

Global Research Trends in Coffee Chemistry and Sensory Profiling: A Bibliometric Analysis (2015–2024)

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ABSTRACT

Understanding global developments in coffee chemistry and sensory profiling is essential for guiding scientific advances and supporting quality, processing, and health-related research worldwide. This study provides a bibliometric mapping of global research on coffee chemistry and sensory profiling between 2015 and 2024. Using data retrieved from Scopus, a total of 1,244 peer-reviewed publications were analyzed. The Bibliometrix R package (Biblioshiny interface) was employed to evaluate publication performance, citation dynamics, thematic structures, and collaboration patterns. The results indicate a rapid annual growth rate of 13.43%, with an average of 20.46 citations per document, reflecting a moderate-to-high scholarly impact. Productivity was distributed across 6,792 authors and 610 publication sources, with *Nutrients*, *Food Chemistry*, and *Coffee Science* identified as key outlets. Two foundational research streams emerged in the literature: one focused on the health-related aspects of coffee consumption, and the other on its chemical and sensory characteristics. Keyword co-occurrence revealed two major clusters: health outcomes of coffee consumption and chemical/processing research on chlorogenic acids, volatile compounds, and fermentation. Thematic mapping placed *coffee* as a motor theme, while *chemistry* was emerging/declining, suggesting opportunities for stronger integration between chemical and health-oriented research. Trend analyses highlighted growing attention to *coffee quality*, *fermentation*, and Fourier-transform infrared (FTIR)-based analytical methods. A collaboration analysis revealed Brazil, the USA, and China as the dominant hubs, whereas European countries exhibited high multi-country publication ratios, reflecting international integration. These findings provide actionable insights for coffee-producing regions by emphasizing the need to strengthen international partnerships, integrate chemical and health research narratives, and invest in processing innovations to enhance coffee quality and competitiveness.

Key words: Coffee science; fermentation; volatile compounds; chlorogenic acids; collaboration networks; analytical methods.

1 INTRODUCTION

Coffee stands at the intersection of culture, economy, and science. As the second most traded global commodity after petroleum, coffee sustains the livelihoods of more than 125 million people worldwide (International Coffee Organization – ICO, 2023). To maintain a balanced global framing, references to specific countries were removed unless globally representative. The rise of the specialty coffee sector, valued at USD 83.5 billion in 2023 (Grand View Research, 2023), has intensified scientific focus on coffee chemistry and sensory profiling.

Coffee chemistry is highly complex: over 1,000 compounds, including chlorogenic acids, caffeine, lipids, and melanoidins, contribute to flavor, aroma, and physiological effects (Farah, 2018). Advances in sensory science, particularly standardized protocols from the Specialty Coffee Association (Specialty Coffee Association of America - SCAA, 2016), have strengthened the objectivity of sensory evaluation. Meanwhile, evolving roasting and fermentation techniques continue to reshape chemical and sensory profiles (Elhalis et al., 2023).

Despite rapid growth, the field remains fragmented across chemistry, sensory science, agronomy, food technology,

and health sciences. This fragmentation limits integrated understanding and reduces the efficiency of knowledge transfer.

Recent studies have expanded this frontier, demonstrating the role of microbial fermentation in modulating volatile and nonvolatile compounds linked to flavor development (Elhalis et al., 2023) and optimizing roasting kinetics across varieties and processing methods (Santos et al., 2021). Despite rapid growth, the field remains fragmented across chemistry, sensory science, agronomy, food technology, and health sciences. This fragmentation limits integrated understanding and reduces the efficiency of knowledge transfer.

Bibliometric analysis offers a systematic and quantitative approach for mapping the structure, development, and impact of scientific research fields (Ellegaard & Wallin, 2015). Unlike traditional narrative or systematic reviews, bibliometric methods enable large-scale, objective analysis of publication trends, collaboration networks, and thematic evolution, making them particularly suitable for multidisciplinary and rapidly expanding research areas such as coffee science.

