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Ginger: a total-scale analysis of the scientific literature on a widely used spice and phytotherapeutic

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Ginger (*Zingiber officinale*) has been utilized for medicinal and culinary purposes for thousands of years. Its extensive history showcases diverse uses and health benefits. In this study, we conducted a thorough analysis of the scientific literature landscape surrounding ginger using bibliometric techniques, aiming to explore recurring topics, trends, influential contributors, and main journals publishing ginger-related research. Utilizing the Web of Science (WoS) Core Collection, we identified 9,881 relevant papers published up to October 4, 2023. The analysis revealed an exponential growth in both publication and citation counts since the mid-2000s. Key phytochemical constituents, including gingerols and shogaols, emerged as focal points of research. The most frequently mentioned medical condition term identified was 'Cancer' (n = 577), followed by 'Obesity' (n = 180) and 'COVID' (n = 176). Journals such as the Journal of Ethnopharmacology and Food Chemistry played leading roles in sharing ginger-related articles. Our bibliometric study offers a broad overview of ginger research, highlighting a significant increase in scholarly interest globally. This analysis not only contributes quantitative insights to the existing literature but also provides a roadmap for future investigations on ginger. The scientific literature positions ginger as a promising candidate for addressing contemporary health challenges, inviting further exploration and clinical studies.

KEYWORDS: ginger / Zingiber officinale / antioxidant / inflammation / bibliometrics / Web of Science

Introduction

Ginger (*Zingiber officinale* Roscoe, Zingiberaceae family) finds its use as a medicine and spice in many cultures throughout the world for thousands of years [Bartley and Jacobs 2000; Da Silveira Vasconcelos *et al*. 2019; Shahrajabian *et al*. 2019]. The rhizome is the widely used plant part, and the plant finds its origins in the Indo-Malayan region. Nowadays it can be found distributed in regions of America, Australia, Asia, and Africa [Kizhakkayil and Sasikumar 2011]. The botanist William Roscoe (1807) is associated with the scientific nomenclature of ginger. Ginger derives its name from the Greek word 'Zingiberis', which in turn is derived from the Sanskrit word 'Shringravera' meaning 'shaped like a deer's antler's' [Elzebroek and Wind 2008]. Volatile oils found in ginger are responsible for its pungent flavor and odor [Rehman *et al*. 2011]. The aroma of ginger is mainly due to the monocyclic sesquiterpene constituents bisabolene and zingiberene, while its odor and pungent taste are due to different monophenolic phytochemicals from the group of shogaols and gingerols [Mcgee *et al*. 2004]. It is a strong antioxidant and helps in scavenging of free radicals [Da Silveira Vasconcelos *et al*. 2019]. The impact of ginger on health is fairly well-established and it is used as a dietary supplement and as constituent of many traditional herbal medicinal preparations throughout the world [Da Silveira Vasconcelos *et al*. 2019, Matin *et al*. 2024a, Shahrajabian *et al*. 2019, Unuofin *et al*. 2021]. Ginger contains flavonoids, anthocyanidins, and other polyphenols [Trinidad *et al*. 2012]. Succinic, citric, oxalic, malic, and tartaric acid are five important organic acids found in ginger [Yeh *et al*. 2014]. Various phytochemicals present in ginger like shogaols, 6-gingerol, paradols, gingerdione, zingerone, sesquiterpenes, among others, play an important role in the medicinal actions of ginger [Unuofin *et al*. 2021]. Vitamin C, calcium, iron, carotene, carbohydrates, fats, protein, dietary fibre, among others, are also found in ginger [Kumari *et al*. 2016]. Ginger finds its use as a functional food due to its nutritional and phytochemical composition [Da Silveira Vasconcelos *et al*. 2019]. The plant has been mentioned in the Ayurvedic and Unani-Tibb herbal medicines and in Chinese traditional medicine recipes for the treatment of various diseases for centuries [Ali *et al*. 2008; Memudu *et al*. 2012, Willetts *et al*. 2003]. Ginger was among one of the first oriental spices that was grown by European countries. Ancient Romans got ginger from Arabs and introduced it to Northern Europe. During the Middle Ages, ginger was considered a very important and significant herb [Kala *et al*. 2016]. The famous explorer Marco Polo came to know about ginger in China and Sumatra in the thirteenth century. He transported some of it to Europe [Afzal *et al*. 2001]. In China ginger is mentioned by the name of jiang and in Chinese culture ginger has been used in complications like stomachache, cholera, nausea, diarrhea, hemorrhage, rheumatism, and toothache [Afzal *et al*. 2001].

