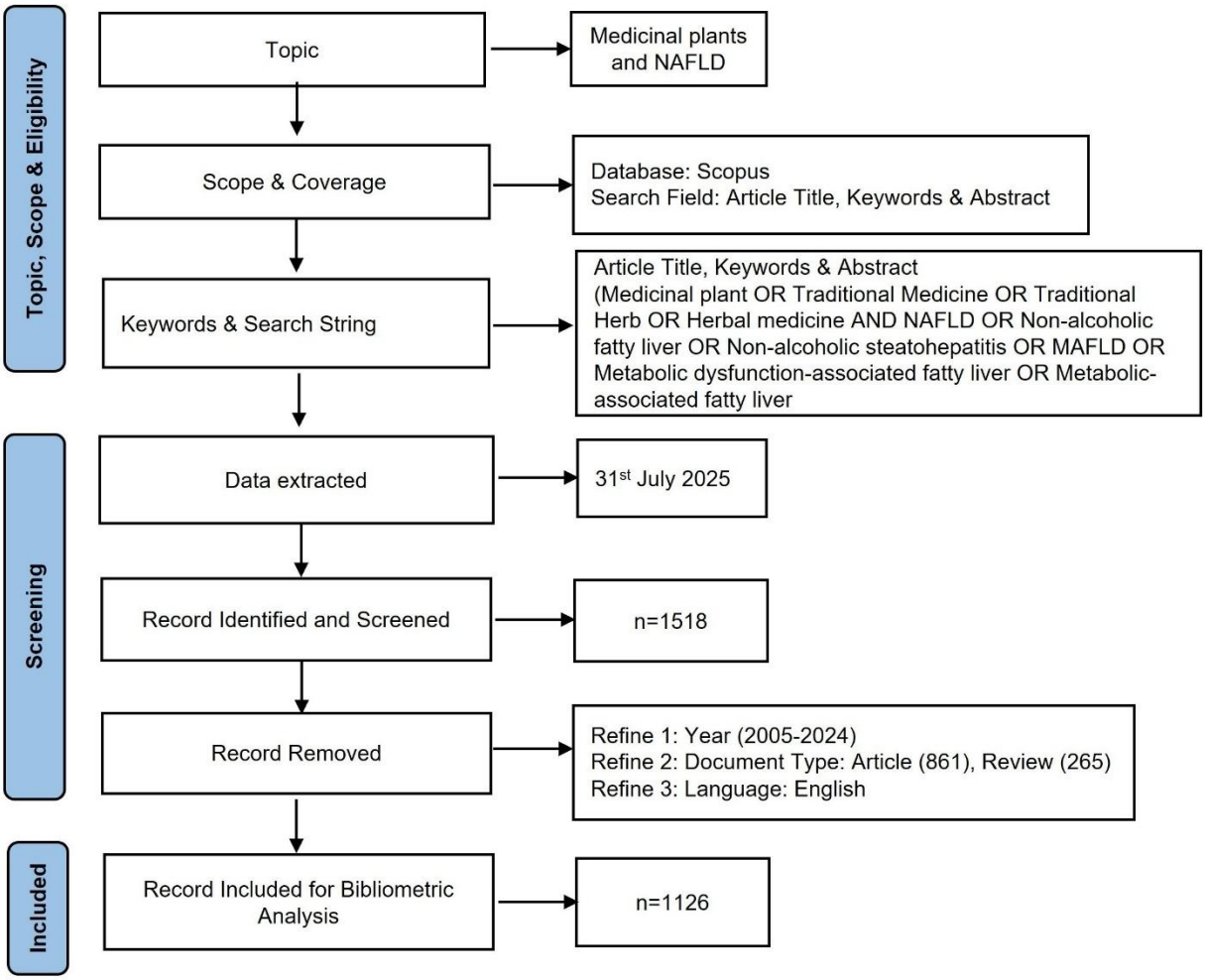
Data extraction and analytical tool

At the time of data collection, 1126 articles on medicinal plants in the treatment of NAFLD were published in the Scopus database between 2005 and 2024. Microsoft Office Excel was used to retrieve and organize the published data. Two independent researchers conducted the literature selection and data extraction to ensure the accuracy of the results. Further analysis was conducted with Harzing's Publish or Perish (PoP) software in.ris format to obtain citation

metrics, including Total Citations (TC), Citations per Paper (C/P), Number of Cited Papers (NCP), Citations per Cited Paper (C/CP), g-index, and h-index. Meanwhile, the bibliometric networks and cluster analysis were generated using the Visualization of Similarities viewer (VOSviewer) software (version 1.6.20) and data in Comma-Separated Values (.csv) format. The color of the bubble or circle nodes indicates which cluster the items belong to. The size of the circle nodes in the graph represented the frequency of the studied items. The links between nodes indicated collaboration or co-occurrence associations, and the distance between nodes represented the degree of association. VOSviewer provides an overlay visualization map in which the color and distance between nodes illustrate their distribution across two-dimensional spaces (time and associations) (Van Eck & Waltman, 2010). The descriptive study included data on the growth of publications, citation metrics, top research areas, organizations, and countries, as well as the most cited papers and journals. In addition, international collaboration among countries and keyword analysis based on the author's keywords were also analyzed.

Figure 1

Search strategy based on PRISMA flow diagram for medicinal plants and NAFLD between 2005 and 2024



