

MAPPING PHARMACOLOGICAL RESEARCH ON CHICORY (*CICHORIUM INTYBUS L.*): BIBLIOMETRIC TRENDS AND COMMERCIAL POTENTIAL

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ABSTRACT

Chicory (*Cichorium intybus L.*), an established industrial crop for inulin and has a record of traditional medicinal use, has increasingly been studied for its pharmacological properties. This study mapped pharmacological research on *C. intybus* and assessed how far its structure supports commercial product pathways. The study covers Scopus records for 2010–2026, which were screened against predefined criteria, and 168 articles were analysed in Bibliometrix/Biblioshiny following PRISMA 2020. Annual output increased from one article in 2010 to 24 in 2025. China, India, Egypt, Iran and Pakistan produced 51.2% of articles; international collaboration was limited (27.3%), and the co-citation network was fragmented into seven communities. Polyphenols, bioactive compounds and chicory root were central, developed themes; inulin, inflammation and obesity were central but less developed; sesquiterpene lactones and anthelmintic activity were peripheral. Evidence was predominantly preclinical, with eight potential application pathways emerging, including standardised extracts, metabolic and hepatic nutraceuticals, gut-health ingredients, antimicrobial agents and veterinary products. The study identifies potential commercial pathways for chicory-derived products while highlighting the need for clinical validation, product-specific safety assessment and techno-economic evaluation to establish their commercial viability.

KEYWORDS: Cichorium intybus, Inulin, Medicinal, Plant Extracts

1. INTRODUCTION:

Chicory (*Cichorium intybus L.*) is a commercially important crop, with potential applications across the pharmaceutical, nutraceutical, cosmetics, veterinary health and biotechnology industries, besides its traditional use in the food and beverage industry. Its root and shoot parts contain bioactive compounds associated with antioxidant, antimicrobial and other pharmacological properties [1,2]. Inulin, a key component of chicory roots, has potential applications in pharmaceutical formulations such as drug delivery, protein stabilisation and vaccine formulations [3]. Chicory-derived materials have also been investigated for cosmetic and personal care applications [4] while processing residues have been investigated for further applications, including the veterinary sector [5].

The importance of plant-derived raw materials is also evident in the international trade in medicinal and aromatic plants, which in 2023 amounted to a value of US\$ 4.18 billion. The export value of this category has seen a 240% rise from 2010 to 2023, indicating an expanding role in global botanical trade [6]. In India, the cultivation of medicinal plants is also identified as a means of rural income generation, value addition and export development, giving a commercial imperative for considering crops such as chicory as sources of specialised raw materials for pharmaceutical and related industries [7]. Chicory is already well established in the industrial ingredient market. The global chicory market is estimated to have generated around US\$332.2 million in 2024, and the global inulin market was valued at US\$1.84 billion. The inulin market was led by chicory-derived inulin, which generated 73.8% of the market revenue, and food and beverages, which led in terms of application, accounting for 61.9% of the market [8,9]. The existing commercial base, traditional medicinal application and potential of the chicory-derived compounds in pharmaceutical formulations and other industrial products provide opportunities to explore other uses of the crop for further market diversification and commercial development.

The quality of the raw material, chemical composition, standardisation and regulatory requirements are essential considerations in the development of plant-derived pharmaceutical products. Chemical profile differences between chicory species and plant parts make it important to identify suitable quality markers to ensure product consistency [2]. Regulatory pathways also vary according to the intended product and its claims [10].

Bibliometric analysis offers an approach to systematically map the evolution of pharmacological research by publication trends, geographical contributions, collaboration patterns, influential authors and sources, and thematic relationships [11–13]. These analyses can be used to determine the major foci of scientific research and the changing priorities of research.

The bibliometric scenario, together with market data, can serve as a starting point for analysing the commercial relevance of chicory research and identifying areas for further research.

Despite this commercial and traditional-medicine background, the pharmacological literature on chicory remains dispersed across many disciplines. Though narrative reviews are present in particular aspects, the question is related where the experimental evidence is concentrated, whether the research streams are integrated or fragmented, and which parts of the field are close enough to raw-material definition, safety assessment and product development to inform commercial decisions. Thus the aim of the present study was to map the pharmacological research on *C. intybus* using bibliometric tools and discuss the implications for commercialisation. It analyses publication trends, geographical contributions, influential authors and sources, research collaboration and major thematic areas. The study correlates scientific advances with published market information to consider potential avenues for commercialisation of chicory beyond its current markets.

2. MATERIALS AND METHODS

2.1. Research Design

This review utilises bibliometric analysis to examine the development and thematic structure of pharmacological research on chicory (*Cichorium intybus* L.). The review followed the reporting principles of the PRISMA 2020 statement [14]. Bibliometric techniques were used to analyse publication trends, authorship patterns, country contributions, citation relationships and the conceptual structure of the literature.

2.2. Data Source and Search Strategy

Scopus was selected as the primary bibliographic database because it provides structured publication records suitable for bibliometric analysis. The literature search and review process were undertaken during July–September 2026. The search covered publications from 2010 to 2026 and focused on the pharmacological and therapeutic applications of *Cichorium intybus*. The retrieved records were exported for screening, data preparation and bibliometric analysis.\

2.3. Eligibility Criteria

Studies were considered eligible when *Cichorium intybus* was a substantive subject of investigation and the research addressed pharmacological, therapeutic or medicinal relevance. Publications primarily concerned with agronomy, crop physiology, food processing without therapeutic relevance, animal feed, chemical characterisation without pharmacological relevance, or other species for which the contribution of *C. intybus* could not be isolated were excluded. Reviews, editorials and bibliometric studies were also excluded according to the screening criteria.