Therefore, the objective of this study is to analyze and map the global research landscape in coffee science, with a focus on coffee chemistry and sensory profiling from 2015–2024, using bibliometric methods. Specifically, the

study seeks to (1) examine publication trends and citation dynamics from 2015 to 2024; (2) identify the most prolific and influential authors, institutions, and countries; (3) determine the most cited journals and seminal publications; (4) analyze co-occurring keywords and thematic clusters; (5) map collaboration networks among authors, institutions, and countries; and (6) synthesize key bibliometric findings into actionable insights that can inform research priorities, innovation strategies, and quality improvement programs in coffee-producing regions

2 MATERIAL AND METHODS

2.1 Research Design and Scope

This study employed a quantitative-descriptive and exploratory design using bibliometric methods. Bibliometrics is the statistical analysis of scientific publications, enabling the mapping of research trends, thematic structures, and collaboration patterns through citation and keyword data. It was selected over narrative or systematic reviews because it allows for large-scale, objective examination of fragmented research domains such as coffee chemistry and sensory profiling, where multiple disciplines contribute to a dispersed body of knowledge.

Bibliometric tools, such as co-citation networks, keyword co-occurrence mapping, and thematic analysis, provide insights into the field's intellectual structure and evolution that cannot be captured solely through qualitative reviews. The analysis focused on peer-reviewed publications from 2015 to 2024 indexed in Scopus, chosen for its comprehensive coverage and high-quality metadata. This time frame represents the period of greatest growth in coffee chemistry and sensory science research, as previously justified in the Introduction.

2.2 Data Source and Search Strategy

Bibliographic data were retrieved from Elsevier's Scopus database on August 1, 2025. Retrieval in 2025 ensured that all publications from the 2024 calendar year were fully indexed before analysis. The search was restricted to English-language journal articles and reviews. Records were retrieved using the following advanced TITLE-ABS-KEY search equation:

TITLE-ABS-KEY ("coffee" OR "coffee bean" OR "Coffea arabica" OR "green coffee" OR "roasted coffee")
AND TITLE-ABS-KEY ("coffee chemistry" OR "chemical composition" OR "volatile compounds" OR "aroma compounds" OR "chlorogenic acid" OR "caffeine" OR "phenolic compounds" OR "bioactive compounds" OR "Maillard reaction" OR "GC-MS" OR "HPLC" OR "spectroscopy" OR "chemometrics" OR "sensory evaluation" OR "cupping" OR "flavor profile" OR "aroma profile" OR

"coffee profile" OR "coffee quality" OR "organoleptic properties" OR "post-harvest processing" OR "roasting" OR "fermentation" OR "specialty coffee")

AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re"))

AND (LIMIT-TO (LANGUAGE , "English"))

AND (PUBYEAR >= 2015 AND PUBYEAR <= 2024)

This search yielded an initial dataset of **4,525 records**, which was exported in CSV format for processing.

Scopus was selected because it offers comprehensive coverage, consistent metadata, advanced citation analytics, and compatibility with Bibliometrix and VOSviewer, making it the preferred database for bibliometric studies.

2.3 Data Cleaning and Validation

Data cleaning and preprocessing were performed in RStudio using the Bibliometrix R package (Aria & Cuccurullo, 2017). Duplicate records were detected using the duplicatedMatching() function and verified manually by cross-checking titles, authors, publication years, and DOIs. Records without essential metadata (title, abstract, keywords, author information) were removed, along with non-English documents and non-article types.

Keyword harmonization was implemented to improve metadata consistency, including (i) standardizing spelling variants (e.g., flavour → flavor), (ii) normalizing singular and plural forms, and (iii) merging synonymous terms and abbreviations (e.g., GCMS and GC-MS). Following validation, 1,244 publications met the inclusion criteria and were retained for analysis.

2.4 Network Construction, Normalization, and Analytical Procedures

Bibliometric networks were constructed using Bibliometrix, Biblioshiny, and VOSviewer (Van Eck & Waltman, 2010), selected for their complementary analytical strengths. Bibliometrix provides a comprehensive quantitative framework for science mapping within R, while VOSviewer is widely recognized for high-quality visualization of co-authorship, co-occurrence, and co-citation networks.