RESULTS

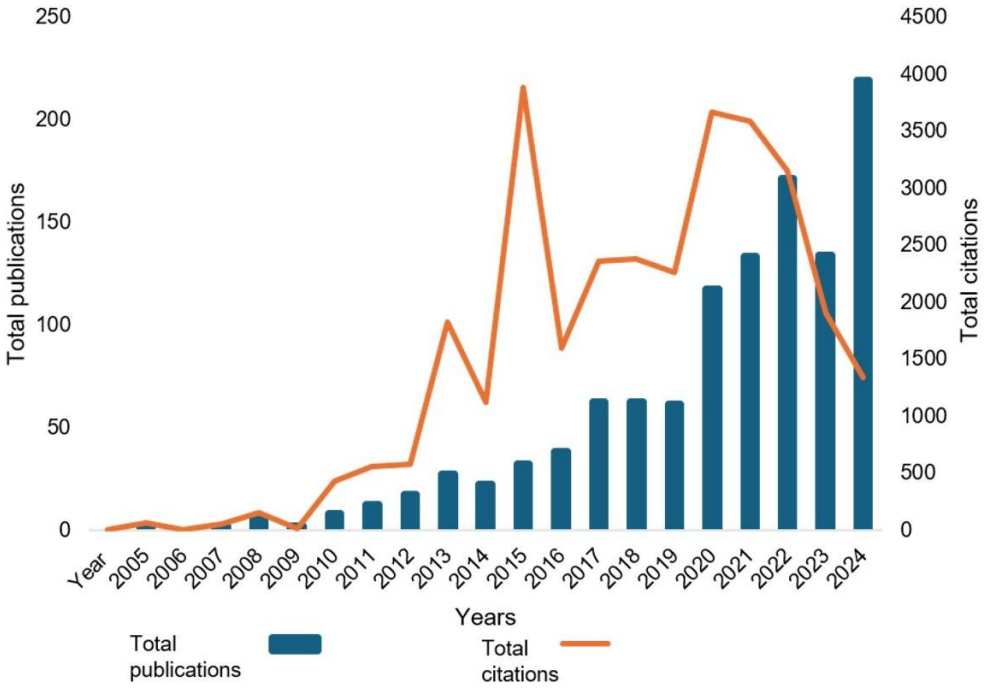
Publication trends and analysis of citations

We found a total of 1,126 articles, comprising 861 (76.46%) original articles and 265 (23.53%) reviews, focused on the use of medicinal plants in the treatment of NAFLD, published between 2005 and 2024. Figure 2 illustrates the total number of publications and total citations globally from 2005 to 2024. There was an upward trend in the number of publications during the study period, except in 2023, when a slight reduction occurred. Although the overall trend demonstrates sustained growth in publications, a noticeable dip in 2023 is evident. This decline is likely attributable to publication lag, indexing delays, or temporary disruptions in research output, rather than a genuine decrease in scientific interest. The findings showed that research on medicinal plants and NAFLD was steadily increasing, and we predicted this growth trend would persist in the future. The highest number of publications was in 2024 (n=219, 19.45%), while there were no publications on this subject in 2006. Meanwhile, the total citations fluctuated, with the highest number in 2015 (n=3882).

Table 1 presents the citation metrics for all articles published between 2005 and 2024. The research identified 1126 publications published within this period, with a total of 30,858 citations. The sample had an average citation rate of 1542.90 per year, with 27.40 citations per paper. However, 46 papers (4.08%) have never been cited, while 423 publications (37.57%) have been cited once to ten times. Table 2 summarizes the annual publishing of the retrieved papers. The highest number of paper citations occurred in 2015, with citations per paper (C/P) and citations per cited paper (C/CP) of 121.31 and 125.22, respectively. In terms of productivity and citation impact, the year 2020 demonstrated the highest h-index (35) and g-index (55) values. The lowest citations of papers were shown in 2009, with citations per paper (C/P) and citations per cited paper (C/CP) values being similar, 7.00. There were no publications in the Scopus database in 2006 concerning medicinal plants and NAFLD research.

Figure 2

The total number of publications and total citations globally from 2005 to 2024 on medicinal plants and NAFLD



Notes: Annual publications show a consistent upward trend, while citations peak in specific years, reflecting increasing research output and evolving scientific impact.

Table 1

Citation metrics

Metrics	Data
Publication years	2005-2024
Citation years	20 (2005-2025)
Papers	1126
Citations	30858
Citations/year	1542.90
Citations/paper	27.40
Citations/author	5414.37
Papers/author	197.45
h-index	74
g-index	124

Table 2

Annual number of publications and citation metrics

Year	TP	NCP	TC	C/P	C/CP	h-index	g-index
2024	219	192	1338	6.11	6.97	16	23
2023	134	128	1899	14.17	14.83	22	34
2022	171	169	3150	18.42	18.64	31	43
2021	133	130	3584	26.95	27.57	33	52
2020	117	113	3670	31.37	32.48	35	55
2019	61	61	2262	37.08	37.08	26	46
2018	62	60	2376	38.32	39.60	26	47
2017	62	62	2361	38.08	38.08	27	46
2016	38	37	1600	42.10	43.24	25	38
2015	32	31	3882	121.31	125.22	21	32
2014	22	22	1123	51.04	51.04	19	22
2013	27	27	1827	67.67	67.67	17	27
2012	17	17	580	34.12	34.12	12	17
2011	12	12	558	46.50	46.50	8	12
2010	8	8	426	53.25	53.25	7	8
2009	2	2	14	7	7	2	2
2008	6	6	146	24.33	24.33	6	6
2007	2	2	48	24	24	2	3
2006	-	-	-	-	-	-	-
2005	3	3	62	20.67	20.67	3	3

Notes: TP = total number of publications; NCP = number of cited publications; TC = total citations; C/P = average citations per publication; C/CP = average citations per cited publication; h = h-index; and g = g-index.

Top ten active countries

Researchers from various countries contributed to publications on medicinal plants and NAFLD from 2005 to 2024, with the top ten countries shown in Figure 3. China was the top publishing country with 709 publications, contributing more than half of the total publications. This was followed by South Korea (82), and the United States, Iran, and India with a similar number of publications (56).