2.4. Study Selection Process

The study selection process followed the identification, screening and eligibility stages of the PRISMA framework. The initial Scopus export contained 703 records. After applying the publication-period, document-type and language filters, 470 records remained for title, abstract and keyword screening. Of these, 298 records were excluded according to the predefined eligibility criteria. The screening audit identified 168 records selected for the final assessment process.

Table 1. PRISMA-based study selection and screening summary

PRISMA stage	Operational procedure	Eligibility decision	Output/count
Identification	Retrieval of records from Scopus for pharmacological and therapeutic research on <i>Cichorium intybus</i> L. published during 2010–2026.	Identify potentially relevant publications on chicory pharmacology and therapeutic applications.	703 records identified
Screening	Application of period, document-type and language filters, followed by title, abstract and keyword screening.	Exclude records outside the specified publication period, document type, language and research scope.	470 records screened; 298 excluded
Eligibility	Further assessment of records retained after initial screening.	Exclude articles that do not satisfy the predefined eligibility criteria after assessment.	172 records assessed; 4 excluded
Inclusion	Finalisation of eligible articles for bibliometric analysis.	Include eligible publications addressing the pharmacological and therapeutic research scope of chicory.	168 articles included
Synthesis	Bibliometric analysis using Bibliometrix and Biblioshiny in R,	Analyse the intellectual, collaborative and conceptual structure of the included literature.	168 articles analysed

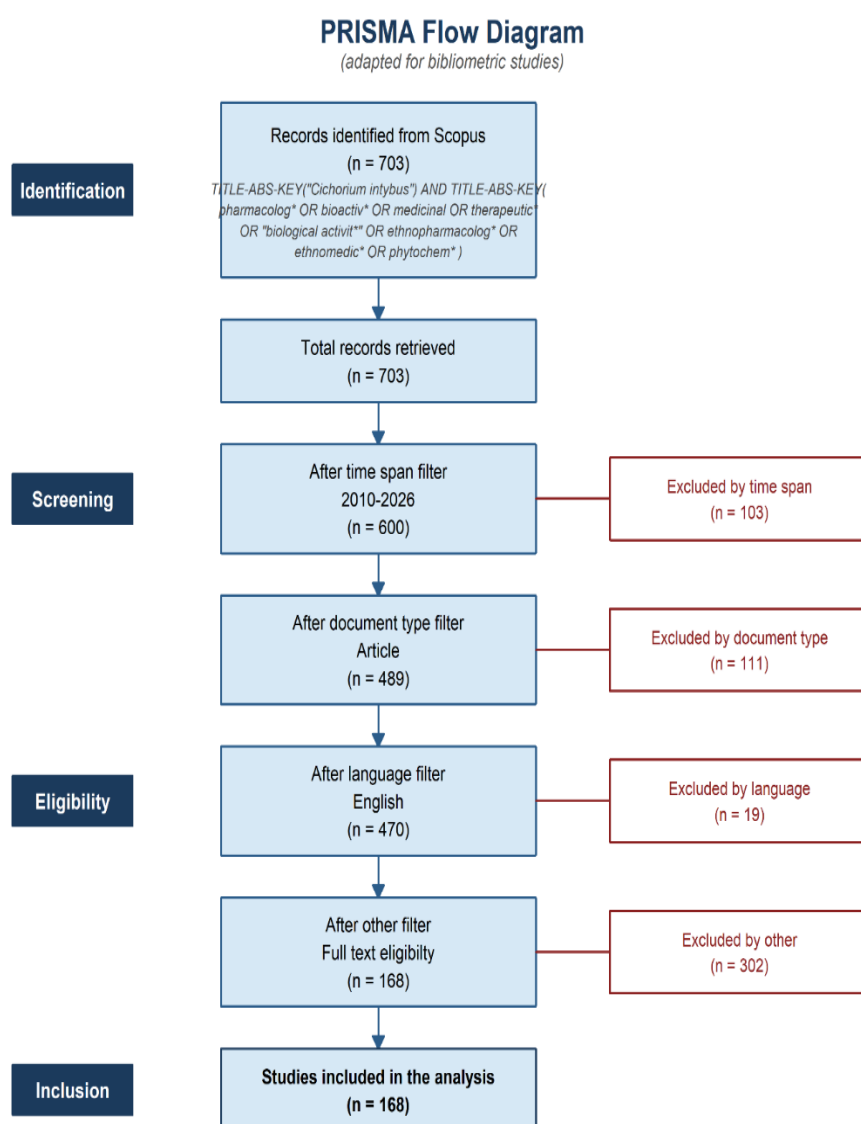


Figure 1. PRISMA 2020 flow diagram of the study selection process

Table 1 summarises the numerical outcomes of the screening process, while Figure 1 illustrates the flow of records through identification, filtering, screening and eligibility assessment. The final study count should be updated after all pending eligibility decisions have been resolved.

