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Unveiling a century of *Taraxacum officinale* G.H. Weber ex Wiggers research: a scientometric analysis and thematically-based narrative review

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Abstract

Background This study aims to conduct a scientometric analysis and thematically-based narrative review of a century of *Taraxacum officinale* research (TOR), uncovering patterns, trends, themes, and advancements in the field to provide insights for future investigations. The study followed PRISMA guidelines and utilized the Scopus database with MeSH terms for bibliographic data retrieval. Scientometric mapping employed VOSviewer and R-package-based Bibliometrix, while extracted themes were reviewed narratively. A detailed analysis of TOR was achieved by including only original studies.

Results The findings include the extensive duration of TOR since 1908 and its significant growth, particularly in the last two decades. China emerges as the most productive country, but the United States leads in recognizable and collaborative TOR. The thematic map displays dynamic and diverse themes, with a rich knowledge structure revealed through the analysis of term co-occurrence. The year 2016 represents a turning point in the thematic map, marked by numerical growth and thematic bifurcation. The study extracted several main research topics within the field of TOR, including germination, antioxidant activity, bioherbicide, oxidative stress, *Taraxacum kok-saghyz*, and heavy metals. These topics represent key areas of investigation and provide insights into the diverse aspects of research surrounding *T. officinale*. Additionally, emerging topics in TOR encompass toxicity, metabolomics, dandelion extract, and diabetes mellitus.

Conclusions The study consolidated knowledge, highlighted research gaps, and provided directions for future investigations on TOR.

Keywords *Taraxacum officinale*, Scientometric analysis, Collaborative research, Thematic map, Knowledge structure

Background

Taraxacum officinale G.H. Weber ex Wiggers., commonly known as dandelion, belongs to the Asteraceae family. It is a perennial herbaceous plant with a deep taproot and rosette of toothed leaves. The plant can grow up to 30 cm in height and produces bright yellow flowers that turn into fluffy seed heads called "dandelion clocks." Dandelions are found in temperate regions worldwide and are known for their ability to thrive in various environments (Zanatta et al. 2021).

Dandelion has a long history of traditional use in herbal medicine. Its leaves, roots, and flowers are employed for their diuretic, digestive, and detoxifying properties. The leaves are commonly used in salads or cooked as a vegetable, while the roots are often dried and brewed into teas or tinctures. Dandelion is also used as an ingredient

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in traditional herbal remedies for conditions like liver disorders, gallstones, and digestive issues (Li et al. 2023; Milovanovic et al. 2023; Piccolella et al. 2023; Zhu et al. 2017). In addition to its traditional uses, dandelion is rich in nutrients and bioactive compounds (Sekhon-Loodu and Rupasinghe 2019). It contains vitamins A, C, and K, as well as minerals such as potassium, calcium, and iron (Zanatta et al. 2021). Various experimental studies were conducted to align with the traditional uses of this plant as shown in Table 1. Dandelion leaves are a good source of antioxidants, including beta-carotene and lutein, which help protect cells from oxidative damage (Milovanovic et al. 2023). The chemical composition of dandelion is diverse and includes various classes of compounds. The leaves contain flavonoids, phenolic acids, and sesquiterpene lactones, such as taraxinic acid and taraxacin. The roots contain inulin, a type of dietary fiber that acts as a prebiotic and supports gut health. Dandelion also contains triterpenes, sterols, and volatile compounds, which contribute to its therapeutic properties (Fan et al. 2023; Gahramanova et al. 2023; Olas 2022; Qadir et al. 2022).

Taraxacum officinale has long been associated with diuretic properties. It has been traditionally used as a diuretic in various traditional medicine systems, including traditional Chinese medicine and traditional European herbal medicine (Qadir et al. 2022). The diuretic effects of *Taraxacum officinale* are believed to be primarily due to its high potassium content and the presence of bioactive compounds such as taraxasterol and taraxerol (Lobine et al. 2020; Yousefi Ghale-Salimi et al. 2018). These compounds have been found to stimulate renal function and increase urine production. Research suggests that dandelion extract or tea consumption can increase urine volume and frequency, promoting the elimination of waste products and potentially reducing fluid retention. The diuretic effects of dandelion may have various potential benefits. They may help alleviate conditions such as edema (fluid retention), high blood pressure, and urinary tract infections. Additionally, dandelion's diuretic properties may aid in detoxification by assisting in the elimination of toxins and metabolic waste from the body. It is important to note that while dandelion is generally considered safe for consumption, individuals with certain medical conditions, such as kidney problems or electrolyte imbalances, should exercise caution and consult with a healthcare professional before using dandelion as a diuretic. Further research is still needed to fully understand the mechanisms of action and potential therapeutic applications of *Taraxacum officinale* as a diuretic. Nonetheless, its traditional use and preliminary scientific evidence support the notion that dandelion possesses diuretic properties, making it a subject of interest in natural diuretic remedies (Li et al. 2022b; Milovanovic et al. 2023).

Bibliometric assessment refers to evaluating and analyzing scientific publications in a particular field. Conducting a bibliometric assessment for *Taraxacum officinale* research (TOR) would provide insights into the volume, trends, and impact of studies related to this plant. It would help identify knowledge gaps, key researchers, productive institutions, and potential collaborations in the field (Donthu et al. 2021). Given the increasing interest in herbal medicine and the potential therapeutic applications of dandelion, a bibliometric assessment would enable researchers, policymakers, and industry stakeholders to make informed decisions regarding funding, research priorities, and commercial development. It would also facilitate knowledge exchange, promote interdisciplinary collaborations, and enhance the overall scientific understanding of this plant. The current study emphasizes the need for a bibliometric assessment to evaluate TOR, outlining the potential benefits of such an assessment for

Table 1 Some biological activities of dandelion

Biological activity	Citations
Diuretic	Mahmoud et al. (2022), Qadir et al. (2022)
Hepatoprotective	Gahramanova et al. (2023), Goyal et al. (2023), Yang et al. (2020)
Antioxidant	Sekhon-Loodu and Rupasinghe (2019), Wang et al. (2021), Wang et al. (2023), Yang et al. (2020)
Anti-inflammatory	Chen et al. (2019), Gahramanova et al. (2023), Liu et al. (2018b), Ma et al. (2015), Xueshibojie et al. (2016)
Antimicrobial	Goyal et al. (2023), Saratale et al. (2018)
Anti-cancer potential	Ovadje et al. (2016), Rezaie et al. (2023), Saratale et al. (2018), Wang et al. (2019), Zhang et al. (2021)
Digestive aid	Zanatta et al. (2021)
Immunomodulatory	Wang et al. (2021)
Hypolipidemic	Choi et al. (2010)
Antiviral	He et al. (2011)

the scientific community and stakeholders involved in herbal medicine research.

Methods

Selection of database and search strategy

The Scopus database was chosen as the primary source for conducting the literature search and retrieving relevant articles (Wanyama et al. 2022) on TOR. A comprehensive search strategy was employed using the MeSH database. The following search terms were selected: (dandelion OR "*Taraxacum officinale*") in the TITLE-ABS-KEY field. This ensured that relevant articles containing either "dandelion" or "*Taraxacum officinale*" in the title, abstract, or keywords were included in the search results. Articles make up the majority, accounting for 85.43% of the documents. Reviews represent 5.86% of the dataset, followed by conference papers at 4.63%. Book chapters account for 1.27% of the documents, while notes make up 0.65%. Short surveys and letters represent 0.55% and 0.53% respectively. Conference reviews and editorials make up 0.41% and 0.34% respectively. Errata represent 0.19% of the dataset, and books make up 0.14%. This distribution provides insights into the types of documents present in the dataset, with articles being the most prevalent, followed by reviews and conference papers. This data was obtained in the initial search and further refined according to the inclusion and exclusion criteria. The data was extracted on July 13, 2023.

Inclusion and exclusion criteria

The PRISMA guidelines were followed to determine the eligibility of articles for inclusion (Fig. 1). The criteria included studies published in the English language, data-driven studies (original articles), no time limitations, and articles indexed in Scopus. The final number of included articles in this study was recorded as N = 3,217.