In Indian, Chinese, Japanese, and Korean cultures ginger has been used both as a spice and medicine. Thus, ginger assumes a significant place in different cultures throughout the world for its therapeutic benefits [Daily *et al*. 2015, Pinn and Pallett 2002]. Researchers have explored that ginger can have significant potential as an analgesic, anti-diabetic, antiobesity, anti-inflammatory, antiapoptotic, anti-tumor, antipyretic, anti-platelet, antioxidant, anti-clotting, analgesic, cardiotonic and cytotoxic agent. It has been widely used for cramps, sprains, sore throats, arthritis, rheumatism, muscular aches, pains, vomiting, constipation, indigestion, hypertension, dementia, and male infertility, among others [Shahrajabian *et al*. 2019, Unuofin *et al*. 2021].

Natural products such as ginger not just have potential implications for human health [Dauletkhan *et al*. 2024, Tammam *et al*. 2024, Varghese and Majumdar 2024], but are also broadly utilised for the improvement of animal health, welfare, and production parameters [Tewari et al. 2017, Yeung et al. 2019, 2020ab, 2021ab, 2022, Charuta *et al*. 2024, Rezende *et al*. 2024, Sarmiento-García *et al*. 2024].

In this work, we have utilized the bibliometric analysis technique to search and evaluate the data regarding ginger in the scientific literature. Bibliometric analysis has nowadays become a significant tool for analyzing and exploring large amounts of scientific data. It is a highly versatile analysis technique that helps to explore both the evolutionary aspects as well as current emerging trends in a particular area of research or topic [Wani *et al*. 2023, Yeung *et al*. 2022, Yeung *et al*. 2023, Yeung *et al*. 2024a, Yeung *et al.* 2024b]. In bibliometric analytic methodology, quantitative techniques (i.e., bibliometric analysis - for example, citation analysis) are applied to bibliometric data (e.g., units of publications and citations) [Broadus 1987]. Bibliometric analysis plays a highly significant role in the fields of applied and basic scientific research [Ellegaard and Wallin 2015]. By the use of bibliometric evaluation, quantitative analysis of written publications can be performed, and bibliometric analysis applies the broadest approach with respect to publications in a given area [Lin 2012, Zhuang *et al*. 2013]. Bibliometric evaluation also assumes a highly significant role in the ranking of institutions and research departments [Ellegaard and Wallin 2015]. Researchers who read the bibliometric type of analysis become aware of trends and competing groups as well as identify opportunities for cooperation. With regard to the above facts, one may use bibliometric methods to many advantages [Ellegaard and Wallin 2015, Li *et al*. 2010]. Over the years it has been observed that there is a significant rise in the use of bibliometric analysis of scientific content in journals throughout the world. The demand for bibliometric types of analysis in the fields of science and productivity is increasing day by day, especially with respect to research communities, funding, and regulatory agencies, since this analysis type is acting as a significant tool for scientific evaluation, and it is having a rising effect on non-library and information science communities as well.

As discussed above, ginger has versatile applications, since it has been broadly used as a spice and condiment for centuries, while also possessing numerous therapeutic benefits. On this background, the aim of the present study is to perform a total scale analysis of the scientific literature available on ginger in order to gain quantitative data on the recurring research topics and trends, as well as impactful authors, institutions, and publishing journals.

Material and methods

On 4 October 2023, the online database Web of Science (WoS) Core Collection was queried with the following search string: TS = (‘ginger*’ OR ‘Zingiber officinale*’). This search identified 11,232 indexed records that listed these words and their derivatives in their titles, abstracts, and/or keywords. However, some records had irrelevant document types, such as film review (n = 23), poetry (n = 19), item about an individual (n = 6). Because of that, an additional filter was applied to limit the results to original articles and reviews only. Finally, 9881 papers remained. The basic publication and citation frequency data were directly acquired from the WoS database, and the full records of these 9881 papers were exported to VOSviewer [Van Eck and Waltman 2010] for subsequent bibliometric analyses. A term map visualizing terms recurring in >1% (n = 99) of the titles and abstracts of the 9881 papers was generated to show the citations per paper (CPP) of the terms. A similar term map was generated to visualize keywords used by the authors. A country/region collaboration map was similarly generated to show international collaborations between countries/regions with >1% contribution (n = 99) each. Other than these threshold settings, default settings were used in VOSviewer for term map generation.