2.5. Bibliometric Analysis

Bibliometric analysis was conducted using the Bibliometrix package and its Biblioshiny interface in R. The analysis covered annual scientific production, corresponding-author countries, single-country and multiple-country publications, author productivity, source productivity, co-citation relationships, keyword co-occurrence and thematic mapping. The bibliometric findings were interpreted to describe the development, collaboration patterns and thematic organisation of pharmacological research on chicory.

2.6. Methodological Limitations

The review was limited to English-language articles indexed in Scopus, which may introduce database, language and publication bias. Selection bias cannot be excluded in terms of article selection. The common formal risk-of-bias assessment was not applied due to the heterogeneity of the included studies.

3. RESULTS AND DISCUSSION:

3.1. Annual Scientific Production

The number of scientific publications on the pharmacology of *Cichorium intybus* L. rose significantly during 2010–2026 (Fig. 2). The final corpus consisted of 168 articles: 1 in 2010, 24 in 2025, and the rest in the intervening years. In the last decade (2010-2019), the number of articles published ranged from 1 to 10 articles per year, with an average of 5.9 articles per year. Publication activity then remained steady between 12 and 13 articles per year from 2020 to 2023, followed by a

rise to 21 articles in 2024 and 24 articles in 2025. Overall, 109 articles (64.9%) were published from 2020 onwards, while 45 articles (26.8%) appeared during 2024–2025 alone.

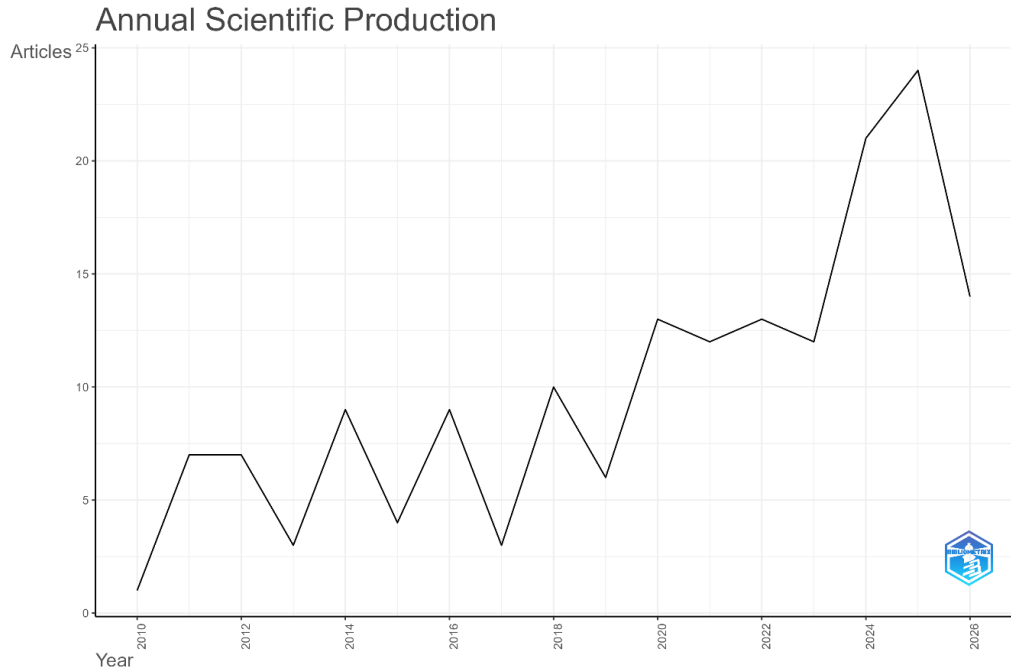


Figure 2. Annual scientific production on the pharmacology of *C. intybus* L., 2010–2026 (n = 168).

The average annual number of articles for 2020-2025 is 15.8 articles, which is about 2.7 times the average number of articles for 2010-2019. The 14 articles for 2026 are for a partial year and should not be interpreted as a decrease in research activity. The temporal distribution indicates that pharmacological research on chicory has gained more attention in recent years. However, this does not necessarily reflect the same level of experimental validation, reproducibility or clinical translation.

3.2. Geographic Distribution of Research and International Collaboration

A corresponding-author country analysis shows that research output is concentrated in Asia and the Middle East and North Africa, with some research coming from Europe and other areas (Fig. 3; Table 3). China had the largest number of articles (24), followed by India (18), Egypt and Iran (16 each) and Pakistan (12). These five countries combined made up 86 articles (51.2% of the corpus). A total of 143 articles (85.1%) were from the 20 countries included in the analysis. European contributions were from France (7), Denmark (6), Poland (6) and Italy (5). The results show that the geographical distribution of chicory pharmacology research is uneven, but that a significant number of the recorded publications come from a relatively small number of countries.