Top ten active organizations

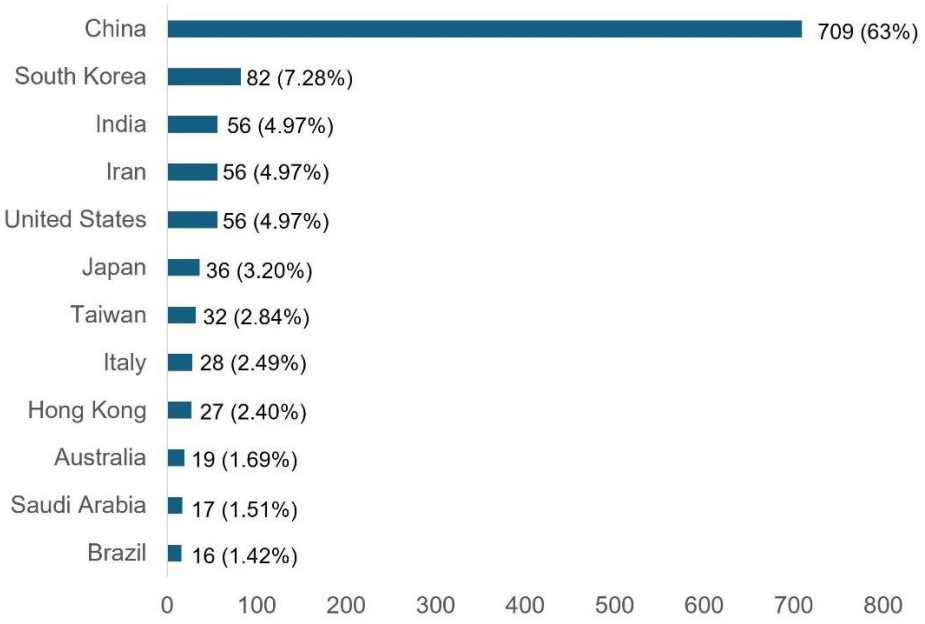
The top ten organizations that published medicinal plants and NAFLD-related research were all from China, with the top three being the Shanghai University of Traditional Chinese Medicine (n=94), the Ministry of Education of the People's Republic of China (n=76), and Chengdu University of Traditional Chinese Medicine (n=45), as shown in Table 3. These top 10 organizations have published over 20 articles in this field of study.

Top ten active research areas

The research area could help researchers better understand the focus of the current study. The 1,126 articles were distributed amongst 21 research areas. Figure 4 demonstrates the top ten research areas by number of publications. The field of 'Medicine' accounts for 586 publication records, making it the most important and popular field of study for medicinal plants in NAFLD treatment (52.04%). This is followed by 'Pharmacology, Toxicology and Pharmaceutics' (46.18%, 520 publications) and 'Biochemistry, Genetics, and Molecular Biology' (27.53%, 310 publications).

Figure 3

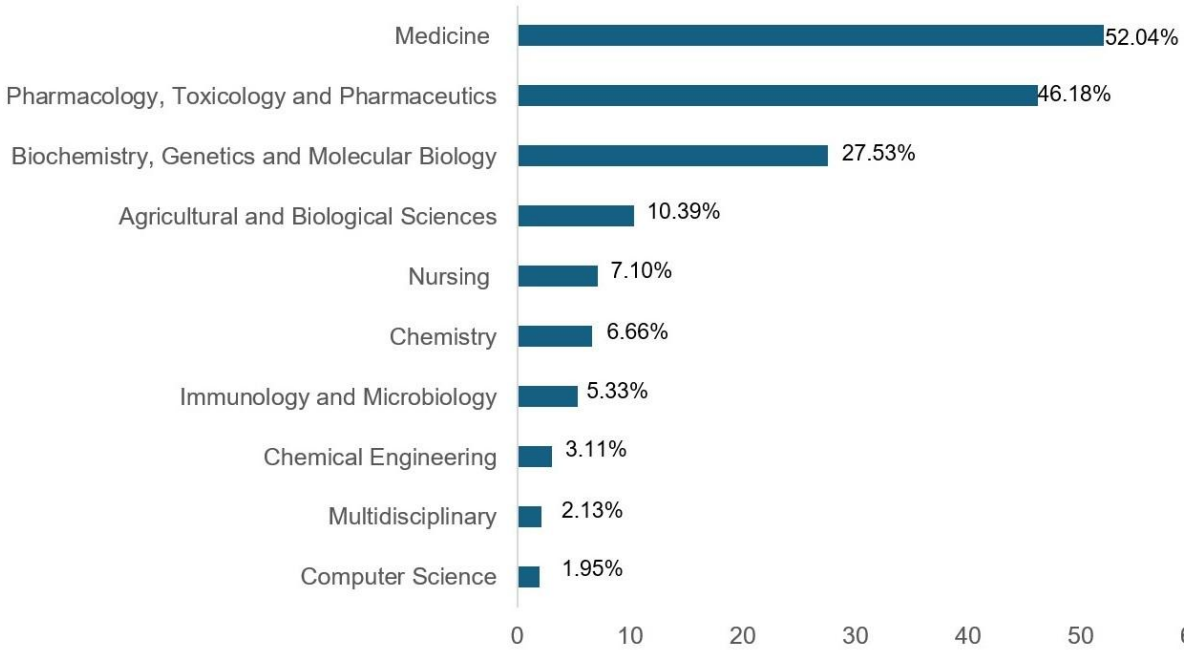
Top 10 publishing countries on medicinal plants and NAFLD



Notes: China is the leading contributor to publications, accounting for 63% of total output, followed by South Korea and the United States, indicating a strong regional dominance in research productivity.

Figure 4

Total percentages of publications of the top 10 subject categories according to Scopus



Notes: The most common subject categories for publications on medicinal plants and NAFLD were medicine, pharmacology, toxicology, and pharmaceutics. Substantial contributions from biochemistry, genetics, and molecular biology further indicate a strong biomedical research orientation.

Table 3

Distribution by organizations

Ranking	Items	TP (n)	Percentage (of 1126)	TC	C/P
1	Shanghai University of Traditional Chinese Medicine	94	8.35	1906	20.28
2	Ministry of Education of the People's Republic of China	76	6.75	1978	26.03
3	Chengdu University of Traditional Chinese Medicine	45	4.00	1375	30.56
4	Longhua Hospital Shanghai University of Traditional Chinese Medicine	40	3.55	864	21.60
5	Beijing University of Chinese Medicine	35	3.11	690	19.71
6	Shuguang Hospital affiliated to Shanghai University of Traditional Chinese Medicine	33	2.93	511	15.48
7	Zhejiang Chinese Medical Sciences	31	2.75	493	15.90
8	Guangzhou University of Chinese Medicine	30	2.66	530	17.67
9	Nanjing University of Chinese Medicine	29	2.58	543	18.72
9	China Pharmaceutical University	29	2.58	921	31.76
10	Jinan University	28	2.49	565	20.18

Notes: TP = total number of publications; TC = total citations; C/P = average citations per publication.