Data analysis

The VOSviewer (1.16.19) and Bibliometrix (4.3.1) applications were utilized for data analysis (Ahmad 2022; Arruda et al. 2022). These tools were used to analyze the bibliographic data, identify key authors, institutions, and research trends, and generate visual representations of the research network. Various parameters were measured during the analysis, including the number of publications over time, author productivity, collaboration patterns between authors and institutions, citation patterns, co-occurrence of keywords, and identification

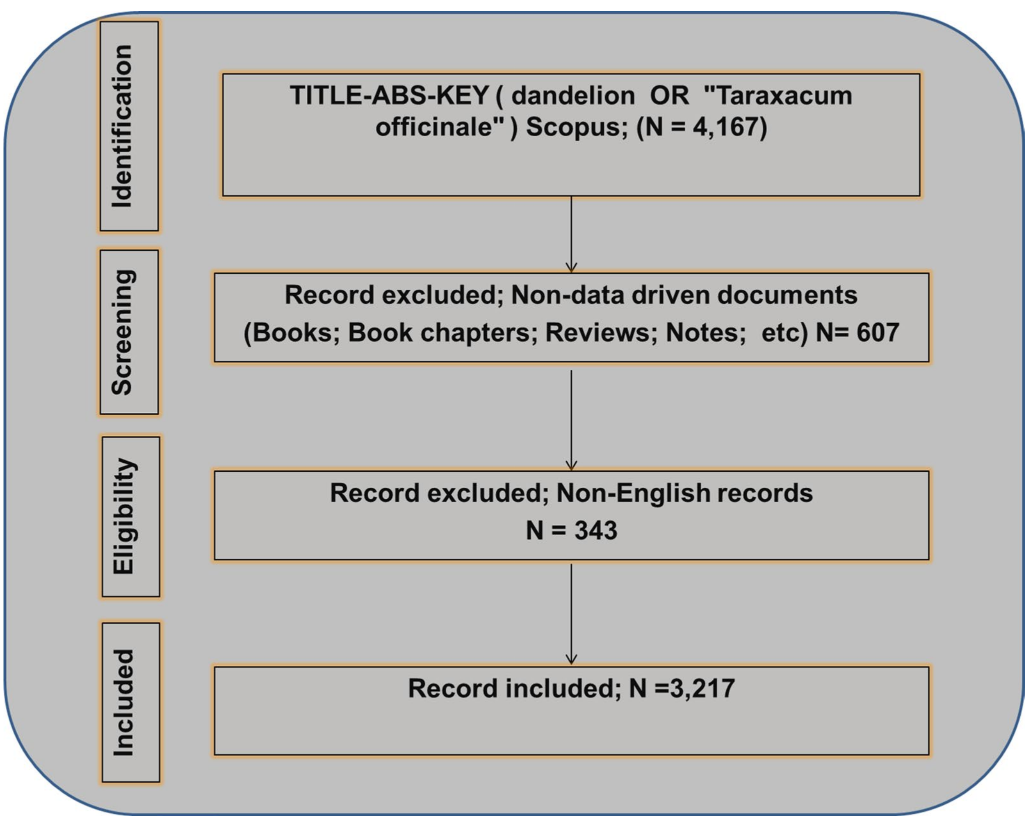

Fig. 1 The PRISMA guidelines were followed to determine the eligibility of articles for inclusion

of research clusters. The H-index, G-index, and M-index are metrics used to evaluate the research impact of authors. The H-index measures an author's impact by considering the highest number of publications that have received at least the same number of citations. It provides an indication of an author's influential works. The G-index takes into account highly cited publications and determines the highest number of publications that have collectively received a specific number of citations. It emphasizes the impact of top-performing publications. The M-index focuses on collaboration by calculating the average number of authors per publication. It sheds light on an author's involvement in multi-authored research. Together, these metrics provide insights into an author's impact, and productivity within their field of study.

Thematically-based narrative review was performed according to the findings of thematic map analysis. The thematic map provides a visual representation of major themes and subtopics within the field, aiding researchers in navigating the literature and understanding the relationships between different research areas. The study utilizes a co-word network analysis and clustering methodology to create a thematic map (Zhu and Zhang 2020). By analyzing the co-occurrence patterns of terms in the literature, the study identifies clusters of related keywords, revealing the thematic structure of TOR. This methodology offers a systematic and comprehensive approach to exploring the research landscape of TOR.

Ethical consideration

As this study was based on the analysis of existing literature and did not involve human subjects or personal data, no separate ethical approval was required. The study adhered to ethical guidelines by ensuring the use of proper citation and respecting the intellectual property of the authors and publishers of the included articles.

Results

Annual production

The timespan for the analyzed documents in TOR is from 1908 to 2024. The average age of the documents is 11.3 years, indicating a relatively recent focus on research. Over the past ten years, there have been a total of 1767 publications on TOR, accounting for approximately 54.91% of the total number of publications (Fig. 2). The highest number of publications within this period was recorded in 2022, with 255 publications (14.43% of the ten-year total). Other notable years include 2021, with 215 publications (12.16%), and 2023, with 209 publications (11.81%). The number of publications on TOR has shown some stability in recent years, with fluctuations occurring but remaining relatively consistent. It is important to remember that these percentages represent a subset of the overall research landscape and may not capture the complete picture of TOR during this period.

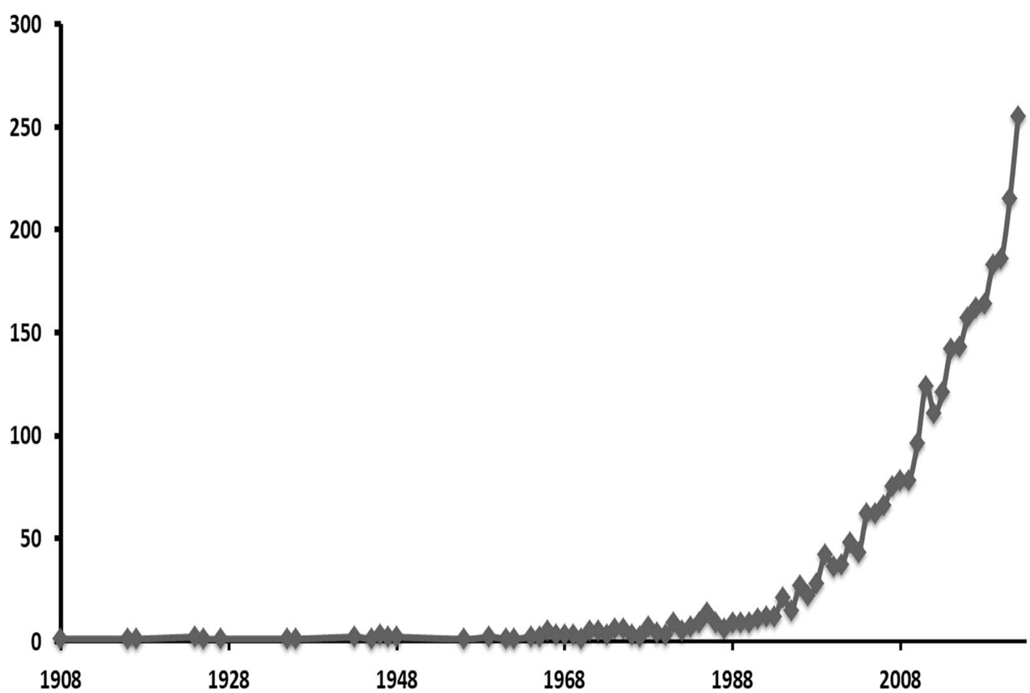

Fig. 2 Annual Production. Y-axis: the number articles published. X-axis: the years since the first article published in the topic of this paper

Hotspots

Hotspots pertaining to authors, their affiliations, and countries are present within the TOR network. The TOR dataset encompasses a comprehensive collection of documents involving 9,839 authors. Out of the total, a subset of 213 authors is identified as exclusively associated with single-authored documents, signifying their independent contributions to the research without any collaborative co-authors. J. Kirschner from the Czech Republic has 28 publications, followed by D. Prüfer from Germany with 27. Notable contributors include J. Štěpánek (Czech Republic) with 23 publications, K. Cornish (USA) with 21, and K.J.F. Verhoeven (Netherlands) with 16. With 75 publications, the Ministry of Education of the People's Republic of China is the most notable affiliation, followed by the Chinese Academy of Sciences with 59. With 40, 39, and 39 articles, the Russian Academy of Sciences, University of Münster (Germany), and Czech Academy of Sciences also contributed to TOR. In TOR, China has emerged as the leading country with 686 publications, accounting for 17.16% of the total. The United States follows closely with 443 publications (11.08%), while Canada, the United Kingdom, and Germany have contributed significantly with 181 (4.53%), 175 (4.38%), and 173 (4.33%) publications, respectively. These five countries collectively represent a substantial portion of TOR, accounting for 41.47% of the total publications. Their contributions demonstrate their active involvement and interest in studying and advancing knowledge on *Taraxacum officinale*. With 69 publications, the Journal of Ethnopharmacology leads the way, followed by PLOS ONE with 38 and Molecules with 34. Also important were 26 and 23 publications from Weed Science and RSC Advances. These TOR hotspots show authors, affiliations, nations, and journals actively contributing to this topic.

Scopus classifies journals that have accommodated documents from TOR into various subject areas. The highest representation is in the Agricultural and Biological Sciences category, accounting for 24.3% of the journals. This is followed by Biochemistry, Genetics, and Molecular Biology with 11.7%, Chemistry with 8.8%, Medicine with 8.5%, and Environmental Science with 8.0%. Other subject areas that have published TOR include Pharmacology, Toxicology, and Pharmaceutics (7.8%), Materials Science (5.5%), Chemical Engineering (4.5%), Engineering (3.8%), and Physics and Astronomy (3.4%). These subject areas highlight the multidisciplinary nature of TOR, encompassing fields such as biology, chemistry, medicine, and environmental science.

Three-field plot

A Sankey diagram, or three-field plot, shows the flow or distribution of quantities between entities or categories rather than numerical values, unlike absolute statistics. It shows flow proportions rather than numerical quantities for each object or category. This graphic helps explain how system or process entities and categories relate. Color separates properties or categories, whereas rectangle size denotes element amount or number. Lines show category flow, with thickness representing volume or strength (Fig. 3). In the context of TOR hotspots, the diagram can be used to visually represent the flow of publications, authors (AU), sources (SO), or countries (AU_CO) across different subject areas or disciplines. Hence, in contradistinction to the statistical data shown in the preceding section, the identities of the influential authors in the initial ten sources exhibited disparities, with Chinese researchers' research occupying prominent positions (Fig. 3).