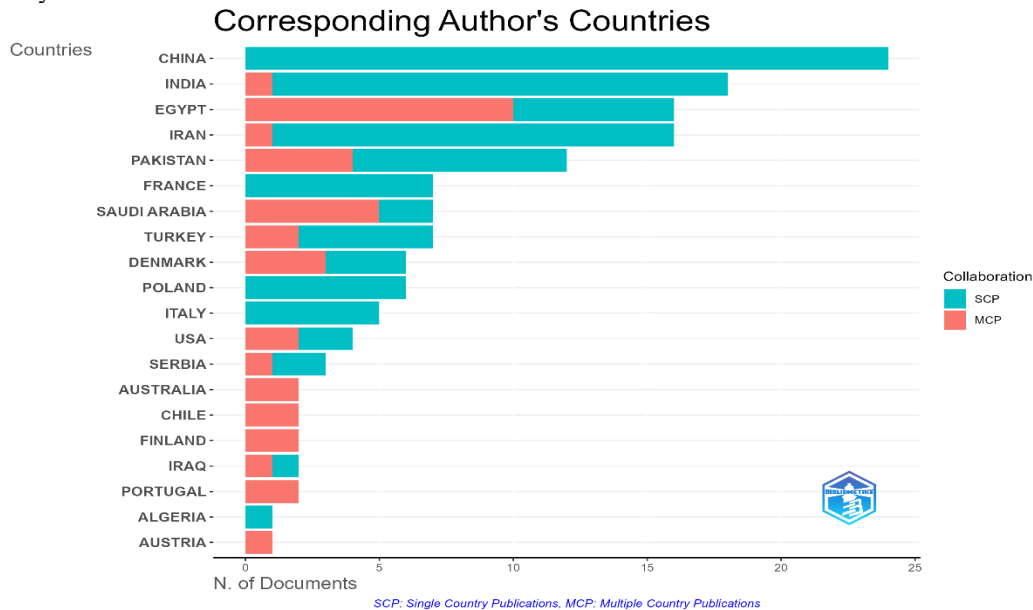


Figure 3. Corresponding authors' countries by single-country (SCP) and multiple-country (MCP) publications (top 20 countries).

Table 2. Top ten countries by corresponding-author articles.

Country	Articles	SCP	MCP	MCP share (%)
China	24	24	0	0.0
India	18	17	1	5.6
Egypt	16	6	10	62.5
Iran	16	15	1	6.3
Pakistan	12	8	4	33.3
France	7	7	0	0.0
Saudi Arabia	7	2	5	71.4
Turkey	7	5	2	28.6
Denmark	6	3	3	50.0
Poland	6	6	0	0.0

The level of international collaboration was widely different between countries. In the country-level analysis, 39 articles out of 143 were multiple-country publications (MCP) representing 27.3%. Ten MCP articles were recorded in Egypt (out of 16), five in Saudi Arabia (out of seven) and three in Denmark (out of six). The six articles from Poland and seven articles from France were all single-country publications (SCP), as were all 24 Chinese articles. India had 17 SCP articles out of 18, and Iran had 15 out of 16. These differences indicate that publication productivity and international collaboration are two different aspects of research activity.

3.3. Author Relevancy and Publication Sources

The authorship of the articles was spread among multiple authors, and no single author had a significant share of the 168 articles (Fig. 4). The most relevant authors were Zhang B. with seven articles (4.2% of the corpus), Simonsen H. T., Thamsborg S. M. and Williams A. R. with six articles each. Valente A. H. and Wang Y. contributed 5 articles each, followed by Chen J., Ekstrand B., Hilbert J.-L. and Lin Z., who contributed 4 articles each. The relatively small number of publications of the top authors suggests that the number of publications is not concentrated on one author.

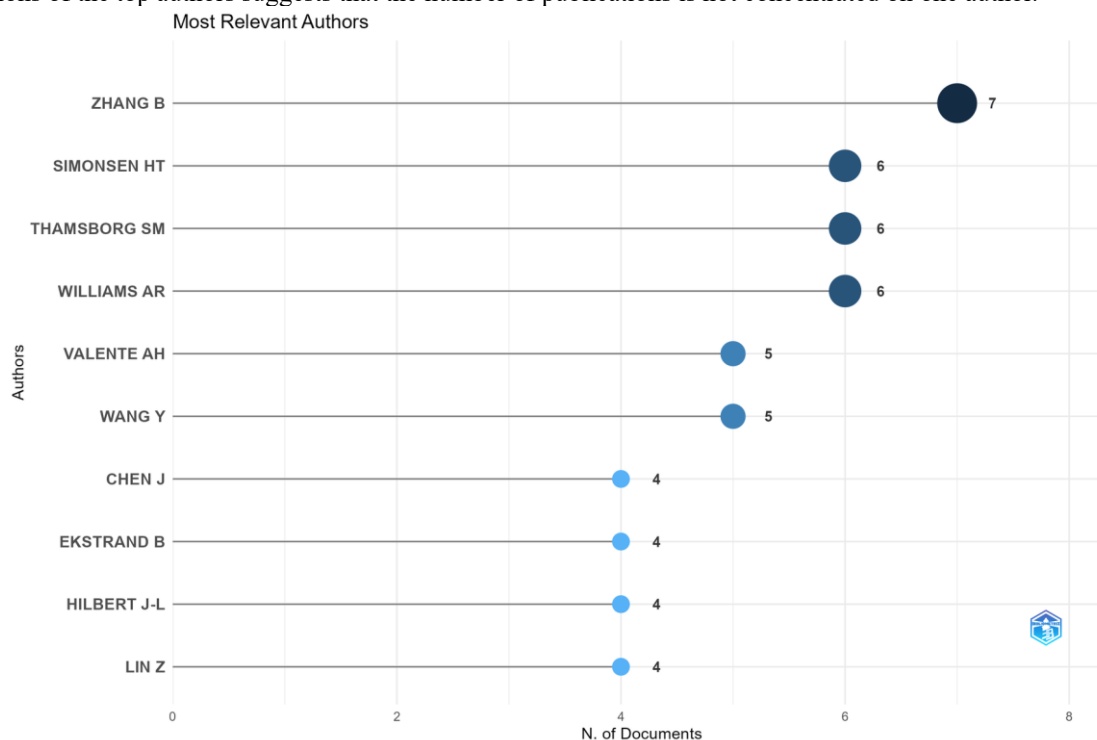


Figure 4. Most relevant authors by number of documents.