Top ten most-cited publications

Table 4 lists the top ten most-cited publications in medicinal plants and NAFLD research. The analysis reveals that 'The role of oxidative stress and antioxidants in liver diseases' by Li et al., as the most cited article, with 1,442 citations (Li et al., 2015). The article appeared in the 'International Journal of Molecular Sciences' in 2015. The second most cited article was 'Ganoderma lucidum reduces obesity in mice by modulating the composition of the gut microbiota, which was published in 2015 in the 'Nature Communications' and received 1,129 citations (Chang et al., 2015). Additionally, the third most referenced paper,'An update on β-sitosterol: A potential herbal nutraceutical for diabetic management', was published in the 'Biomedicine & Pharmacotherapy' in 2020 and had 548 citations (Babu & Jayaraman, 2020).

Top ten most-cited journals

Table 5 lists the top ten journals based on the number of publications in medicinal plants and NAFLD research. The analysis reveals that 'Journal of Ethnopharmacology' ranked first (n=96, 8.52%), followed by 'Frontiers in Pharmacology' (n=77, 6.84%), 'Biomedicine and Pharmacotherapy' (n=48, 4.26%), 'Phytomedicine' (n=40, 3.55%), and 'Evidence Based Complementary and Alternative Medicine' (n=38, 3.37%).

Co-occurrence of Author keywords

The co-occurrence of the authors' keywords was analyzed using the VOSviewer software (1.6.20). Figure 5 presents network (top) and overlay (bottom) visualization. A minimum threshold of 70 occurrences was applied, revealing that 50 of the 11795 keywords met the criteria. The findings revealed that the top five most popular author keywords were 'NAFLD' (952 occurrences), 'animal model' (686 occurrences), 'lipid' (633 occurrences), 'liver' (549 occurrences), and 'triacylglycerol' (418 occurrences). Our analysis revealed five distinct cluster sizes within the author's keyword network. These keywords were grouped into five clusters and nodes with the same color indicate a similar topic in the

Table 4

Top cited publications

No	Author(s)	Title	Year	Source	TC
1.	(Li et al., 2015)	The role of oxidative stress and antioxidants in liver diseases	2015	International Journal of Molecular Sciences	1442
2.	(Chang et al., 2015)	Ganoderma lucidum reduces obesity in mice by modulating the composition of the gut microbiota	2015	Nature Communications	1129
3.	(Babu & Jayaraman, 2020)	An update on β-sitosterol: A potential herbal nutraceutical for diabetic management	2020	Biomedicine & Pharmacotherapy	548
4.	(Savini et al., 2013)	Obesity-Associated Oxidative Stress: Strategies Finalized to Improve Redox State	2013	International Journal of Molecular Sciences	416
5.	(Oni et al., 2013)	A systematic review: Burden and severity of subclinical cardiovascular disease among those with nonalcoholic fatty liver; Should we care?	2013	Atherosclerosis	314
6.	(Dai et al., 2018)	Chemoproteomics reveals baicalin activates hepatic CPT1 to ameliorate diet-induced obesity and hepatic steatosis	2018	Proceedings of the National Academy of Sciences of the United States of America	299
6.	(Russell et al., 2013)	Colonic bacterial metabolites and human health	2013	Current opinion in Microbiology	299
7.	(Wong et al., 2019)	The changing epidemiology of liver diseases in the Asia–Pacific region	2019	Nature Reviews Gastroenterology and Hepatology	269
8.	(Zhao et al., 2023)	The crucial role and mechanism of insulin resistance in metabolic disease	2023	Frontiers in Endocrinology	254
9.	(Abidov et al., 2010)	The effects of Xanthigen™ in the weight management of obese premenopausal women with non-alcoholic fatty liver disease and normal liver fat	2010	Diabetes, Obesity and Metabolism	245
10.	(Fan et al., 2011)	Guidelines for the diagnosis and management of nonalcoholic fatty liver disease: Update 2010	2011	Journal of Digestive Diseases	236

Table 5

Top cited journals

Ranking	Source Title	TD (n)	% (of 1126)	Publisher	CS	SJR	SNIP
1	Journal of Ethnopharmacology	96	8.53	Elsevier	10.4	1.142	1.578
2	Frontiers in Pharmacology	77	6.84	Frontiers	8.9	1.220	1.153
3	Biomedicine and Pharmacotherapy	48	4.26	Elsevier	12.8	1.775	1.561
4	Phytomedicine	40	3.55	Elsevier	11.6	1.694	1.703
5	Evidence Based Complementary and Alternative Medicine	38	3.37	Hindawi	3.5	0.469	0.831
6	Nutrients	33	2.93	MDPI	9.1	1.473	1.334
7	Pharmacological Research	16	1.42	Elsevier	18.6	2.664	2.026
8	Chinese Medicine United Kingdom	15	1.33	Springer Nature	9.0	1.066	1.327
8	Molecules	15	1.33	MDPI	8.6	0.865	1.137
8	Phytotherapy Research	15	1.33	John Wiley & Sons	14.4	1.477	1.573
8	World Journal of Gastroenterology	15	1.33	Baishideng Publishing Group Inc	8.1	1.418	1.381
9	International Journal of Molecular Sciences	14	1.24	MDPI	9.0	1.273	1.177
10	Pharmaceutical Biology	13	1.15	Taylor & Francis	9.2	0.964	1.041

Notes: TD = total documents; % = percentage; CS = Cite Score measures average citations received per document published in the serial in 2024; SJR = SCImago Journal Rank measures weighted citations received by the serial in 2024. Citation weighting depends on the subject field and prestige (SJR) of the citing serial; SNIP = Source Normalized Impact per Paper measures actual citations received relative to citations expected for the serial's subject field in 2024.

publications. Examples of the keywords in the red cluster (cluster 1, 16 items), including antioxidant, Chinese medicine, liver disease, NAFLD, and liver protection, reflects the use of medicinal plants as hepatoprotective agents. This cluster highlights the central role of plant-derived antioxidants in mitigating oxidative stress, a key mechanism in NAFLD progression. In the green cluster (cluster 2, 11 items), keywords such as animal model, drug therapy, liver, mice, and ultra-performance liquid chromatography, represents preclinical and pharmacological studies. It demonstrates the importance of experimental models in evaluating the efficacy and mechanisms of medicinal plant–based interventions.