Mapping of co-authorship

In the dataset, there are 235 single-authored documents, with an average of 4.72 co-authors per document. International co-authorships account for 18.62% of the collaborations, indicating a considerable level of international research collaboration. Figure 4 provides information on co-authorship mapping in terms of single-country publications (SCP), multiple-country publications (MCP), and the MCP ratio for each country. The MCP ratio indicates the extent of multiple-country collaborations in research publications, with higher ratios indicating a higher level of collaboration between countries. China has 686 publications, of which 87 are MCPs, resulting in an MCP ratio of 0.141. The USA has an MCP ratio of 0.201. Korea has 115 publications, with 22 being MCPs, resulting in an MCP ratio of 0.161.

A Fig. 5 represents the mapping co-authorship using VOSviewer. The expression in this figure is presented as TLS. Total Link Strength (TLS) is a metric used in network analysis to quantify the overall strength of connections or links between nodes in a network. It represents the sum of the strengths of all the links connected to a particular node. The TLS value provides insights into the centrality or importance of a node within the network, with higher TLS values indicating stronger and more influential connections. It is a useful measure for identifying key nodes or entities that have significant interactions or relationships with other nodes in the network. The map depicted in Fig. 5A, network visualization, exhibits total link strength of 611. It comprises four distinct clusters and encompasses a total of 183 links. The thirty countries that engaged in the highest level of collaboration were categorized into four distinct clusters: red, green, blue, and purple. The United States, China, Germany, the United Kingdom, and the Netherlands are the leading countries in terms of collaboration with TLSs

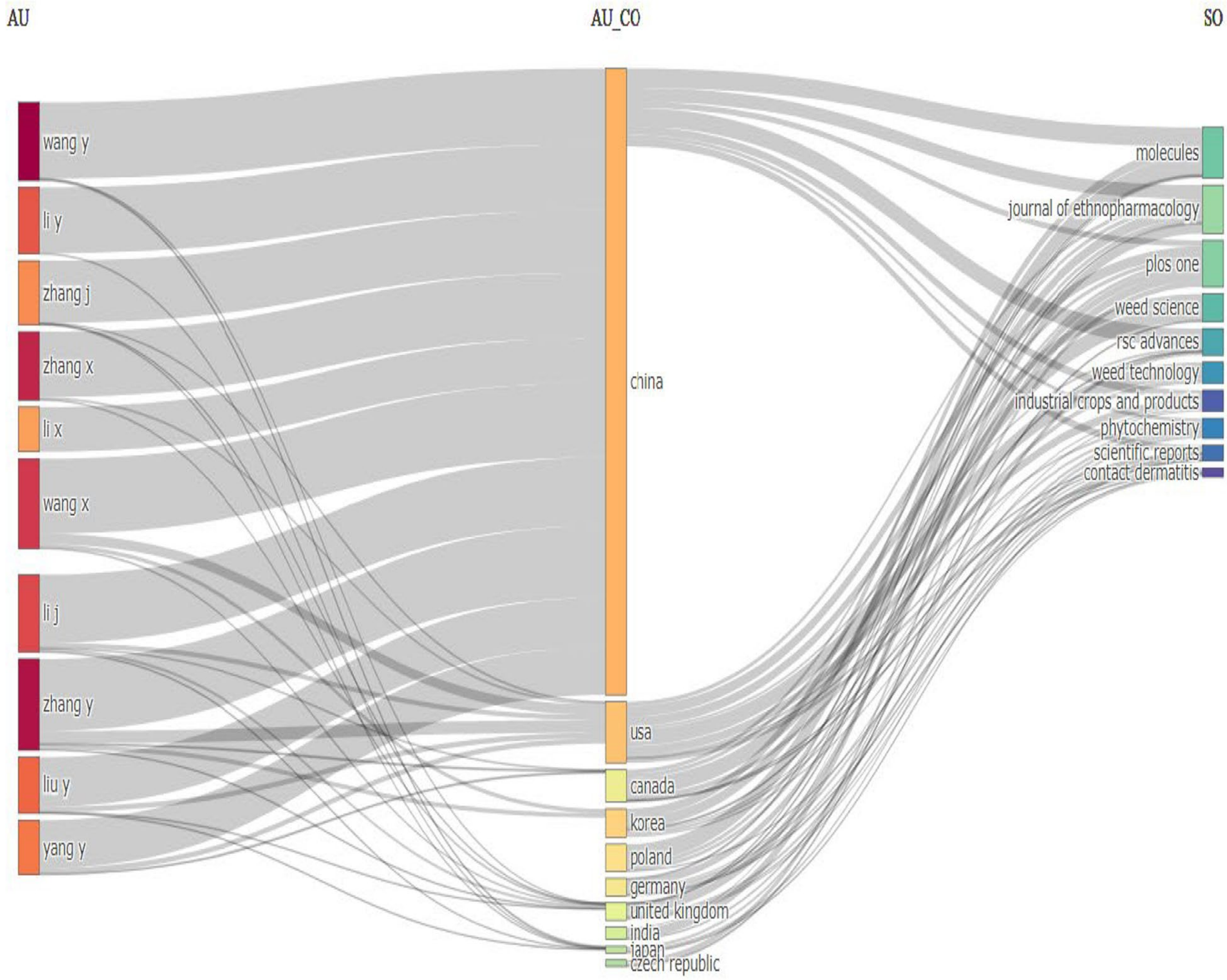

Fig. 3 Three-field plot. *AU*: authors; *AU_CO*: country of the authors; *SO*: sources. The thickness of the lines connecting authors from different countries would represent the number of papers that they have co-authored. The thickness of the lines connecting countries and sources would represent the number of papers from each country that has been published in each source. Each rectangle represents a node. The size of the rectangle represents the importance of the node in the network. This figure was generated using the Bibliometrix application and the BibTex data file

of 160, 132, 108, 87, and 56, respectively. The examination of co-authorship mapping in terms of temporal aspects was conducted utilizing overlay visualization, as depicted in Fig. 5B. The nations shown in yellow, such as Ukraine and Saudi Arabia, within this diagram represent novel research collaboration participants within the TOR realm. Simultaneously, countries characterized by purple are at the forefront of facilitating international collaboration by welcoming scholars from outside.

Visualization of impactful TOR

Top-cited documents

Table 2 represents the top ten most impactful documents in the field of TOR based on their citation counts and citation averages. The document ranked first is titled "Mesoscale organization of CuO nanoribbons: Formation of 'dandelions'," published in the Journal of the American Chemical Society in 2004. It has received 851 citations, with an average of 42.55 citations per year. The second-ranked document is "A versatile, ultralight, nitrogen-doped graphene framework," published in Angewandte Chemie—International Edition in 2012, with 734 citations and an average citation count of 61.17 per year. In the third position is "Multiple routes of pesticide exposure for honey bees living near agricultural fields," published in PLoS ONE in 2012, accumulating 603 citations and an average of 50.25 citations per year. The remaining documents in the top ten include "Fabrication of ZnO