Results and discussion

The 9881 papers were cited a total of 224,099 times, meaning an average of 22.67 citations per paper (CPP). Both the publication and citation counts demonstrated an exponential growth since the mid-2000s as shown in Figure 1. This rapid increase in research output reflects growing scientific interest in ginger’s therapeutic potential and aligns with broader trends in natural product research and integrative medicine [Wang *et al*. 2017]. Moreover, the surge in research output might not only reflect growing interest in ginger’s therapeutic potential but also coincides with advancements in analytical techniques and a broader shift towards evidence-based evaluation of traditional medicines [Buenz *et al*. 2018]. There were much more original articles (n = 8853, 89.6%, CPP = 21.1) than reviews (n = 1028, 36.1%, CPP = 36.1). The original article-to-review ratio was 8.6:1. Majority of the publications were written in English (n = 9647, 97.6%). The top 5 most productive authors, affiliations, countries/regions, journals, and journal categories are listed in Table 1.

Notably, the primary contributors among the five most productive countries were situated in Asia, with the exception of the United States. The most productive author was Shengmin Sang (n = 35, CPP = 34.1) from North Carolina A&T State University.

Egyptian Knowledge Bank (EKB) was the most productive affiliation (n = 404, CPP = 16.3). India (n = 1725, CPP = 19.8), China (n = 1567, CPP = 18.6), and the

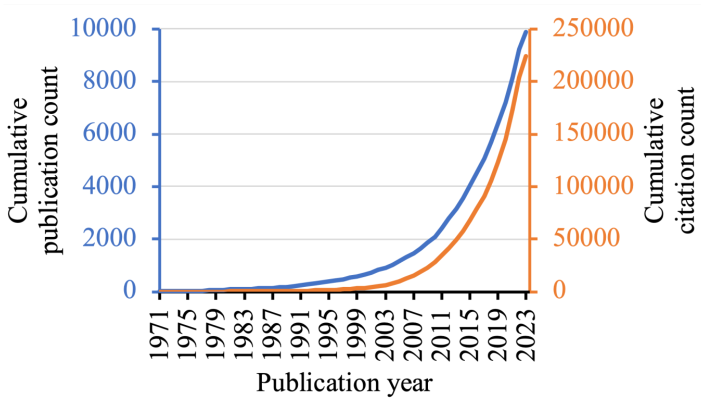

Fig. 1. Cumulative publication and citation counts.

Table 1. The top five most productive authors, affiliations, countries/regions, journals, and journal categories

Item	Number of papers (% of 9881)	Citations per paper (CPP)
Authors		
Sang, Shengmin	35 (0.4)	34.1
Khan, Rifat Ullah	26 (0.3)	31.3
Shelly, Todd E.	21 (0.2)	32.4
Ghasemzadeh, Ali	19 (0.2)	57.7
Aggarwal, Bharat B	19 (0.2)	243.6
Roufogalis, Basil D	19 (0.2)	87.5
Di Virgilio, Angela	19 (0.2)	12.5
Affiliation		
Egyptian Knowledge Bank (EKB)	404 (4.1)	16.3
Indian Council of Agricultural Research (ICAR)	205 (2.1)	18.7
Council of Scientific Industrial Research (CSIR) India	202 (2.0)	32.5
Chinese Academy of Sciences	133 (1.3)	19.2
King Saud University	131 (1.3)	17.7
Country		
India	1725 (17.5)	19.8
China	1567 (15.9)	18.6
United States	1321 (13.4)	38.3
Iran	567 (5.7)	17
Japan	530 (5.4)	29.2
Journal		
Journal of Ethnopharmacology	147 (1.5)	46.2
Journal of Agricultural and Food Chemistry	125 (1.3)	49.1
Molecules	120 (1.2)	23.6
Food Chemistry	114 (1.2)	59.6
Evidence Based Complementary and Alternative Medicine	107 (1.1)	19.1
Journal category		
Food Science & Technology	1764 (17.9)	29.2
Pharmacology & Pharmacy	1497 (15.2)	26.5
Plant Sciences	922 (9.3)	22.2
Chemistry, Medicinal	776 (7.9)	28.7
Biochemistry & Molecular Biology	758 (7.7)	29.8