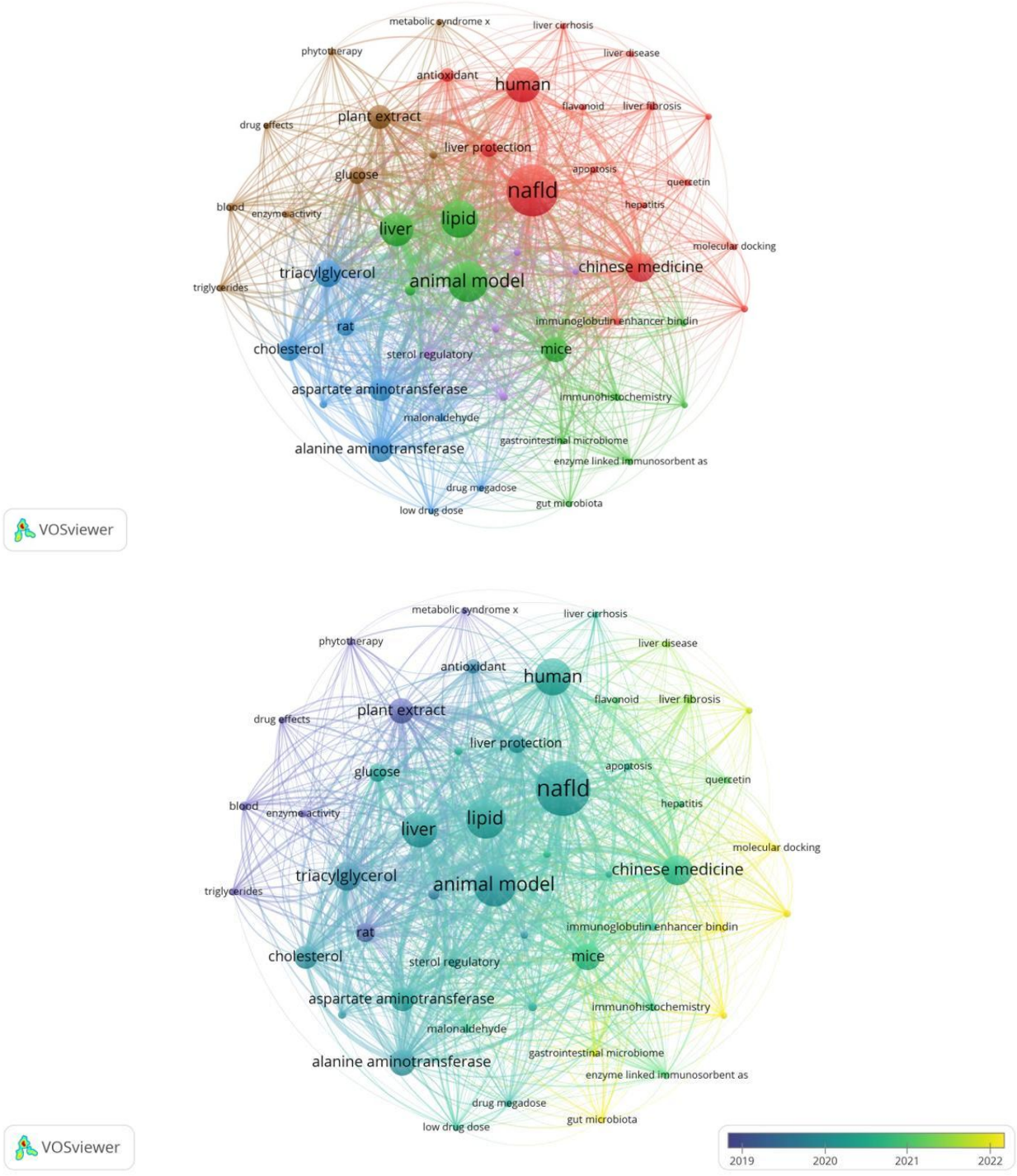
It also indicates the use of advanced analytical techniques to characterize bioactive compounds and their pharmacokinetics. Additionally, in the blue cluster (cluster 3, 9 items), the keywords include alanine aminotransferase, aspartate aminotransferase, cholesterol, malonaldehyde, and superoxide dismutase. This cluster emphasizes the role of these biomarkers in diagnosing liver injury and monitoring disease progression. It also highlights their importance in assessing the therapeutic effects of medicinal plant interventions. In the brown cluster (cluster 4, 9 items), keywords include blood, drug effects, enzyme activity, hyperlipidemia, and plant extract are related to metabolic and therapeutic outcomes. This cluster suggests a strong research focus on the therapeutic effects of plant extracts in improving lipid profiles and metabolic abnormalities associated with NAFLD. It also indicates ongoing efforts to validate the efficacy and safety of these interventions in experimental settings. In the purple cluster (5 items), the keywords include fatty acid oxidation, peroxisome proliferator-activated receptor alpha, and sterol regulatory, represents molecular mechanisms of lipid metabolism. It highlights key metabolic pathways targeted by bioactive compounds from medicinal plants in the management of NAFLD.

The overlay visualization of keyword co-occurrence illustrates the temporal evolution of research topics in medicinal plants and NAFLD. Earlier studies (blue–green) primarily focused on lipid metabolism, liver function, and biochemical

markers such as cholesterol, triacylglycerol, and aminotransferases. More recent keywords (yellow) indicate a shift toward emerging areas, including molecular docking, gut microbiota, immunological techniques, and bioactive compounds such as flavonoids. Core terms such as 'NAFLD', 'lipid', 'liver', and 'animal model' remain central throughout the timeline, reflecting their continued importance in the field.

Figure 5

Network visualization (top) and overlay visualization (bottom) analysis based on co-occurrence of author keywords