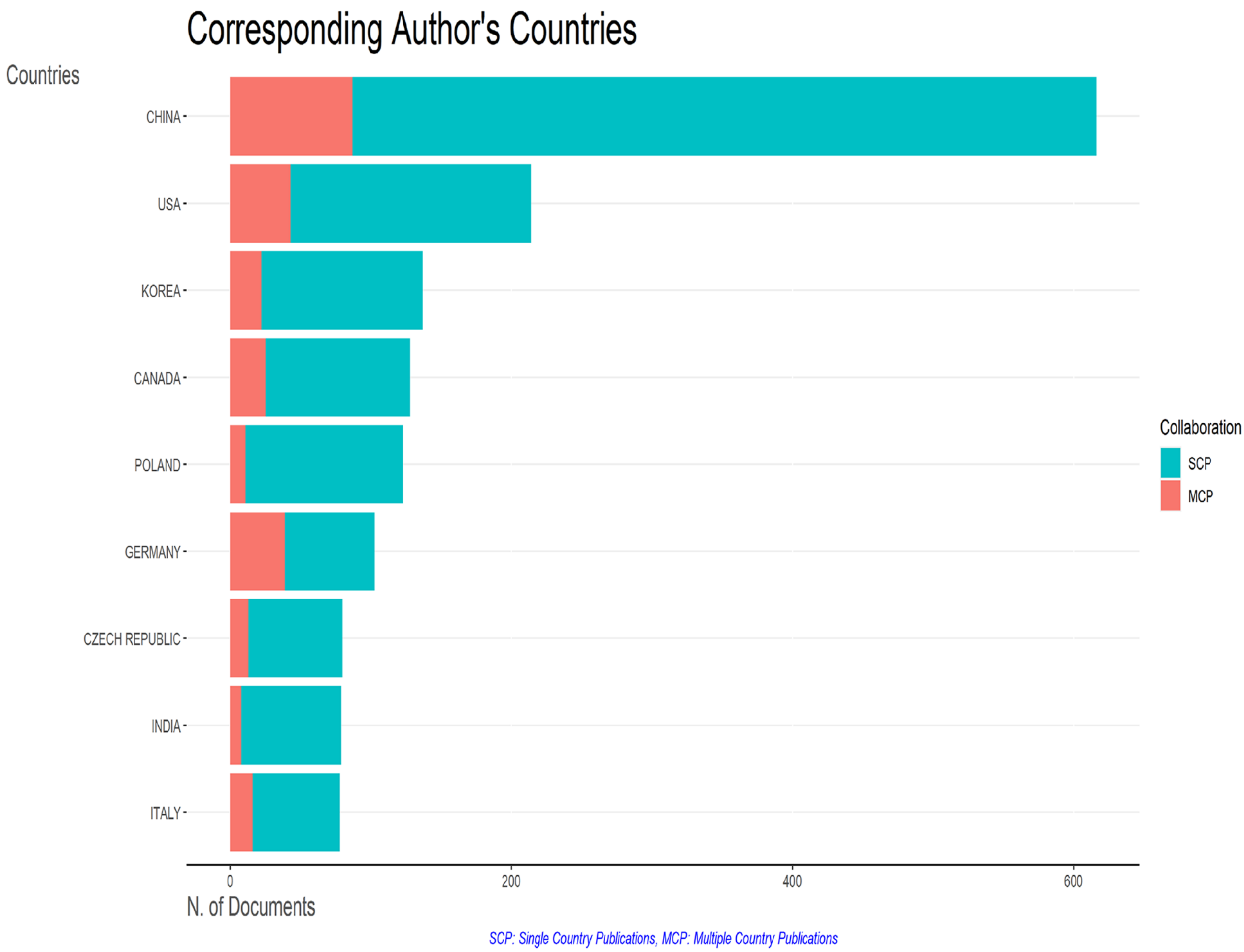

Fig. 4 Co-authorship mapping in terms of single-country publications (SCP; Aqua color), multiple-country publications (MCP, orange color), and the MCP ratio for each country. The MCP ratio indicates the extent of multiple-country collaborations in research publications, with higher ratios indicating a higher level of collaboration between countries. This figure was generated using the Bibliometrix application and the BibTex data file

'Dandelions' via a modified Kirkendall process" (Journal of the American Chemical Society, 2004, 590 citations), "The composition of a field of maize" (Journal of Heredity, 1908, 540 citations), "Stress-induced DNA methylation changes and their heritability in asexual dandelions" (New Phytologist, 2010, 463 citations), "Ni-Pd core–shell nanoparticles modified fibrous silica nanospheres as highly efficient and recoverable catalyst for reduction of 4-nitrophenol and hydrodechlorination of 4-chlorophenol" (Applied Catalysis B: Environmental, 2015, 376 citations), "Polyphenols and antioxidant capacity of Bulgarian medicinal plants" (Journal of Ethnopharmacology, 2005, 370 citations), "Antioxidant activity in medicinal plants associated with the symptoms of diabetes mellitus used by the Indigenous Peoples of the North American boreal forest" (Journal of Ethnopharmacology, 2002, 314 citations), and "Total phenolic content, antioxidant and antimicrobial activities of some medicinal plants" (Pakistan Journal of Pharmaceutical Sciences, 2009, 267 citations). These highly cited documents provide valuable insights and have made significant contributions to the field of TOR, covering various aspects such as nanoribbon formation, graphene frameworks, pesticide exposure, DNA methylation, catalysts, and more (Table 2).

Density visualization of the most cited countries

The density visualization highlights the citation counts for the most cited countries in TOR (Fig. 6). China has the highest citation count with 17,803 citations, followed by the United States with 13,517 citations. The United Kingdom has 5,727 citations, Canada has 5,205 citations, and Germany has 4,901 citations. South Korea and the Netherlands have 3,998 and 3,595 citations respectively. This visualization emphasizes the research impact and recognition of these countries in the field of TOR.

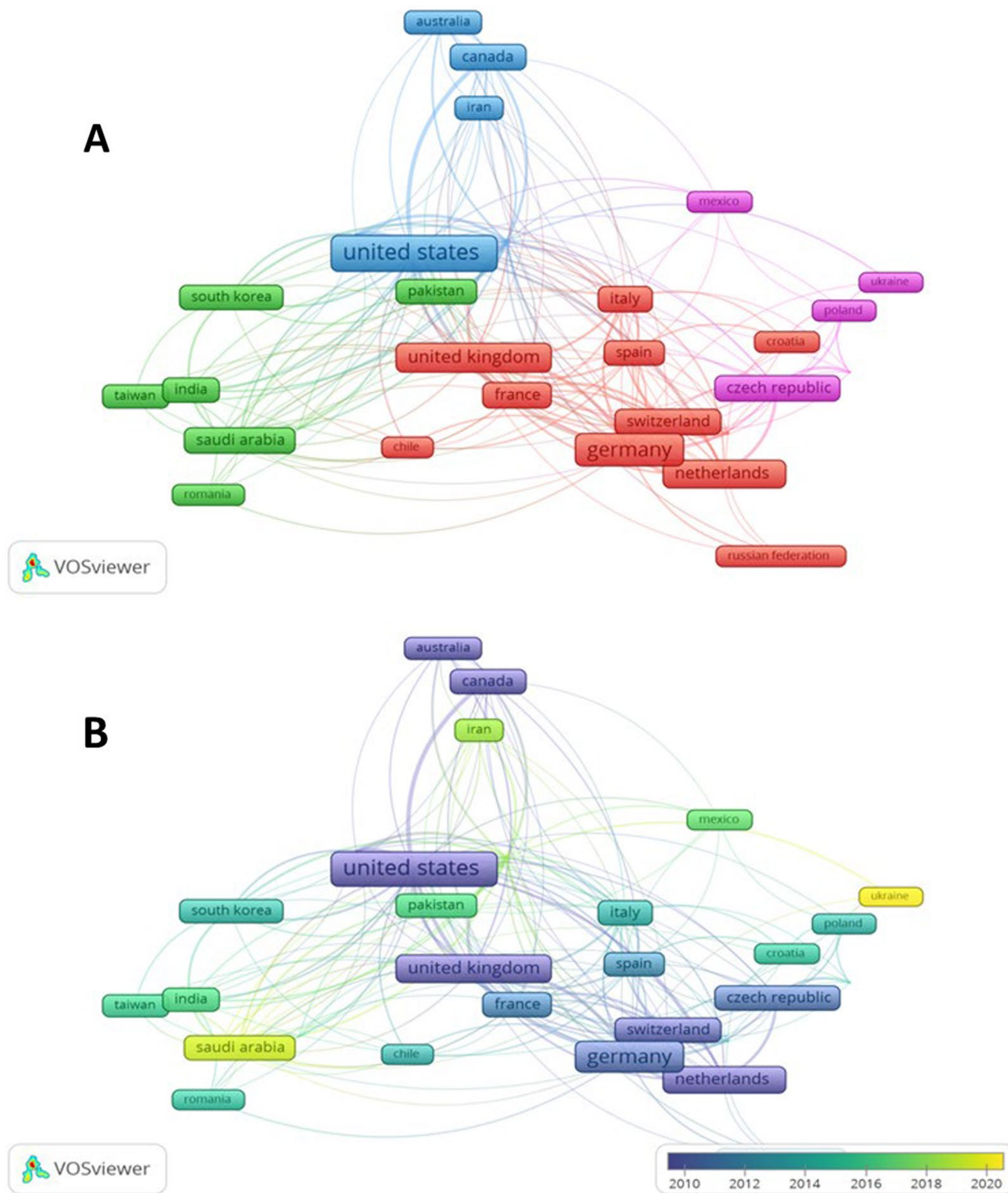

Fig. 5 VOSviewer mapping of co-authorship. **A** Network visualization, exhibits total link strength. Nodes represent TLS. **B** The examination of co-authorship mapping in terms of temporal characteristics (overlay visualization), where yellow color indicate the recent involvement in collaborative TOR. This figure was generated using VOSviewer

Temporal recognition of TOR

The timespan for the analyzed documents in TOR is from 1908 to 2024. On average, each document receives 24.98 citations, suggesting a significant level of recognition and impact within the field. Figure 7 illustrates the average article citation per year in TOR. The averages vary across different years, with a range from 0.00 to 4.66 citations per year. Notably, there is a general upward trend in the average over the years, reaching a peak in 2019 with 4.10 per year.