Please note that the most productive authors were identified from the most productive ‘researcher profiles’ function in WoS. If a user directly examined the ‘author’ filter, the top author would be Kumar A, which was a collection of papers from multiple authors (‘A’ could actually refer to Avdhesh, Amit, Arun, etc.); and the second author would be Wang Y (‘Y’ could refer to Yan, Yao, Yu, etc.).

United States (n = 1321, CPP = 38.3) each contributed to 13–18% of the papers, but the CPP of the United States was double of the former two. The dominance of Asian countries like India and China in ginger research likely stems from the plant's cultural importance and traditional use in these regions, as well as their rich biodiversity and investment in natural product research [Mao *et al*. 2019]. This regional concentration of research efforts underscores the importance of preserving traditional knowledge and biodiversity in these areas, while also highlighting opportunities for increased global collaboration and knowledge transfer [Heinrich *et al*. 2020]. Middle East countries were also upcoming contributors to this field, such as Egypt (n = 408, CPP = 16.5) and Saudi Arabia (n = 404, CPP = 15.3). They had strong collaborations with Asian countries, the United States, England, and Germany as illustrated in Figure 2. These strong collaborative networks, particularly between Asian countries and Western nations like the US and UK, highlight the global nature of ginger research and may facilitate knowledge exchange between traditional medicine systems and modern scientific approaches [Prasad and Tyagi 2015]. Journal of Ethnopharmacology was the most productive journal (n = 147, CPP = 46.2), but Food Chemistry received the highest CPP among the top 5 journals (n = 114, CPP = 59.6). On a related note, Food Science & Technology (n = 1764, CPP = 29.2) and Pharmacology & Pharmacy (n = 1497, CPP = 26.5) were the two leading journal categories, followed by Plant

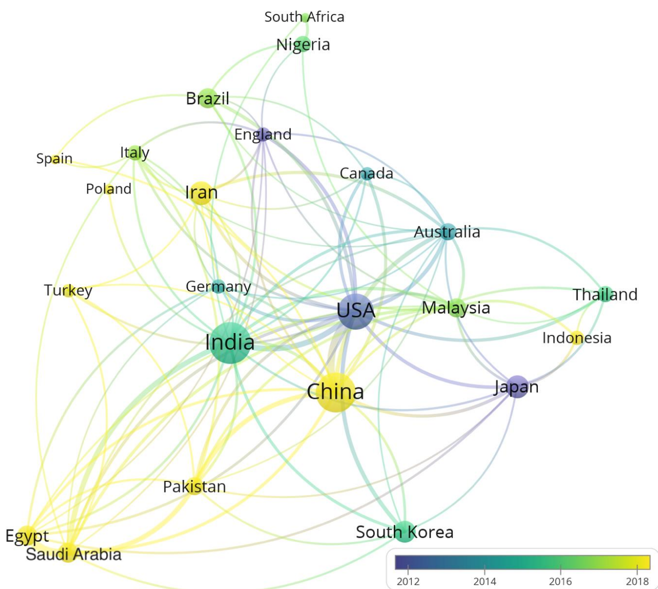

Fig. 2. International collaboration map of most productive countries/regions. The node color represents the average recency of their publications, whereas the node size represents the number of papers, and the inter-node distance represents how frequently the countries/regions collaborated with each other. The lines indicate the 100 strongest collaborations.

Sciences (n = 922, CPP = 22.2), Chemistry, Medicinal (n = 776, CPP = 28.7), and Biochemistry & Molecular Biology (n = 758, CPP = 29.8).