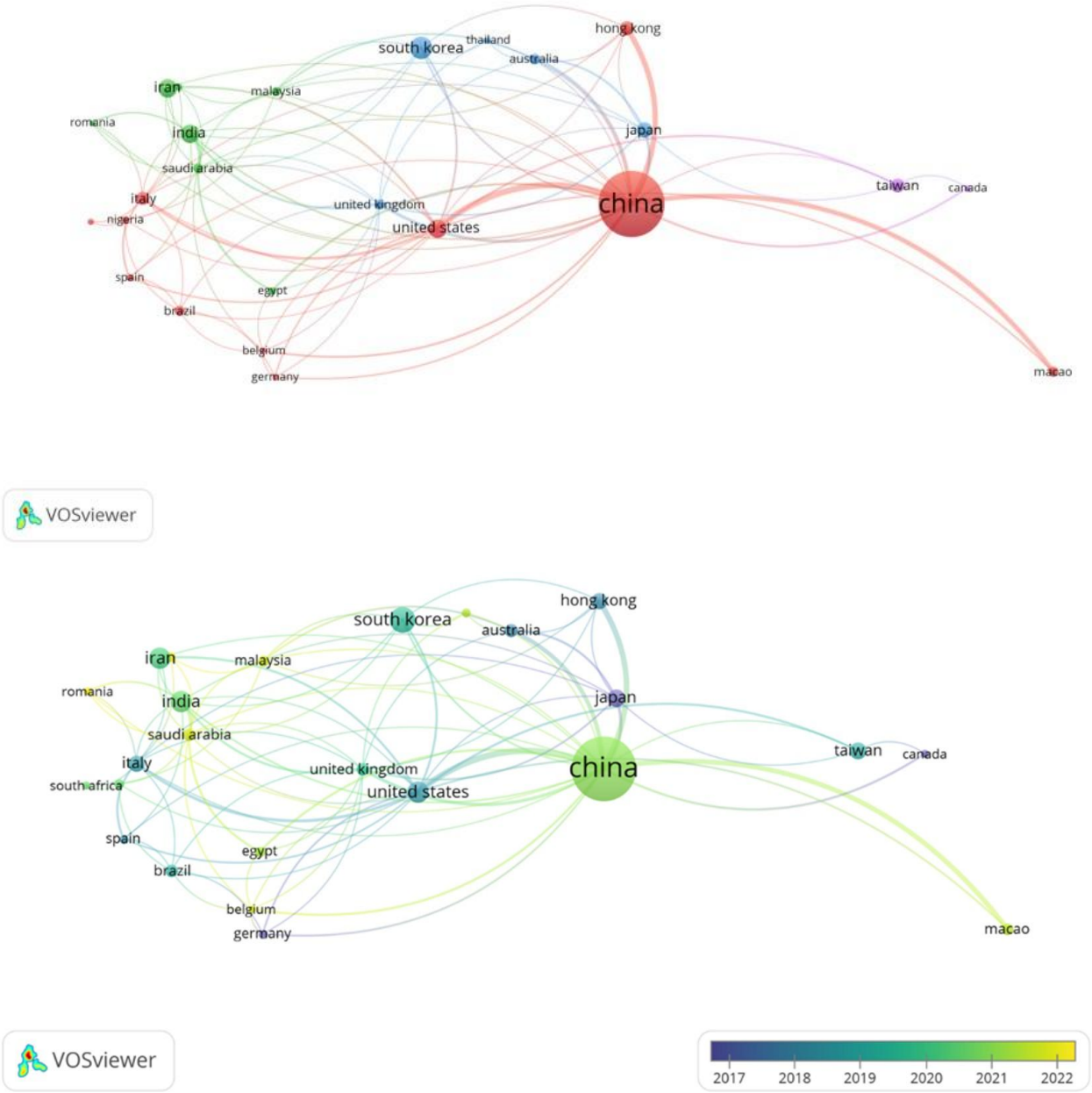
Notes: Keyword co-occurrence network generated using VOSviewer, revealing major research clusters such as NAFLD, lipid metabolism, liver function, and animal models. VOSviewer overlay visualization illustrating the temporal progression, where earlier studies focused on lipid metabolism and liver function, while recent trends emphasize molecular docking, microbiome research, and phytochemical mechanisms.

Analysis of collaboration between countries

Figure 6 illustrates the diagram of interactions between co-authors from different countries generated by VOSviewer. The criteria for inclusion were set at a minimum of 5 documents and 1 citation per country. Among 64 countries, 25 met this threshold, forming five clusters represented by five distinct node colors. The first cluster is brown, which includes Belgium, Brazil, Germany, Italy, Nigeria, South Africa, Spain, and the United States. The second cluster is green, which includes Egypt, India, Indonesia, Iran, Malaysia, Romania, and Saudi Arabia. Additionally, the third cluster is blue, including Australia, Japan, South Korea, Thailand, and the United Kingdom. The fourth cluster is red and comprises China, Hong Kong, and Macao. The fifth cluster is purple, comprising Canada and Taiwan.

Figure 6

Network of co-authorship occurrence of 22 countries (VOSviewer)



Notes: Co-authorship network visualization (top) shows China as the dominant hub with extensive collaborations across multiple countries. Overlay visualization (bottom) highlights emerging contributions from countries such as India, Iran, Malaysia, and Saudi Arabia in recent years.

Research collaboration exhibits strong synergy among multiple countries, particularly China, the United States, and Hong Kong. In the diagram, node size reflects the strength of co-authorship; the larger the node, the greater the co-

authorship with other countries (Sajovic & Boh Podgornik, 2022). Meanwhile, the country cluster is represented by the color of the node and the line thickness signifies the strengths of the co-authorship link. China has the highest total link strength, 96, which is represented by a larger node indicating strong global collaboration.

Overlay visualization of international collaboration showing China as the central hub, with extensive research partnerships across Asia, Europe, and North America. In addition, earlier collaborations (blue) were concentrated among developed countries, while more recent collaborations (green-yellow) show increased participation from emerging regions, reflecting the expanding global interest and research activity in this field.

DISCUSSION

The bibliometric analysis of medicinal plants in NAFLD research from 2005 to 2024 highlights significant growth in scientific output. The steady increase in publications, peaking in 2024, shows the growing interest in medicinal plants as potential treatments for NAFLD. However, a dip in 2023 may reflect changes in research funding or publication delays. Notably, the citation trend fluctuated and did not mirror the number of publications, with citations peaking in 2015 before declining. This may be due to the time needed for research impact to develop, as well as a possible shift in research focus within the wider hepatology field. The highest 'h' index and 'g' index in 2020 indicate that many publications that year were cited frequently, highlighting their influence in the fields of medicinal plants and NAFLD research.

A recent bibliometric review of NAFLD publications from 1987 to 2022 was conducted, with a focus on the role of diet and medicinal plants in managing NAFLD (Shakhshir & Sa'ed, 2024). They identified oxidative stress and inflammation as key factors in the disease process. In another study, Vaisha et al. centred their analysis on research from 2001 to 2022 in the Indian subcontinent (Vaishya et al., 2024). Although publications from this region contributed only 3.43% to worldwide NAFLD research, 24.59% of studies involved international collaboration. The increasing trend in total publications observed in this study is consistent with previous bibliometric analyses of herbal medicine research in obesity (Seo et al., 2022), chronic kidney disease (Xu et al., 2022), rheumatoid arthritis (Kang et al., 2022), and cardiovascular disease (Chen et al., 2024).