The most prominent authors are those involved in anthelmintic and antiprotozoal research, research on porcine hepatic enzymes, hairy-root cultures and chromatographic fingerprinting and quality-marker research. These contributions indicate that there are different experimental and application-oriented interests in the field and not a single coherent pharmacological programme.

The distribution of publication sources also highlights the multidisciplinary nature of chicory pharmacology (Fig. 5). The top ten sources accounted for 23.8% of the corpus with 40 articles. The International Journal of Molecular Sciences had the highest number of articles (8), followed by the Journal of Ethnopharmacology (7) and Molecules (4). Three articles

were published in each of seven other sources: Food and Chemical Toxicology, International Food Research Journal, International Journal for Parasitology: Drugs and Drug Resistance, International Journal of Cancer Management, Pakistan Journal of Pharmaceutical Sciences, Pharmaceuticals and Scientific Reports.

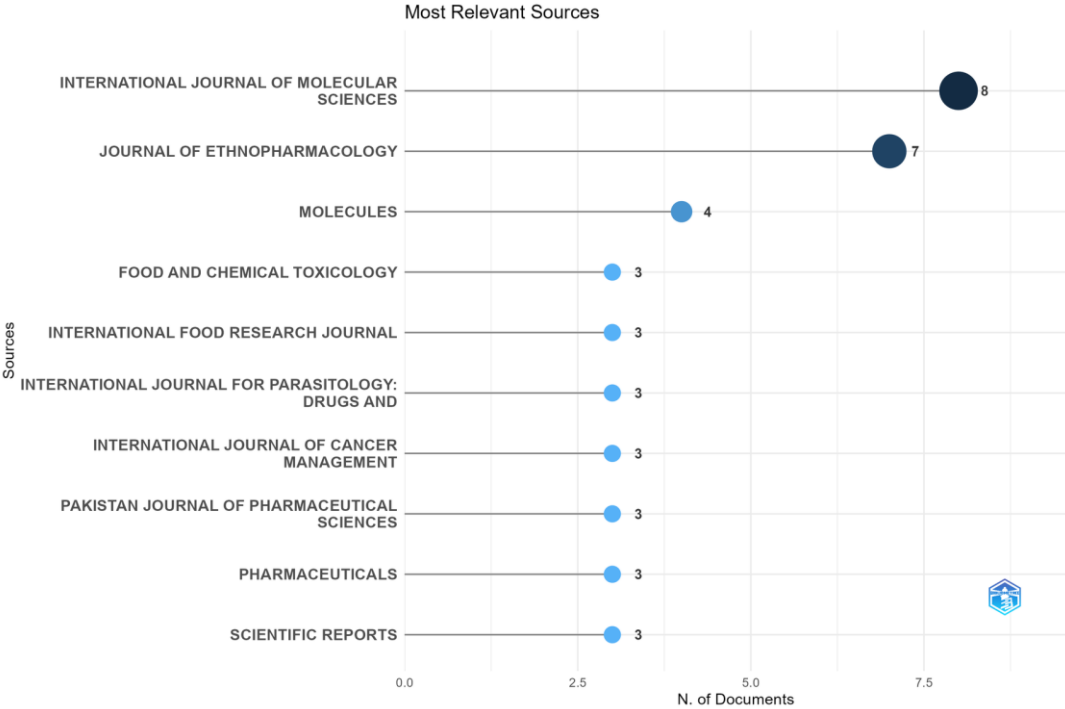


Figure 5. Most relevant sources by number of documents.

The top two journals combined published only 15 articles (8.9%), suggesting that literature is not highly centralised in one publication venue. The sources include molecular sciences, ethnopharmacology, food science, toxicology, parasitology, oncology and pharmaceutical sciences. This dispersion reflects the variety of biological activities and experimental approaches explored in the research on chicory.

3.4. Co-citation of Cited References.

The co-citation network reveals the intellectual structure of pharmacological research on *Cichorium intybus* L. and results in seven communities of different size and cohesiveness (Fig. 6). The largest community (red) is hub-and-spoke with the hub being Perović J. and many peripheral references, such as those by Kisiel W. (2001), Norbaek R. (2002), Hazra B. (2002), Bischoff T. A. (2004), Fan H. (2017) and Bian M. (2020). This is a configuration that suggests a strong common ground shared by a diverse set of studies and not a tightly knit literature. The blue community, centered on Abbas Z. K., Carazzone C. and Nwafor I. C., shows more internal relationships, indicating that the references of these authors are often cited in combination.