Author's local impact

The author's local impact analysis in TOR using Bibliometrix reveals the individual research impact of several authors (Table 3). Y. Wang, has an H-index of 21, a G-index of 35, and an M-index of 1.105, with 1,295 total citations and 52 publications starting in 2005. Y. Zhang, has similar metrics with an H-index of 21, a G-index of 36, an M-index of 1.235, and 1,335 total citations from 51 publications starting in 2007. X. Zhang, has an H-index of 20, a G-index of 32, and an M-index of 1.429, with 1,057

Table 2 The top ten cited documents in TOR

Rank	Title	Journal	Year	Citation	Citation average
1st	Mesoscale organization of CuO nanoribbons: Formation of "dandelions" (Liu and Zeng 2004a)	Journal of the American Chemical Society	2004	851	42.55
2nd	A versatile, ultralight, nitrogen-doped graphene framework (Zhao et al. 2012)	Angewandte Chemie—International Edition	2012	734	61.17
3rd	Multiple routes of pesticide exposure for honey bees living near agricultural fields (Krupke et al. 2012)	PLoS ONE	2012	603	50.25
4th	Fabrication of ZnO "Dandelions" via a modified Kirkendall process (Liu and Zeng 2004b)	Journal of the American Chemical Society	2004	590	29.50
5th	The composition of a field of maize (Shull 1908)	Journal of Heredity	1908	540	4.66
6th	Stress-induced DNA methylation changes and their heritability in asexual dandelions (Verhoeven et al. 2010)	New Phytologist	2010	463	33.07
7th	Ni-Pd core–shell nanoparticles modified fibrous silica nanospheres as highly efficient and recoverable catalyst for reduction of 4-nitrophenol and hydrodechlorination of 4-chlorophenol (Dong et al. 2015)	Applied Catalysis B: Environmental	2015	376	41.78
8th	Polyphenols and antioxidant capacity of Bulgarian medicinal plants (Ivanova et al. 2005)	Journal of Ethnopharmacology	2005	370	19.47
9th	Antioxidant activity in medicinal plants associated with the symptoms of diabetes mellitus used by the Indigenous Peoples of the North American boreal forest (McCune and Johns 2002)	Journal of Ethnopharmacology	2002	314	14.27
10th	Total phenolic content, antioxidant and antimicrobial activities of some medicinal plants (Sengul et al. 2009)	Pakistan Journal of Pharmaceutical Sciences	2009	267	17.80

total citations and 48 publications beginning in 2010. J. Li, has an H-index of 16, a G-index of 28, and an M-index of 1, with 829 total citations and 37 publications starting in 2008. D. Prüfer, has an H-index of 16, a G-index of 27, and an M-index of 0.889, with 759 total citations and 27 publications beginning in 2006. P.J. Van Dijk, has an H-index of 16, a G-index of 19, and an M-index of 0.615, with 1,326 total citations and 19 publications starting in 1998. X. Wang, Y. Yang, H. Zhang, and J. Kirschner also contribute significantly to TOR research with their impact metrics. These analyses provide insights into each author's research impact, productivity, and longevity within the TOR field.

Conceptual structure

Keywords co-occurrence

The dataset includes 23,482 instances of Keywords Plus (ID), which are additional keywords provided by the databases to enhance the document's indexing and discoverability. Additionally, there are 8,644 instances of Author's Keywords (DE), representing the specific keywords chosen by the authors to describe the content and themes of their research. These keyword categories contribute to the comprehensive understanding and categorization of the documents in TOR. The analysis of the conceptual structure of TOR using keywords co-occurrence reveals the following prominent words: dandelion (299), *Taraxacum officinale* (282), Asteraceae (100), antioxidant (98), medicinal plant (98), *Taraxacum* (97), apomixis (52), Compositae (46), heavy metals (45), oxidative stress (40), *Taraxacum kok-saghyz* (38), plants (34), ethnobotany (30), natural rubber (30), taxonomy (29), herbs (28), taraxasterol (27), soil (24), apoptosis (23), weeds (23), honey (22), herbal medicine (21), bioherbicide (20), pollen (19), *Taraxacum mongolicum* (19), diabetes mellitus (18), inflammation (17), germination (16), HPLC (16), inulin (16), phenolic compounds (16), phytoremediation (16), competition (15), latex (15), polyphenols (15), *Taraxacum brevicorniculatum* (15), traditional medicine (15), agamospermy (14), morphology (14), phytochemicals (14), plant extracts (14), rubber (14), toxicity (14), and climate change (13).

Thematic evolution

Analysis of thematic evolution reveals modifications in TOR dynamics between 1908 and 2024. 2015 marked a pivotal year with the expansion of topics from five to seven (Fig. 8). "Heavy metals" is one of the subjects whose timeline was extended from 1908 to 2015 to 2016–2024. Similar to this, "medicinal plants" continued to exist but for a longer time from 1908–2015 to 2016–2024. From 2016 to 2024, the topic of natural rubber changed to one that was more narrowly focused on "*Taraxacum kok-saghyz*". The term "*Taraxacum*" in the earlier period (1908–2015) changed into new topics in the later period (2016–2024), such as "antibacterial

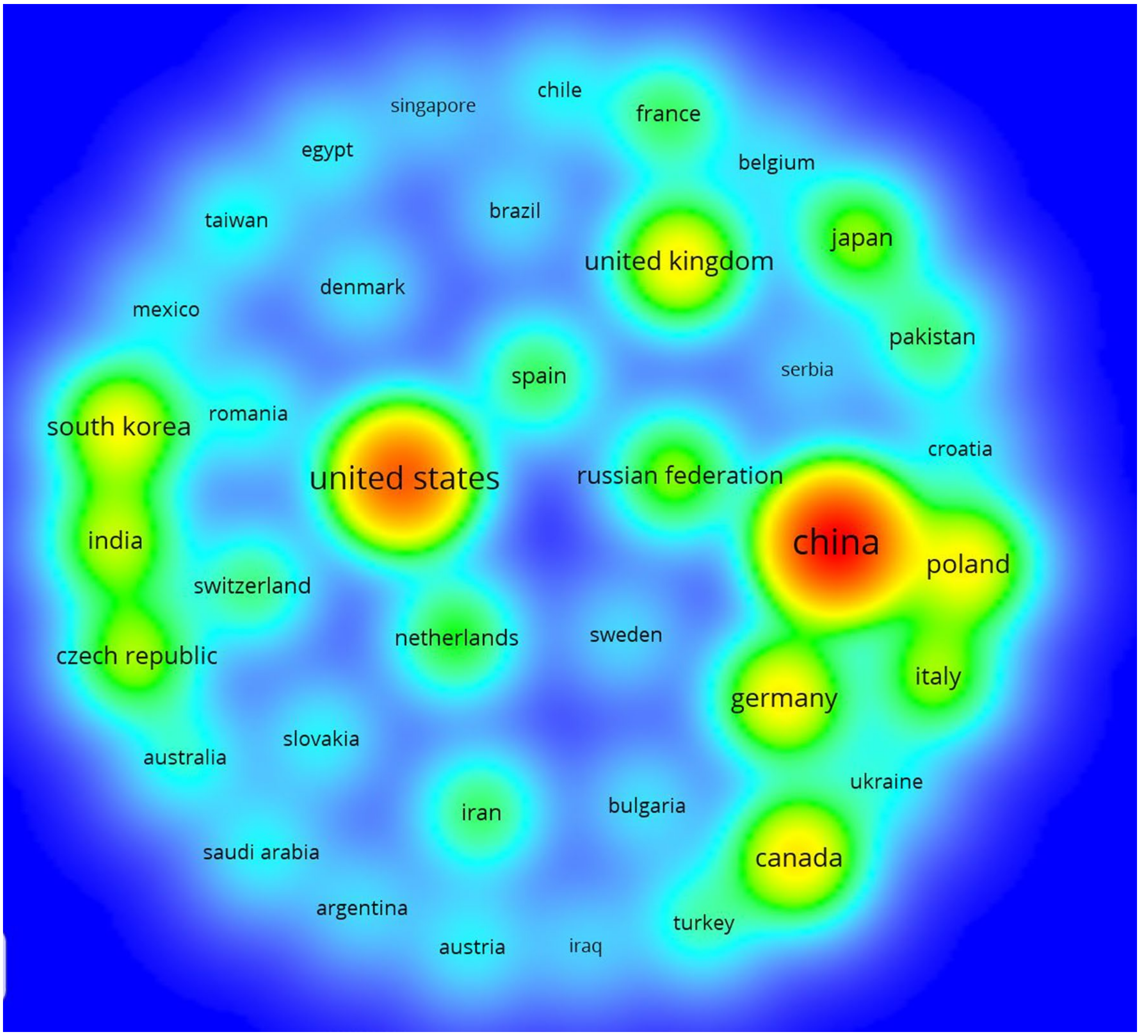

Fig. 6 Density visualization of the most cited countries. This figure was generated using VOSviewer. Density visualization in VOSviewer represents the density of citations across a map or network. It is commonly used to visualize the concentration or distribution of citations within a given map or network. Higher density areas will typically appear darker or more intense in color, indicating a higher concentration of the attribute

activity," "dandelion," and "medicinal plants". Additionally, the term "*Taraxacum officinale*" from the earlier period (1908–2015) evolved into new subjects in the later period (2016–2024), including "dandelion," "honey," "medicinal plants," and "pollen". These modifications reflect the ongoing thematic development and changing research priorities in TOR.