Figure 3 shows a bubble map of recurring terms in the titles and abstracts of the papers. The size of each text bubble corresponds to how often the keywords were employed, while the color of the bubble indicates the citation frequency of the manuscripts featuring those keywords. Thus, a larger text bubble suggests a greater number of papers addressing the specific topic, and a more intense color (as per the provided color scale) signifies a higher impact, indicating that the associated manuscripts have accumulated more citations. Some of the most recurring terms located around the upper part of the map concerned mechanism or bioactivity, in particularly featuring the terms mechanism (n = 1227, CPP = 28.1) and activity (n = 2712, CPP = 27.4). The prevalence of terms related to mechanisms and bioactivities suggests a focus on elucidating ginger's molecular targets and modes of action, which is crucial for establishing its efficacy and safety. This trend aligns with the increasing interest in understanding the pharmacological basis of traditional medicines [Mohd Yusof 2016]. Meanwhile, the lower part of the map concerned the health benefits for people, such as treatment (n = 2382, CPP = 21.6), medicine (n = 648, CPP = 23.3), and pregnancy (n = 194, CPP = 39.6). Upon closer examination of ginger papers dealing with pregnancy, it was found that the most cited one (356 citations) was a

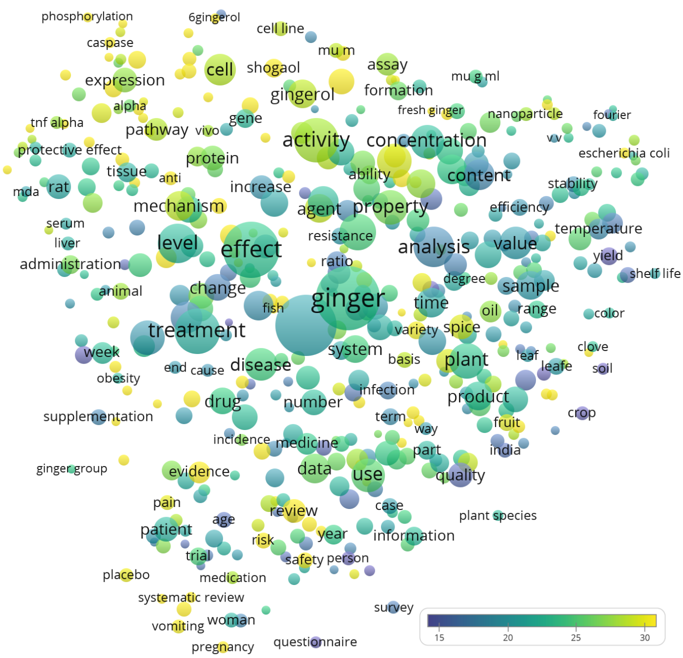

Fig. 3. Term map of recurring terms in the titles and abstracts of the papers. The node color represents the citations per paper (CPP) of the terms, the node size represents the publication count, and the inter-node distance represents the frequency of co-occurrence with each other in the same papers.

review that stated, 'although clinical and experimental studies suggest that ginger has some antiemetic properties, clinical evidence beyond doubt is only available for pregnancy-related nausea and vomiting' [Chrubasik *et al*. 2005]. The beneficial effect of ginger intake on pregnancy-related nausea and vomiting was also discussed in a paper published in the New England Journal of Medicine, as clinical trials indicated 'ginger in capsules (tasteless) was superior to placebo' and 'efficacy of ginger was similar to that of vitamin B6' [Niebyl 2010]. Along the same, a total-scale analysis of the clinical trials registered on ClinicalTrials.gov related to ginger revealed that 'nausea and vomiting' was the most frequent outcome measure aimed to be evaluated in the clinical studies with ginger [Matin *et al*. 2024b].