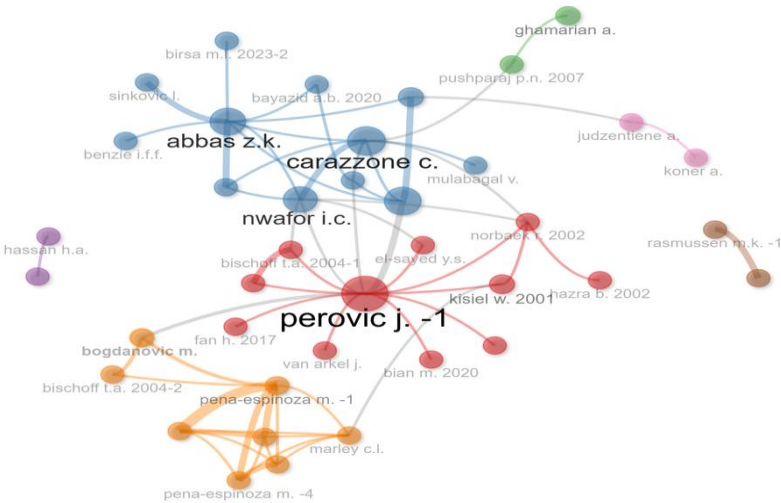


Figure 6. Co-citation network of cited references; node colours indicate communities and edge width represents co-citation strength

The orange community consists of Peña-Espinoza M., Bischoff T. A., Bogdanović M. and Marley C. L., and is considered to be linked to parasitology and research on forage-chicory, due to the relevance of Peña-Espinoza's work in the context of

chicory's anthelmintic activity. Four smaller communities, linked to Ghamarian A. and Pushparaj P. N., Judzentienė A. and Koner A., Hassan H. A. and Rasmussen M. K., are mostly isolated from the main network.

Some inter-community links can be seen, especially between the largest community and the orange and blue communities, but the network as a whole indicates a low level of integration between a number of research streams. This fragmentation could make the integration of results from various chicory preparations and experimental applications more difficult.

3.5. Keyword Co-occurrence Analysis

The keyword co-occurrence network (Fig. 7) shows three interconnected research clusters, which represent different but complementary aspects of chicory (*Cichorium intybus* L.) pharmacology. The red cluster is for phytochemical characterisation and extraction, including chemical composition, polyphenols, phenol derivatives, sesquiterpene lactones, isolation and purification, and chromatographic techniques, including ultra-performance liquid chromatography. The relationship between compound identification and in vitro pharmacological investigation is indicated by its association with antimicrobial and antibacterial activity, cytotoxicity, human cells and molecular docking. The blue cluster is related to antioxidant activity and bioactive compounds, such as flavonoids, chlorogenic acid and cichoric acid. Its links with IC50, high-performance liquid chromatography, glucose, hypoglycaemic and antidiabetic terms, and anti-inflammatory activity indicate a research focus on antioxidant properties, compound characterisation and metabolic effects.

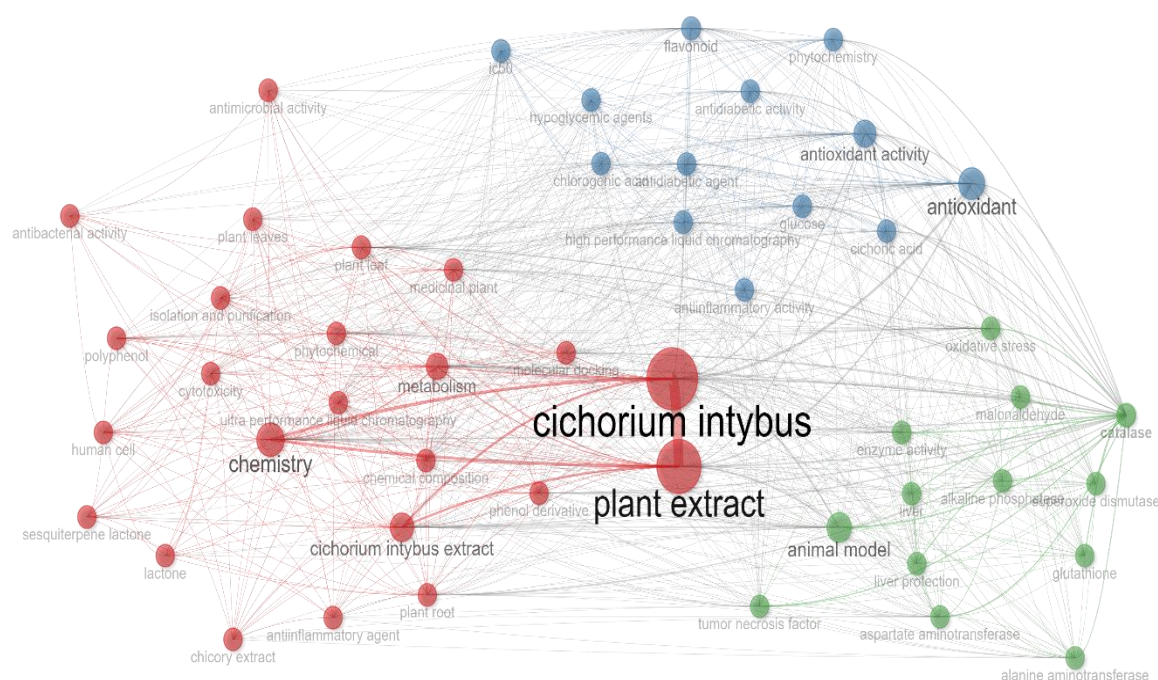


Figure 7. Keyword co-occurrence network (three clusters).