To ensure comparability across nodes, association strength normalization was applied to all VOSviewer networks, while bibliometrix keyword co-occurrence matrices also used the association normalization method. For network construction, full counting was applied for co-authorship and co-citation analyses to reflect absolute link strengths. Fractional counting was not used, as the objective was to characterize the intensity of collaboration and citation relationships.

Consistent with established bibliometric standards:

Keyword co-occurrence: ≥ 5 occurrences

Author co-authorship: ≥ 3 publications

Co-citation analysis: ≥ 20 citations

These thresholds reduced noise and highlighted substantively meaningful patterns.

For each analytical dimension, the study employed the software tool best suited to the task. Bibliometrix and its web interface Biblioshiny were used to assess annual scientific production, citation performance, and the productivity of authors, institutions, and countries, generating descriptive trends, citation matrices, and productivity indicators. Bibliometrix was also used to evaluate journal and document impact metrics such as the h-index and g-index. Keyword co-occurrence, thematic mapping, and multiple correspondence analysis (MCA) were performed within Bibliometrix to identify statistical clusters, thematic structures, and conceptual evolution. To complement these quantitative analyses, VOSviewer was employed for visualizing keyword networks, co-authorship clusters, and co-citation structures, providing high-resolution graphical mapping of collaboration patterns and the field's intellectual foundations. This combined workflow ensured robust quantitative outputs supported by intuitive, high-quality network visualizations.

2.5 Analytical Framework

The bibliometric workflow was organized into five analytical dimensions, each addressed with suitable tools and parameters. First, scientific production, including annual publication and citation trends, was analyzed using Bibliometrix and its Biblioshiny interface. Second, authorship and institutional output were evaluated with Bibliometrix/Biblioshiny to identify the most productive authors, affiliations, and contributing countries. Third, source and document impact, covering influential journals and highly cited papers, was assessed using source-level metrics generated in Bibliometrix. Fourth, the study explored the thematic structure of the field through keyword co-occurrence analysis, thematic mapping, and factorial or multiple correspondence analysis (MCA), integrating Bibliometrix for statistical modeling with VOSviewer for visual cluster representation. Finally, collaboration networks, including co-authorship and inter-country linkages, were mapped using VOSviewer with association-strength normalization to ensure clear and meaningful visualizations. Collectively, these analytical components offered a thorough and reproducible overview of the global research landscape in coffee chemistry and sensory profiling.

3 RESULTS

3.1 General Characteristics of the Dataset

Between 2015 and 2024, a total of 1,244 documents on coffee chemistry and sensory profiling were published across 610 sources, authored by 6,792 contributors. The field

steadily expanded, with the annual output increasing from 65 documents in 2015 to 202 in 2024, reflecting a 210.8% cumulative growth and an annual growth rate of 13.43%.

Citations totaled 25,451, with an average of 20.46 citations per document. Early publications (2015–2017) achieved the highest cumulative citation counts per article owing to longer exposure times, whereas more recent cohorts (2020–2024) exhibited greater citation velocity, particularly in 2020. This pattern reflects a well-established knowledge base alongside emerging work that is gaining rapid attention.

Table 1: Summarizes the annual publication and citation metrics, while Figure 1 visualizes the trend in publication output over the period.

Table 1: Annual scientific production and citation metrics (2015–2024).

Year	Publications	Total Citations	Mean Citations/Article	Mean Citations/Article/Year
2015	65	2710	41.69	3.79
2016	81	2880	35.56	3.66
2017	74	2999	40.53	4.5
2018	108	3668	33.96	4.24
2019	102	2866	28.1	4.01
2020	125	3416	27.33	4.56
2021	156	2895	18.56	3.71
2022	173	2041	11.8	2.95
2023	158	1172	7.42	2.47
2024	202	717	3.55	1.77

3.2 Prolific Authors and Institutions

3.2.1 Authors

Collaboration is the norm in this field, with only 28 single-authored papers identified in the dataset. The most prolific contributors between 2015 and 2024 were Wang X (14 publications), Wang Y (11), Navarini L (10), Zhang Y (10), and Schwan RF (9). Additional highly productive authors included Liu X, Liu Y, Ristenpart WD, Soccol CR, and Borém FM, each with 7–8 publications (Table 2).