Furthermore, we investigated prevalent medical conditions in ginger research. The most frequently mentioned medical condition term was 'Cancer' (n = 577, CPP = 30.9). Notably, a study highlighted [6]-gingerol, acknowledged as a pytochemical antioxidant, revealing considerable potential as a complementary medicine for preventing and treating cancers due to its multifaceted effects, including antiproliferative, antitumor, anti-invasive, and anti-inflammatory actions, along with its cytotoxic impact on cancer cell lines and efficacy in mice [De Lima *et al*. 2018]. Importantly, a meta-analysis of clinical trials revealed the efficacy of ginger supplementation to suppress both acute and delayed chemotherapy-induced nausea and vomiting in breast cancer patients [Kim *et al*. 2022]. Concurrently, 'Obesity' (n = 180, CPP = 21.7) and 'COVID' (n = 176, CPP = 28.3) emerged as the next frequently discussed medical conditions. For instance, in silico molecular studies demonstrated that ginger, with its rich nutritional components and pharmacological activities, shows promising results in addressing various health issues, including obesity and the potential inhibition of SARS-CoV-2 [Unuofin *et al*. 2021]. Meta-analysis of human clinical studies also revealed the efficacy of ginger in reducing body weight and fasting glucose in obese subjects [Maharlouei *et al*. 2019]. Furthermore, several clinical trials indicated potential efficacy of ginger application in COVID-19 patients when applied in combination with other herbal remedies [Mesri *et al*. 2021, Singh *et al*. 2023]. It is worth mentioning, that although the three most prominent medical conditions were cancer, obesity, and COVID, the second most cited term after cancer was cardiovascular disease (n = 114, CPP = 30.6). The diverse range of medical conditions studied in relation to ginger highlights its potential as a multifaceted therapeutic agent. However, it also underscores the need for more targeted, high-quality clinical trials to establish efficacy and safety across these various applications [Marx *et al*. 2017].

Gingerol (n = 1145, CPP = 28.1) appears as the most frequently discussed phytochemical, featuring in 11.6% of the total 9881 papers as listed in Table 2. However, it is noteworthy that the specific derivative 6-gingerol (n = 143, CPP = 43.0) has more CPP than gingerol. The compound with the highest CPP is capsaicin (n = 124, CPP = 72.8), despite its lower prevalence, showing an impactful contribution to the scientific discussion on ginger-related research. Shogaol (n = 501, CPP = 32.8) and curcumin (n = 324, CPP = 45.5) also exhibit substantial prevalence accompanied by

Table 2. Recurring phytochemicals mentioned by the papers in their title and abstract

Phytochemical	Number of papers (% of 9881)	Citations per paper (CPP)
Gingerol	1145 (11.6)	28.1
Shogaol	507 (5.1)	32.8
Curcumin	324 (3.3)	45.5
Flavonoid	288 (2.9)	25.6
Phenolic compound	207 (2.1)	33.5
Zingerone	178 (1.8)	28.8
Zerumbone	166 (1.7)	34.3
6-Gingerol	143 (1.4)	43.0
Capsaicin	124 (1.3)	72.8
Quercetin	116 (1.2)	27.3

noteworthy CPP values. The data suggests a significant scholarly interest in exploring the therapeutic potential and biochemical attributes of these phytochemicals. The high citation rates for papers mentioning specific compounds like 6-gingerol and curcumin indicate particular research interest in these molecules, possibly due to their potent bioactivities and potential as lead compounds for drug development. Future research may focus on optimizing the delivery and bioavailability of these compounds for therapeutic applications [Zhen *et al*. 2020].

Figure 4 visualizes the recurring author keywords. Many of them are concerned about antioxidation, such as antioxidant (n = 254, CPP = 30.0), oxidative stress (n = 202, CPP = 20.6), apoptosis (n = 201, CPP – 35.6), and inflammation (n = 188, CPP = 29.4). Phytochemicals or compound classes as shown in Figure 5, in the keywords of the analyzed publications included 6-gingerol (n = 143, CPP = 43.0), 6-shogaol (n = 507, CPP = 32.8), curcumin (n = 324, CPP = 45.5), zingerone (n = 178, CPP = 28.8), and zerumbone (n = 166, CPP = 34.3). The focus on specific compounds like 6-gingerol and curcumin reflects a trend towards isolating and studying individual bioactive components. However, there is growing recognition of the potential synergistic effects of whole plant extracts, suggesting a need for more holistic approaches in future research [Rasoanaivo *et al*. 2011].

While this bibliometric analysis reveals significant progress in ginger research, it also highlights several areas for future investigation. These include exploring the molecular mechanisms of ginger's bioactive compounds, investigating potential drug interactions, and conducting long-term safety studies. Additionally, there is a need for more research on standardization of ginger preparations and dosages for various therapeutic applications [Mao *et al*. 2019].