The green cluster is mainly in vivo studies on organ protection and oxidative stress. The keywords related to animal models, liver protection, catalase, superoxide dismutase, glutathione and malondialdehyde suggest that studies on antioxidant defence and oxidative damage were investigated. Biochemical and inflammatory markers are also used to investigate organ function and biological responses, as evidenced by the presence of alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase and tumour necrosis factor. The three clusters together illustrate a related research process starting from extraction and characterisation of phytochemicals (red), to antioxidant and metabolic activity assessment (blue) and to animal-based evaluation of protective effects and physiological responses (green).

3.6. Thematic Map Analysis

The thematic map shows the variations in the relevance and internal development of the main research themes in chicory pharmacology (Fig. 8; Table 4). The motor-theme quadrant is characterized by themes related to polyphenols, bioactive compounds and chicory root, which are central to the research field and have a relatively high internal development. Also close to the centrality axis, the themes of antimicrobial activity, medicinal plants and hepatoprotective research are present, albeit less developed. Antioxidant activity, cytotoxicity and antibacterial activity are close to the motor–niche boundary, indicating that these areas are fairly well developed but with varying degrees of integration into the research structure. Liver toxicity, oxidative stress and liver-related themes, on the other hand, are located in the niche quadrant, indicating specialised research with relatively low centrality. Molecular docking, network pharmacology and gut microbiota are located close to the niche–emerging boundary, which suggests a relatively specialised thematic niche, but not that these approaches are a newly emerging research direction.

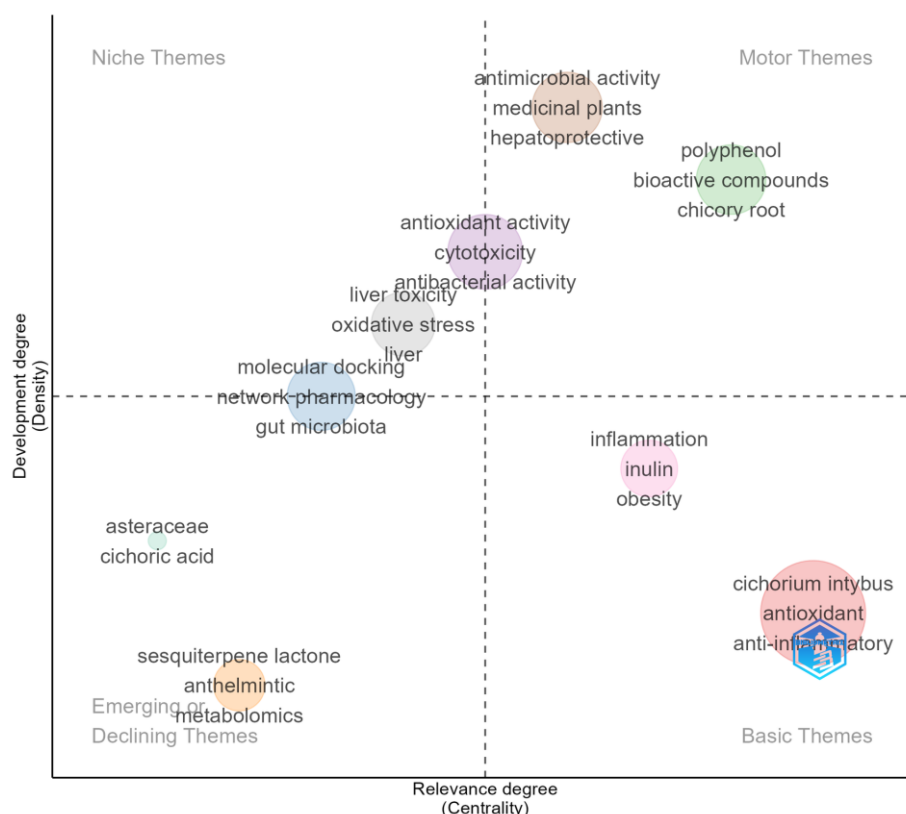


Figure 8. Thematic map of author keywords

Table 4 also shows the difference between central themes and specialised or less developed topics. Inflammation, inulin and obesity, along with the general *Cichorium intybus*, antioxidant and anti-inflammatory theme, are in the basic-theme quadrant. Their central positions mean they have relevance throughout the field, but their relatively lower density means that the related keyword groups are less internally developed. The commercial aspect is especially significant in the context of the position of inulin, where it links to a known functional ingredient and a product-development pathway. In contrast, sesquiterpene lactones, anthelmintic activity and metabolomics are in a low-centrality, low-density periphery, indicating low levels of integration with the dominant research themes. The same applies to Asteraceae and cichoric acid. Cichoric acid is relevant to the field of phytochemical characterisation and possible quality-marker research, but its location does not suggest a significant contribution to the central keyword of the field. The classification is based on the thematic map at the time of analysis: low-centrality, low-density themes are not necessarily emerging or declining without longitudinal thematic-evolution evidence.