Thematic map

A thematic map is a cartographic representation that focuses on a certain theme or subject matter. The themes in every map are niche, motor, basic, and merging or declining. The thematic map of TOR focuses on various themes including "*Taraxacum officinale*," "germination," "antioxidant activity," "*Taraxacum*," "bioherbicide," "oxidative stress," "medicinal plants," "herbs," "*Taraxacum kok-saghyz*," and "heavy metals". These themes are categorized into different clusters based on their Callon Centrality, Callon Density, and classification (Table 4):

1. *Taraxacum officinale*: This cluster is classified as "basic" and has a relatively high Callon Centrality value of 0.073. It includes terms such as "*Taraxacum officinale*," "dandelion," "Asteraceae," "Compositae," "weeds," "*Taraxacum mongolicum*," "and "HPLC". These terms are likely associated with the botanical aspects, chemical analysis, and characteristics of *Taraxacum officinale*.
2. Germination: This cluster is categorized as a "niche" theme, with a Callon Centrality value of

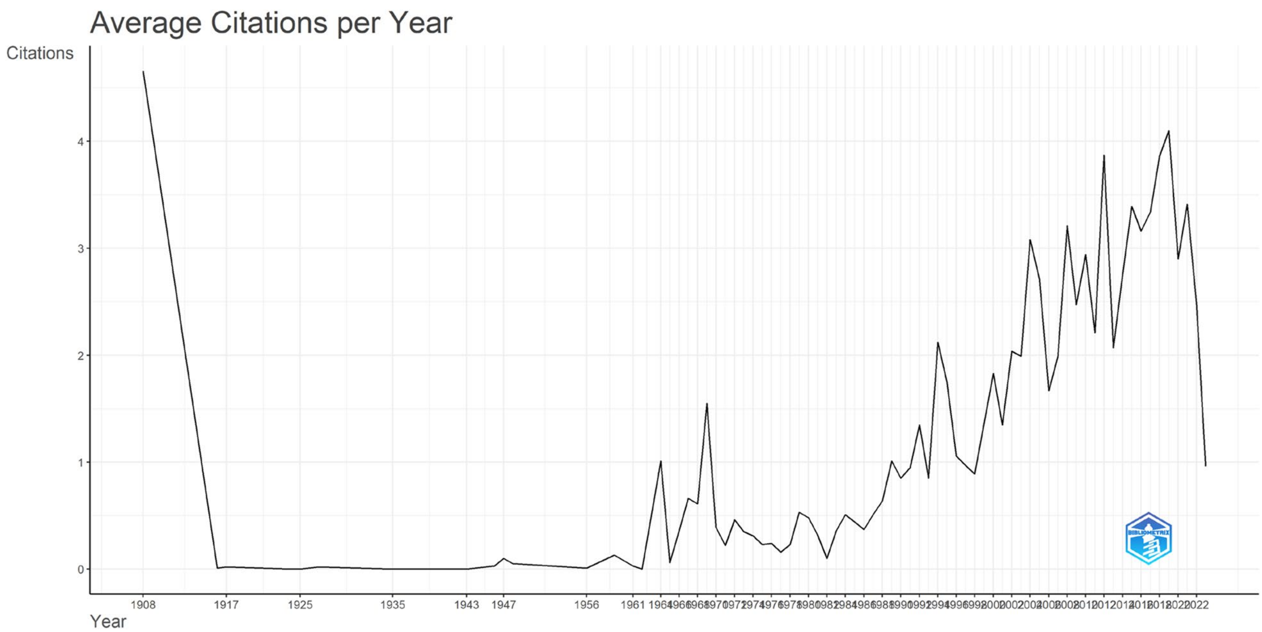

Fig. 7 Average article citation per year. This figure was generated using the Bibliometrix application and the BibTex data file

Table 3 Author's local impact

Authors	H index*	G index	M index	TC	NP	PY_start
Y. Wang	21	35	1.12	1295	52	2005
Y. Zhang	21	36	1.24	1335	51	2007
X. Zhang	20	32	1.43	1057	48	2010
J. Li	16	28	1.00	829	37	2008
D. Prüfer	16	27	0.89	759	27	2006
P.J. Van Dijk	16	19	0.66	1326	19	1998
X. Wang	16	33	0.84	1102	45	2005
Y. Yang	16	27	1.00	761	33	2008
H. Zhang	16	27	0.63	888	27	1998
J. Kirschner	15	24	0.54	624	28	1996

* H-index, G-index, and M-index evaluate an author's impact, highly cited works, and collaboration involvement in research.TC: total citations; NP: number of papers PY_start: year of starting publication

0.004. The component term in this cluster is simply "Germination," indicating a focus on the process of seed germination.

3. Antioxidant activity: This niche cluster has a Callon Centrality of 0.008 and includes terms like "antioxidant activity," "honey," "pollen," "diabetes mellitus," "inulin," and "phenolic compounds". It suggests a thematic focus on the antioxidant properties of various substances, including honey, pollen, and their potential implications in managing conditions like diabetes.
4. *Taraxacum*: This cluster is classified as "emerging or declining" and has a Callon Centrality value of 0.005. The component terms include "*Taraxacum*," "apomixes," "taxonomy," and "dandelions". This theme may explore the taxonomic classification and reproductive mechanisms of *Taraxacum* species.
5. Bioherbicide: Categorized as a "niche" theme, this cluster has a Callon Centrality of 0.003. The component terms are "bioherbicide" and "competition", suggesting a focus on the development and application of bioherbicides as an alternative to chemical herbicides in managing weed competition.
6. Oxidative stress: This cluster is delineated between "basic" and "motor" themes, with a Callon Central-

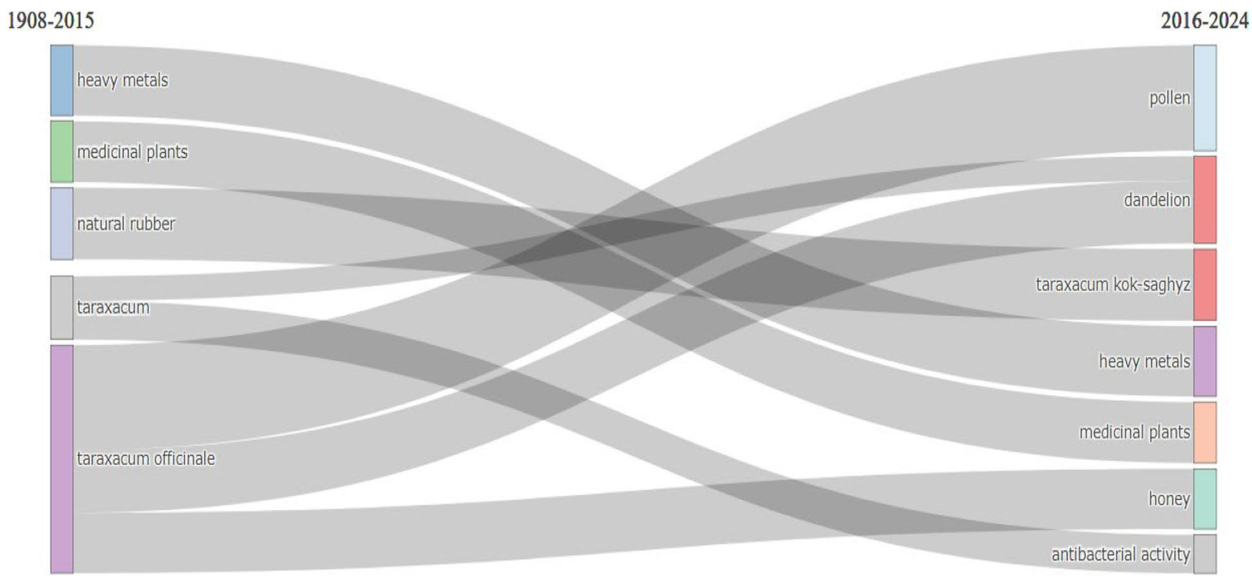

Fig. 8 Thematic evolution. 2015 was a crucial point for the trans-formation of the main topics. This figure was generated using the Bibliometrix application and the BibTex data file

Table 4 Clusters of the thematic map in TOR. The cluster was named by giving it the name of the most frequent word in that cluster

Cluster	Callon centrality	Callon density	Classification	Component terms
Taraxacum officinale	0.073	3.01	Basic	*Taraxacum officinale,* dandelion, Asteraceae, compositae, weeds, *Taraxacum mongolicum,* HPLC
Germination	0.004	6.25	Niche	Germination
Antioxidant activity	0.008	5.71	Niche	Antioxidant activity, honey, pollen, diabetes mellitus, inulin, phenolic compounds
Taraxacum	0.005	3.67	Emerging or declining	*Taraxacum*, apomixes, taxonomy, dandelions
Bioherbicide	0.003	6.00	Niche	Bioherbicide, competition
Oxidative stress	0.015	4.86	delineated between basic and motor	oxidative stress, antioxidant, taraxasterol, apoptosis, antioxidants, inflammation, polyphenols
Medicinal plants	0.012	4.47	Basic	Medicinal plants, ethnobotany, herbal medicine, traditional medicine
Herbs	0.009	3.57	delineated between basic and emerging	Herbs
Taraxacum kok-saghyz	0.011	5.50	Motor	*Taraxacum kok-saghyz*, natural rubber, *Taraxacum brevicorniculatum*
Heavy metals	0.017	4.72	Basic	Heavy metals, plants, soil, phytoremediation

The clustering was conducted using biblioshiny application in Bibliomtrix and Bib data format

ity value of 0.015. The component terms include “oxidative stress,” “antioxidant,” “taraxasterol,” “apoptosis,” “inflammation,” and “polyphenols”. It indicates a thematic exploration of oxidative stress, its impact on cellular processes, and the potential role of natural compounds like taraxasterol and polyphenols as antioxidants.

7. Medicinal plants: Categorized as a "basic" theme, this cluster has a Callon Centrality of 0.012. The component terms include “medicinal plants,” “ethnobotany,” “herbal medicine,” and “traditional medicine,” suggesting a focus on the study and application of medicinal plants, their traditional uses, and ethnobotanical practices.
8. Herbs: This cluster is delineated between "basic" and "emerging" themes, with a Callon Centrality value of 0.009. The component term in this cluster is "Herbs," indicating a thematic focus on the broader category of herbal plants and their uses.