China emerged as the foremost contributor to the field, producing over half of the total publications. These findings may be linked to China's emphasis on Traditional Chinese Medicine (TCM) and extensive research in pharmacology and hepatology. The data are expected, as China is a megadiverse country that harbours over 30,000 medicinal plant species (Tahir et al., 2024). Most recently, it has been reported in a statistical analysis that herbal medicine plays a significant role in China's healthcare system, where it is formally integrated into national health policies and supported by strong government investment, improving accessibility, affordability, and population health outcomes (Wang et al., 2026). This development further enhances disease prevention and chronic disease management while strengthening primary healthcare infrastructure, making it a key pillar of China's public health strategy. Furthermore, although challenges such as high cost and genetic instability remain, China has adopted innovative approaches such as space breeding to enhance genetic diversity, active compound production, and yield of medicinal plants, thereby reinforcing its position as a leading country in this field (Li et al., 2026a). Notably, China was identified as the leading contributor in the previous studies of herbal medicine in chronic kidney disease (Xu et al., 2022), rheumatoid arthritis (Kang et al., 2022), and cardiovascular disease (Chen et al., 2024).

South Korea and the United States also contributed significantly, reinforcing the global interest in herbal medicine for NAFLD. Although the United States is known for advanced research in hepatology and metabolic diseases, it ranks third, suggesting a different focus on NAFLD treatment strategies. The dominance of Chinese organizations in medicinal plant-related NAFLD research further highlights China as the leading nation in this area. Organizations such as Shanghai University of Traditional Chinese Medicine and the Ministry of Education of the People's Republic of China lead in publications, reflecting strong governmental and academic support for TCM-based NAFLD interventions.

In terms of research areas, 'Medicine' had the highest number of publications, which is consistent with NAFLD being a major global health concern and prompting extensive medical research to develop effective treatments. From the analysis, 'Pharmacology, Toxicology, and Pharmaceutics' is another significant research area. The growing interest in identifying bioactive compounds from medicinal plants and their therapeutic potential in managing NAFLD underlines the importance of this field. Moreover, compared to synthetic drugs, compounds derived from medicinal plants are often perceived to have a favorable safety profile, with fewer side effects, thus encouraging further research in pharmacology and toxicology. Although treatment options for NAFLD remain limited, the therapeutic landscape is evolving, with several agents currently under clinical investigation. Additionally, newly developed drugs can be costly and may cause adverse effects with prolonged use (Mahjoubin-Tehran et al., 2021).

Although no pharmacological treatments for NAFLD have received approval, research into alternative therapies such as TCM is gradually advancing. For instance, Potentilla discolor Bunge (PDB), a TCM herb, has shown hepatoprotective, anti-inflammatory, and lipid-lowering effects, making it a promising candidate for NAFLD treatment (Ji et al., 2022). This plant contains several bioactive compounds, including flavonoids, terpenoids, organic acids, steroids, and tannins, which contribute to its medicinal properties. Additionally, various medicinal plants such as *Phyllanthus niruri* Linn., *Phyllanthus emblica* Linn., *Curcuma longa* Linn., and *Cinnamomum verum* have demonstrated potential in the

treatment of NAFLD (Askari et al., 2014; Al Zarzour et al., 2017; Kirschweng et al., 2018; Mansour-Ghanaei et al., 2019). The findings in 'Biochemistry, Genetics, and Molecular Biology' as another major research area may indicate a growing interest in integrating molecular mechanisms with clinical applications. Applying this multidisciplinary approach has become a key strategy in developing more effective and personalised plant-based therapies for liver diseases.

Citation analysis revealed that the most influential publications focus on the pathogenesis of liver disease. The review article by Li et al. entitled 'The role of oxidative stress and antioxidants in liver diseases' received 1442 citations, emphasized the role of oxidative stress as a central pathological mechanism in liver disease and proposed antioxidants as a promising strategy for prevention and management (Li et al., 2015). However, despite this strong theoretical basis, supporting preclinical evidence for the hepatoprotective effects of antioxidants remains limited and requires further validation. Its broad scope, interdisciplinary relevance, and timely contribution during a period of rapidly expanding research on oxidative stress have made it a foundational reference for subsequent studies. The second most cited article by Chang et al. entitled '*Ganoderma lucidum* reduces obesity in mice by modulating the composition of the gut microbiota', demonstrates that *Ganoderma lucidum* helps reduce obesity in mice, and the proposed mechanism involves altering the balance of gut bacteria, which is known to play a crucial role in body weight and metabolism (Chang et al., 2015). Its high citation count can be attributed to several factors, including the growing global interest in microbiome research, the rising prevalence of obesity and metabolic disorders, and the study's innovative approach linking traditional medicinal fungi with modern microbiota-based therapeutic strategies. Moreover, by providing experimental evidence that dietary interventions can reshape gut microbiota to influence host metabolism, the study has served as a key reference for subsequent research exploring microbiome-targeted treatments and functional foods. Meanwhile, the third most cited article by Babu & Jayaraman entitled 'An update on β-sitosterol: A potential herbal nutraceutical for diabetic management' indicated the role of β-sitosterol, a plant-derived phytosterol, as a promising natural compound for managing diabetes (Babu & Jayaraman, 2020). The high citation count of this article can be attributed to its comprehensive and timely synthesis of evidence on the antidiabetic properties of β-sitosterol, including its effects on glucose metabolism, insulin sensitivity, and lipid regulation. By bridging traditional herbal knowledge with emerging pharmacological insights, the review has become a key reference for researchers exploring natural compounds as complementary strategies in metabolic disease management.