Table 4. Thematic clusters and their approximate positions

Cluster (leading terms)	Position	Reading
Polyphenol; bioactive compounds; chicory root	Motor (upper right)	Well-developed and central
Antimicrobial activity; medicinal plants; hepatoprotective	Motor (upper)	Highest density in the map
Antioxidant activity; cytotoxicity; antibacterial activity	Motor/niche boundary (upper)	Developed, moderately central
Liver toxicity; oxidative stress; liver	Niche (upper left)	Developed but peripheral
Molecular docking; network pharmacology; gut microbiota	Niche/emerging boundary (left, on density axis)	Mechanistic and computational
Inflammation; inulin; obesity	Basic (lower right, near density axis)	Central, moderately developed
<i>Cichorium intybus</i> ; antioxidant; anti-inflammatory	Basic (lower right)	Largest cluster; central, least developed internally
Sesquiterpene lactone; anthelmintic; metabolomics	Emerging or declining (lower left)	Peripheral, low development
Asteraceae; cichoric acid	Emerging or declining (lower left)	Smallest cluster; peripheral

3.7. Commercial Implications of Pharmacological Research.

The bibliometric results point to two areas where pharmacological research relates to commercial product development (Table 5). The first is characterisation of the raw materials. The red keyword cluster (Fig. 7) and the fingerprinting, quality-marker and hairy-root studies of leading authors (Fig. 4) are related to the definition of the composition of chicory

preparations. The second is the use of by-products and specialised applications. The orange co-citation community (Fig. 5) and the anthelmintic work of leading authors (Fig. 4) include studies on an industrial by-product, compound identification and extraction.

Table 5. Potential commercial pathways arising from chicory pharmacological research

Pathway	Corpus basis	Evidence status
Standardised extracts and quality control	Fingerprinting, quality-marker and hairy-root studies [2,15,16]	Analytical, laboratory-scale work; commercial products not assessed.
Metabolic and hepatic nutraceuticals	41 metabolic and 25 hepatoprotective records; two randomised trials of seed preparations [17,18]	Mostly animal studies
Gut health and inulin-linked ingredients	18 gastrointestinal or prebiotic records [19-21]	Preclinical
Antimicrobial agents	33 records, none using animal models [22,23]	In vitro only
Veterinary and livestock health	Four target-species studies in horses, lambs, laying hens and broilers [24-27]	Few studies; dosing and field efficacy not established.
Compound recovery from by-products	Root pulp and roots as sources of sesquiterpene lactones [5,28]	Laboratory scale; yield, cost and safety not assessed.
Dermal and wound-care uses	Six records on wound healing, burns and tyrosinase inhibition [29,30]	Few records; limited evidence base.
Polyherbal formulations and delivery systems	40 multi-herb records; a leaf-juice granule and chitosan nanoparticles as examples [31,32]	Early-stage; the contribution of chicory is difficult to isolate.

Source: Author's Synthesis.

The pathways relate to the thematic structure in different ways. Metabolic, hepatic and antimicrobial work follows the central themes of the field (Fig. 8) but rests largely on animal model or in vitro studies, and the antioxidant domain, although the largest (60 records), reflects a property common to many plant extracts and gives limited basis for differentiating a chicory product. Veterinary use and by-product recovery lie in the periphery of the map, yet they include the four target-species studies in the corpus and relate to the root pulp left after inulin extraction; independent replication would strengthen it. For every pathway, commercial development would depend on standardised preparations, safety data, and regulatory evidence for each intended. These areas should be interpreted with caution. Sesquiterpene lactones, anthelmintic activity and metabolomics are in the periphery of the thematic map (Fig. 8; Table 4), and several co-citation communities are not connected to the main network (Fig. 6). There is no correlation between bibliometric prominence and market demand, nor between laboratory activity and industrial feasibility.

The three research gaps can be identified. Firstly, in the given keyword clusters, the keywords phytochemical, in vitro, and animal-model are prevailing, and there is a need for evidence related to the preparation and plant part used before positioning products. Second, chemical profiles vary between species and plant parts, and agronomy was not the focus of this review, so the effect of cultivation and processing on composition was not examined. Third, there are no known yield, cost or demand for the areas listed in Table 5, and techno-economic studies would be required to assess the subsequent commercial potential of these product pathways.

4. CONCLUSION

The study findings indicate increasing research attention, particularly since 2020, with major themes centred on phytochemical characterisation, antioxidant and metabolic activities, and organ-protective effects. Keyword co-occurrence analysis identified three interconnected research streams: phytochemical characterisation and in vitro bioactivity, antioxidant and metabolic investigations, and in vivo studies of organ protection and oxidative stress. The thematic map further highlighted polyphenols, bioactive compounds and chicory root as well-developed central themes, whereas sesquiterpene lactones and anthelmintic activity remained peripheral. Geographical contributions were concentrated in a small group of countries, while limited international collaboration and a fragmented co-citation structure indicated scope for stronger research integration.

From an agribusiness perspective, the findings indicate potential application pathways in standardised botanical extracts, metabolic and hepatic nutraceuticals, gut-health ingredients, antimicrobial preparations, veterinary products and the recovery of bioactive compounds from processing by-products. However, the evidence supporting these pathways is predominantly preclinical, and the bibliometric prominence of a research theme does not necessarily indicate commercial demand or industrial feasibility. Progress towards commercial application requires characterised raw materials, reproducible extraction and processing methods, product-specific safety and efficacy evidence, and techno-economic assessment. By linking the structure of pharmacological research with potential product-development pathways, this study identifies areas for further investigation while highlighting the need to bridge laboratory research and commercially viable applications of chicory.

Funding

This research received no external funding.

Acknowledgement

The authors wish to thank Tamil Nadu Agricultural University, Coimbatore, for providing research facilities.

Conflict of Interest

The authors declare no conflict of interest.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The authors acknowledge the use of Grammarly for grammar correction and language refinement during the preparation of this manuscript. All content was reviewed and revised by the authors, who accept full responsibility for the accuracy, originality and integrity of the work.

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