9. *Taraxacum kok-saghyz*: Classified as a "motor" theme, this cluster has a Callon Centrality of 0.011. The component terms include "*Taraxacum kok-saghyz*," "natural rubber," and "*Taraxacum brevicorniculatum*". It suggests a thematic exploration of *Taraxacum kok-saghyz* as a source of natural rubber and potentially its cultivation and industrial applications.
10. Heavy metals: This cluster is classified as a "basic" theme and has a Callon Centrality value of 0.017. The component terms include "heavy metals," "plants," "soil," and "phytoremediation". This theme likely focuses on the interaction between plants and heavy metals in contaminated soil, as well as the potential use of plants for phytoremediation purposes.

Trending topics

Based on the provided data, it can be observed that several trending topics in TOR as shown in Fig. 9. One topic that stands out is "*Taraxacum kok-saghyz*," which has a high frequency of 38 and has been consistently discussed since 2016. This indicates a sustained interest in the study of this plant species. Other noteworthy topics include "apoptosis" and "*Taraxacum mongolicum*," both of which have a significant frequency and have been subjects of research for several years. Additionally, "toxicity" and "metabolomics" have gained attention in recent years and are expected to continue being trending topics in TOR. The emergence of "dandelion extract" as trending topics in more recent years suggests a growing interest in exploring the potential of dandelion and its derivatives. Overall, this analysis highlights a diverse range of topics in TOR, including medicinal plants, and health-related areas like obesity and growth performance. These topics

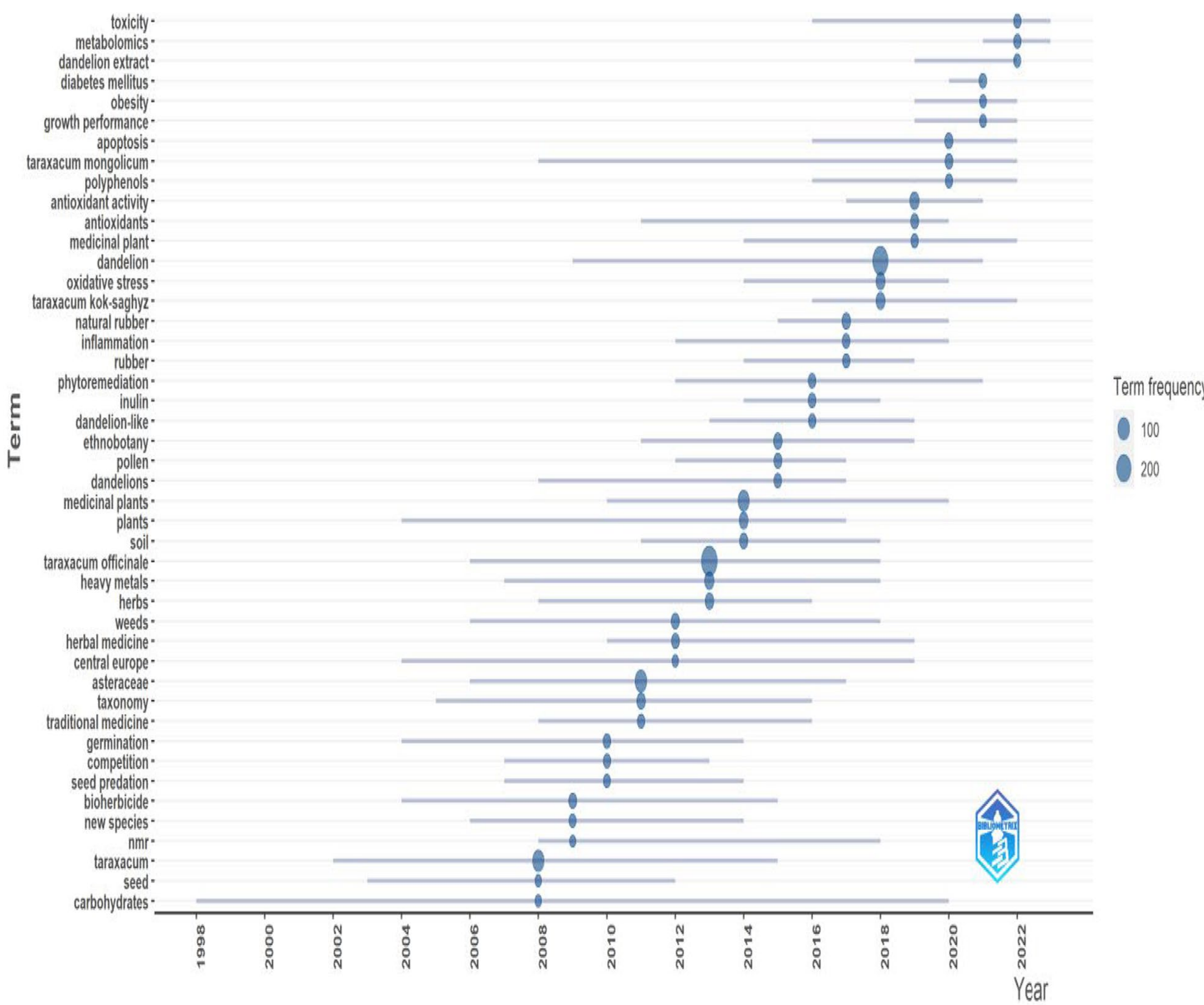

Fig. 9 Trending topics. This figure was generated using the Bibliometrix application and the BibTex data file

reflect the dynamic nature of organic chemistry research and demonstrate the ongoing exploration of new substances, processes, and applications within the field.

Discussion

The present study presents a bibliometric analysis of TOR. It explores the citation patterns, prolific authors, influential institutions, and collaboration networks to provide a comprehensive overview of the research landscape surrounding TOR. A narrative review with a thematic focus was conducted based on the results obtained from the analysis of thematic maps. Based on original research, the findings shed light on key trends and highlight important contributions in the field. Focusing on original research papers in bibliometric analysis is important as they contain primary data and novel findings, advancing scientific knowledge. These papers undergo rigorous peer review, have direct impact, and contribute to new theories and advancements. Other document types serve different purposes and excluding them ensures a focused assessment of original contributions and impact (Donthu et al. 2021).

The high citation counts of China and the United States in TAR could be attributed to several factors. These include robust research output supported by strong academic institutions, research funding, and infrastructure (Zhang et al. 2020). Extensive studies on *Taraxacum officinale* contribute to larger publications, increasing the likelihood of generating more citations. Active research collaboration networks, both domestically and internationally, enhance visibility and impact, leading to increased citations. Adequate research funding enables comprehensive and high-quality studies, further contributing to citation counts (Birkle et al. 2020). The expertise of researchers and institutions in both countries attracts attention from the scientific community, resulting in citations from researchers referencing their work. Additionally, the global research influence of China and the United States, through reputable journals, conferences, and collaborations, amplifies the visibility of their *Taraxacum officinale* research, attracting citations from researchers worldwide (Zhang et al. 2020). These factors collectively contribute to the high citation counts, showcasing the significant contributions of China and the United States to the field.

Collaboration plays a vital role in enhancing TOR by fostering knowledge sharing, resource access, interdisciplinary approaches, large-scale studies, conservation efforts, and translational research (Hou and Wang 2023; Vadukapuram et al. 2023). Through collaboration, researchers from different disciplines and institutions can share their expertise, findings, and resources, leading to a comprehensive understanding of *Taraxacum officinale*'s morphology, biochemistry, genetics, medicinal properties, and ecological interactions. Furthermore, collaboration between researchers, conservation organizations, and policymakers supports effective conservation strategies and sustainable management of *Taraxacum officinale* (Hou and Wang 2023; Jeyaraman et al. 2023; Vadukapuram et al. 2023). By working together, researchers and industry partners can translate scientific findings into practical applications, maximizing the impact of TOR across various fields.

"Bioherbicides," a niche theme in TOR, focuses on developing and applying natural alternatives to chemical herbicides (Charudattan 2023). *Taraxacum officinale* presents challenges in turfgrass stands, where synthetic herbicides are commonly used but face increasing scrutiny. Limited organic options have prompted studies on the effectiveness of fertilizers, organic herbicides, and bioherbicides such as chelated iron, ammonium nanonate, citrus oil, acetic acid, and sodium chloride for dandelion control (Bailey et al. 2013; Carroll et al. 2022; Eggert and Thiele 2020). As pesticide use undergoes scrutiny in various countries, alternative weed control methods are crucial. *Sclerotinia minor*, a fungus, can infect dandelion plants, leading to symptoms like wilting, stem rot, and *sclerotia* formation, offering potential as a bioherbicide (Faria et al. 2019; Hahn et al. 2020). *Phoma herbarum*, another fungal pathogen, has also been explored as a bioherbicide for *Taraxacum officinale* control. Additionally, research has investigated the efficacy of using these fungi for parasitic weed management and the role of interspecific competition (Golijan et al. 2023; Hahn et al. 2020; Neumann and Boland 1999). *Taraxacum officinale* exhibits allelopathy, emitting allelochemicals that impact nearby plants and their ecosystem interactions (Cepeda et al. 2021). Understanding the ecological functions and relationships of dandelions with other plant species, including their allelopathic impacts, provides valuable insights for management strategies. (Cepeda et al. 2021).