Conclusion

In conclusion, our bibliometric analysis offers a comprehensive overview of the scientific knowledge surrounding ginger (*Zingiber officinale*). The study indicates a notable increase in scholarly attention, especially since the mid-2000s, highlighting the widespread global importance of ginger research. Key contributors, including countries

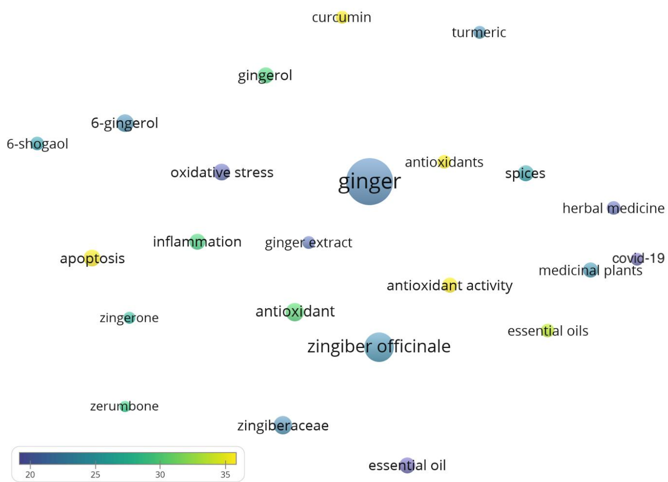

Fig. 4. Term map of recurring author keywords of the papers. The node color represents the citations per paper (CPP) of the terms, whereas the node size represents the number of papers, and the inter-node distance represents how frequently the terms co-occurred with each other in the same papers.

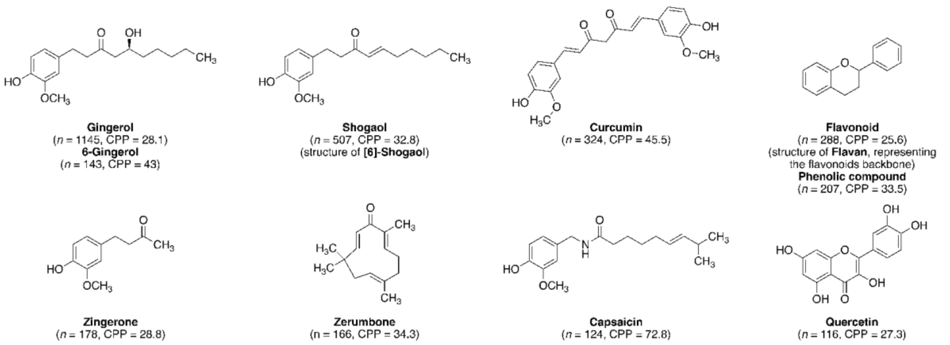

Fig. 5. Chemical structures of frequently mentioned food chemicals/chemical classes. In brackets are indicated the number of papers (n) in which the respective phytochemical was cited and the citations per paper (CPP).

like China and India, have played major roles in driving this research momentum. The diverse applications of ginger, extending from its traditional use as a spice to its therapeutic benefits, stand out as prominent themes. The compound group of gingerols, with a specific focus on the derivative 6-gingerol, takes center stage in research discussions, reflecting its significance in the field. The most recurring terms related to antioxidation and oxidative stress, apoptosis, and inflammation among author keywords, highlighting the ongoing efforts to understand the underlying mechanisms and bioactivities of ginger. International collaborations, as seen through affiliations and contributions, represent a collective effort to push forward ginger-related research. Journals such as the Journal of Ethnopharmacology and Food Chemistry were prevailing publishing platforms for sharing significant contributions with the scientific community in this research area. As we explore common medical conditions; cancer, obesity, and COVID stand out as key areas of ginger research which attracted a lot of scientific attention. The accumulating academic knowledge positions ginger as a promising candidate for tackling currently significant health issues, encouraging additional study and clinical investigations. Our analysis suggests possible future research paths, like enhancing the body-distribution of ginger compounds, investigating novel delivery approaches, and addressing emerging health issues. This bibliometric study not only provides numerical insights into the existing literature but might also acts as a guide for future inquiries in the dynamic field of ginger research.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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