The Journal of Ethnopharmacology stands out as the highest number of publications in medicinal plants and NAFLD (n=96). This prominence is likely due to its specialized focus on traditional medicine and natural products, particularly the biological and pharmacological evaluation of plant-derived substances. As NAFLD research increasingly explores alternative and complementary therapies, especially those derived from medicinal plants, the journal provides a highly relevant platform for such studies. This journal covers the observation and experimental investigation of the biological activities of plant and animal substances that are used in traditional medicine. With a 5-year impact factor of 5.4 and a Journal Citation Indicator (JCI) quartile of Q1 in chemistry and medicinal, it upholds an extensive abstracting and indexing coverage. Frontiers in Pharmacology ranks second based on the highest number of publications in medicinal plants and NAFLD (n=77). This journal is an interdisciplinary journal that publishes research on the interactions between drugs and living organisms to prevent and cure human disease. It has a 5-year impact factor of 4.8 and a Journal Citation Indicator (JCI) quartile of Q1 in the fields of pharmacology and pharmacy. Biomedicine and Pharmacotherapy, and Phytomedicine ranked third and fourth, respectively, in producing the highest number of publications in this field. Both journals cover pre-clinical and clinical studies, including the molecular and cellular mechanisms of drug action, as well as natural product-based therapies.

Analyzing keyword co-occurrence provides valuable insights into the central themes and emerging research directions within the field. Keywords highlight the core topics discussed in a publication, offering a clearer understanding of prevailing trends and knowledge gaps. In this study, 'NAFLD', 'animal model', and 'lipid' are the most frequently used terms. This pattern highlights the reliance on animal models to elucidate lipid metabolism dysregulation, which is a key driver in the pathogenesis and progression of NAFLD. It also indicates a strong emphasis on mechanistic studies aimed at identifying therapeutic targets and evaluating potential interventions for lipid-related metabolic disturbances. Notably, 'NAFLD' remains the preferred term over 'MAFLD' due to its long-established usage in clinical guidelines, research literature, and public health policies. NAFLD ensures consistency in epidemiological studies and allows for better comparison with past research, while MAFLD's new diagnostic criteria may lead to classification discrepancies. Additionally, not all global hepatology associations have fully adopted MAFLD, and many high-impact journals and funding agencies still recognize NAFLD as the standard term. Despite MAFLD's metabolic relevance, NAFLD remains dominant due to historical precedence, widespread acceptance, and practical considerations in research and clinical practice.

The overlay visualization further reveals an evolving research landscape, demonstrating a transition from foundational studies focused on lipid metabolism and liver enzymes to more recent interests in computational approaches and microbiome-related mechanisms. This shift reflects a broader movement toward mechanistic and translational research in NAFLD. Increasing attention to the gut-liver axis highlights the role of intestinal dysbiosis, microbial metabolites, and inflammation in disease progression. Recently, it is reported that gut microbiota dysbiosis plays a central role in NAFLD development by disrupting the gut-liver axis, promoting inflammation, impairing lipid metabolism, and contributing to metabolic dysfunction, particularly during the vulnerable adolescent period (Kurhaluk

et al., 2026). Concurrently, the growing application of computational methods, such as molecular docking, indicates an increasing focus on identifying bioactive compounds from medicinal plants and predicting their interactions with molecular targets involved in NAFLD (Li et al., 2026b). Collectively, these trends suggest a shift toward a more integrative research paradigm that combines experimental, computational, and systems-level approaches, bridging traditional phytotherapy with modern precision medicine in NAFLD management.

Collaboration analysis highlights China's leading role in international research collaboration. The formation of five distinct country clusters suggests the existence of regional research networks, with China and the United States forming the strongest collaborative link. This finding indicates that while research is becoming more globally interconnected, regional collaborations remain crucial in advancing medicinal plant-NAFLD related research. The overlay visualization of international collaboration highlights China as the central hub, consistent with its leading publication output and strong global engagement. While earlier collaborations were concentrated among developed countries, recent trends show increasing participation from emerging regions, indicating a shift toward a more globally distributed research landscape. Overall, these patterns highlight China's pivotal role not only in research productivity but also in facilitating international collaboration and innovation in this field.

Despite an increase in global collaboration, the network shows relatively low participation from many regions, including sections of Africa and Latin America. This disparity may be due to differences in research funding, infrastructure, and access to international collaboration networks, which can limit scientific productivity and exposure. Limited collaboration may also impede knowledge exchange, reduce research diversity, and inhibit the translation of locally relevant medicinal plant resources into worldwide applications. Addressing these gaps through increased financing, capacity-building programs, and inclusive international collaborations is critical to promoting more equitable and comprehensive research advances in this sector. Additionally, restricted collaboration networks can contribute to disparities in citation impact and academic visibility, as studies from less-connected regions may receive lower recognition in the global scientific community.

CONCLUSION

The findings of this bibliometric analysis provide important guidance for future research, clinical applications, and policy development. By identifying key themes and emerging hotspots, this study highlights priority areas such as elucidating molecular mechanisms, investigating bioactive compounds, and integrating advanced approaches including computational modeling and microbiome analysis. The observed global disparities in research output further emphasize the need to strengthen international collaboration and build research capacity in underrepresented regions. Future studies should prioritize well-designed clinical trials to establish efficacy, safety, and optimal dosing, alongside mechanistic investigations targeting lipid metabolism, inflammation, and the gut–liver axis. In addition, standardized phytochemical profiling and quality control are essential to ensure reproducibility and support regulatory approval. Collectively, these efforts are crucial for translating preclinical findings into clinically applicable and evidence-based therapeutic strategies.

This study is subject to certain constraints. First, the analysis was restricted to the Scopus database, which may have overlooked some relevant studies, including PubMed and Web of Science. Therefore, other databases should be considered in future for a more comprehensive analysis. Second, the restriction to English-language publications may introduce language bias, potentially excluding relevant studies published in other languages. Third, citation-based metrics may be influenced by factors such as citation inflation, self-citation, and time-dependent accumulation of citations, which may not necessarily reflect the true scientific quality or impact of the research. These limitations emphasize the need for a more inclusive and thorough approach to future research in this field, even though the study offers insightful information about the research landscape of medicinal plants in the treatment of NAFLD.

AUTHOR CONTRIBUTIONS

Nabilah Auni Marzuki, Balqis Karimah Amri, Fazalda Annuar, and Liyana Nursyahirah Johari involved in performing literature search, drafted the manuscript, and analysis the data. Zaleha Kamaludin, Wan Amir Nizam Wan Ahmad, and Liza Noordin supervised and revised the manuscript. All authors contributed to the manuscript and approved the submitted version.

ETHICS APPROVAL

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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