Dandelions are known for their prolific seed production and germination capabilities. Germination in TOR has been studied from two perspectives: examining germination on dandelion plants and assessing its inhibitory impact on the germination of other plant species (Caser et al. 2022). Li et al. investigated the effects of an aqueous extract from fig tree leaves on dandelion seed germination and seedling growth (Li et al. 2021). Another study evaluated the influence of plant growth regulators and carbon sources on dandelion germination and growth in a controlled laboratory environment (Martínez et al. 2021). Allelopathic plants release chemical compounds that can affect neighboring plants. A previous investigation explored the allelopathic impact of chicory on wheat (Naila et al. 2021). Dandelions release allelochemicals that can inhibit the germination and growth of certain plant species, providing a competitive advantage in certain environments (Caser et al. 2022; Li et al. 2021; Martínez et al. 2021; Naila et al. 2021). The medicinal value of dandelion is primarily attributed to its chemical composition, including flavonoids, sesquiterpene lactones, and phenolic compounds. While germination may not directly impact the chemical composition, optimizing germination conditions and cultivation practices can indirectly enhance the overall health and vigor of the plants, potentially influencing their medicinal value (Li et al. 2021; Martínez et al. 2021).

Dandelion's antioxidant properties can be attributed to its bioactive compounds, including polyphenols, flavonoids, and carotenoids (Diaz et al. 2012; Ghaima et al. 2013). These antioxidants help counteract free radicals and reactive oxygen species, reducing oxidative stress (Sekhon-Loodu and Rupasinghe 2019; Wang et al. 2021). They play a significant role in mitigating apoptosis (Ovadje et al. 2012), inflammation, cellular damage caused by oxidative stress (Gahramanova et al. 2023; Jeon et al. 2017, 2008). Taraxasterol, a triterpene compound found in dandelion, exhibits antioxidant properties by inhibiting reactive oxygen species production and enhancing antioxidant enzyme activity (Chen et al. 2019; Ge et al. 2023; Li et al. 2022a, 2023; Movahhed et al. 2023; Sang et al. 2023; Yang et al. 2023). It also possesses anti-inflammatory effects, hepatoprotective properties, potential as an anticancer agent, and antimicrobial activity (Chen et al. 2019; Jiang et al. 2016; Liu et al. 2018a; Xueshibojie et al. 2016; Zhang et al. 2014, 2012). Further research is needed to fully understand taraxasterol's mechanisms of action and its potential applications in medicine. Nevertheless, its diverse biological activities make it an intriguing compound for further investigation in health and therapeutic contexts.

The theme "*Taraxacum*" discusses the taxonomy of dandelions. A morphologically constrained group of species, the dandelions are found throughout Europe's oceanic and sub-oceanic zones (Gilman 2022). In apomictic plant groupings like *Taraxacum*, DNA fingerprinting has proven effective for the research of genotypic dispersion and assessment of genetic relatedness. In one instance using apomictic *Taraxacum*, interspecific hybridization has been shown to cause speciation. The use of molecular markers on offspring produced by experimental cross-pollinations has provided data on the prevalence of apomixis in *Taraxacum* as well as its inheritance and regulation (Van Dijk et al. 2020).

Taraxacum officinale is a significant plant within the theme of medicinal plants, ethnobotany, herbal medicine, and traditional medicine (Sekhon-Loodu and Rupasinghe 2019). This plant has a long history of traditional use in various cultures worldwide. Its leaves, roots, and flowers have been employed in traditional medicine systems for their diuretic, anti-inflammatory, antioxidant, and hepatoprotective properties (Hfaiedh et al. 2016; Kantah et al. 2011; Nazari et al. 2015). *Taraxacum officinale* is a valuable plant in ethnobotanical practices and traditional medicine. It has been used for centuries to treat various ailments, and is incorporated into herbal preparations like teas, tinctures, and extracts. Exploring its properties contributes to understanding its potential health benefits and cultural significance in natural medicine (Gahramanova et al. 2023; Goyal et al. 2023; He et al. 2023; Xia et al. 2023).

Dandelion has been studied for its potential health benefits, particularly in relation to diabetes mellitus. It shows promise in regulating blood sugar levels and improving insulin sensitivity. The plant's roots contain inulin, a prebiotic dietary fiber that can contribute to improved gut health and help regulate blood sugar levels (Cho et al. 2002; McCune and Johns 2002; Sekhon-Loodu and Rupasinghe 2019). Dandelion exhibits potent antioxidant properties, protecting cells from oxidative damage. It contains phenolic compounds known for their antioxidant, anti-inflammatory, and potential antidiabetic effects (Ahmadi et al. 2023; Arczewska-Włosek et al. 2023; He et al. 2023; Lobine et al. 2020; Sekhon-Loodu and Rupasinghe 2019; Xia et al. 2023; Yousefi Ghale-Salimi et al. 2018; Zhou et al. 2023). Dandelion flowers serve as a source of nectar for bees, and dandelion honey may have unique properties and potential health benefits attributed to its bioactive compounds. Dandelion pollen is rich in proteins, vitamins, minerals, and bioactive compounds, making it a valuable dietary supplement (Aylanc et al. 2021; Maric et al. 2020; Straumite et al. 2022). Overall, dandelion's antioxidant activity, presence of inulin, phenolic compounds, and its potential benefits for diabetes mellitus make it a subject of interest for further research into its health-promoting properties.

Taraxacum kok-saghyz theme was classified as a "motor" theme. The component terms include "*Taraxacum kok-saghyz*," "natural rubber," and "*Taraxacum brevicorniculatum*". It suggests a thematic exploration of *Taraxacum kok-saghyz* as a source of natural rubber and potentially its cultivation and industrial applications. *Taraxacum kok-saghyz*, also known as Russian dandelion, is a species within the *Taraxacum* genus that has gained attention for its potential in natural rubber production (Schuchovski et al. 2020). The latex derived from its roots contains high levels of rubber-producing latex. This is significant because natural rubber, traditionally obtained from the rubber tree, is a valuable material used in various industries. *Taraxacum kok-saghyz* and other alternative rubber-producing plants, including certain species within the *Taraxacum* genus, offer the potential for sustainable and diversified sources of natural rubber. *Taraxacum brevicorniculatum* is another species within the *Taraxacum* genus, representing a distinct species within the diverse *Taraxacum* genus (Kuluev et al. 2020; Niephaus et al. 2019; Piccolella et al. 2023). These keywords highlight the relevance of specific *Taraxacum* species in the context of natural rubber production and the potential for alternative sources of this valuable material.

The keywords provided—heavy metals, plants, soil, phytoremediation—are related to the process of phytoremediation, which involves using plants to remove or neutralize pollutants, particularly heavy metals, from contaminated soil. *Taraxacum officinale* has the potential to be used in phytoremediation, a process that utilizes plants to remove heavy metals from contaminated soil (Adamczyk-Szabela and Wolf 2022). The plant can uptake heavy metals, such as lead and cadmium, through its extensive root system. *Taraxacum officinale* accumulates these metals in its roots and shoots, which can be subsequently harvested, effectively reducing the metal concentrations in the soil. Additionally, the plant's deep taproot can improve soil structure, and its high biomass production and rapid growth enhance its effectiveness in extracting heavy metals. Overall, *Taraxacum officinale* shows promise as a natural and sustainable solution for remediating heavy metal-contaminated soil environments (Sabreena et al. 2022).

Limitations

Some potential limitations of this bibliometric study include data availability and bias, language and geographic bias, publication and citation practices that can introduce biases or distort results, exclusion of non-peer-reviewed sources, lack of contextual information, and interpretation challenges. It is crucial to acknowledge these limitations and exercise caution when interpreting the results, emphasizing the need for a comprehensive approach that combines bibliometric analysis with other research methodologies.

Conclusions

In conclusion, the scientometric analysis and narrative review of a century of *Taraxacum officinale* research offer valuable insights into advancements, trends, and themes that have shaped our understanding of this plant species. Through quantitative methods, we have gained knowledge about research growth, collaboration patterns, and impact in this field over the years. The narrative review has allowed us to delve into the key themes and topics that have emerged from this body of research, shedding light on the diverse aspects of *Taraxacum officinale*. This comprehensive examination of a century of TOR underscores this plant species' significance and enduring interest. It highlights the contributions of researchers across various disciplines and emphasizes the collaborative efforts that have driven scientific progress. The scientometric analysis provides a broader perspective on the research landscape and identifies potential avenues for future investigations. This scientometric look and narrative review offer a valuable resource for researchers, policymakers, and stakeholders interested in *Taraxacum officinale*. It consolidates our knowledge and points towards promising directions for further exploration, fostering continued advancements in our understanding of this versatile plant species.

Abbreviations

AR	Article
AU	Authors
AU_CO	Country of the authors
CP	Conference paper
CSV	Comma-separated values
MCP	Multiple-country publications
MeSH	Medical subject headings
MS Excel	Microsoft excel
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
SCP	Single-country publications
SO	Sources
TITLE-ABS-KEY	Title + abstract + keywords
TLS	Total link strength
TOR	*Taraxacum officinale* Research

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Author contributions
SIA planned the investigation, evaluated the findings, wrote the article, and oversaw the administrative aspects. MMET gathered the information and revised the text. Both authors have read and approved the manuscript.

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Availability of data and materials
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Declarations

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There is no form of human subject involved in this manuscript; therefore, ethics approval is not required.

Consent for publication
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