The longitudinal outputs of these authors are shown in Figure 1, which illustrates distinct temporal patterns in their research activity. For example, Wang X and Zhang Y demonstrate sustained productivity across nearly the entire decade, with noticeable peaks after 2020. In contrast, authors such as Navarini L and Ristenpart WD exhibit more concentrated periods of output, reflecting bursts of activity aligned with thematic developments in coffee chemistry and quality analysis. Within the dataset, Brazilian scholars such as

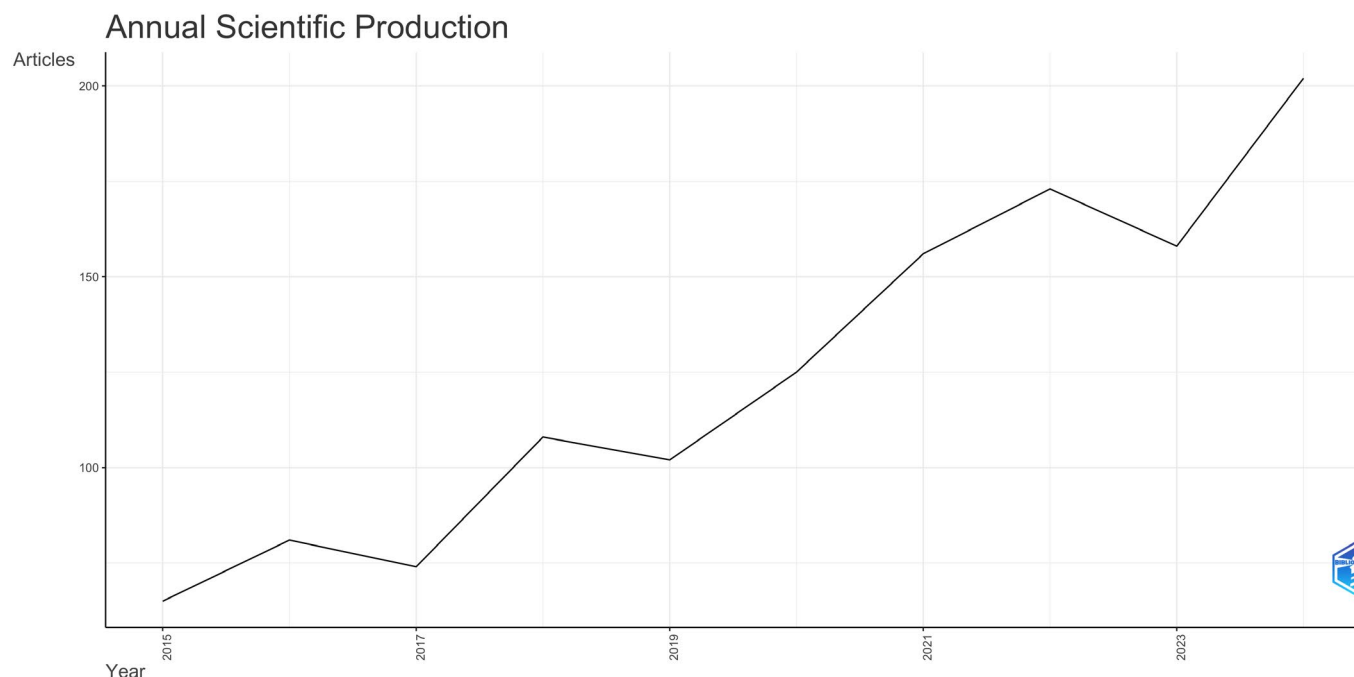


Figure 1: Annual scientific production in coffee chemistry and sensory profiling (2015–2024).

Table 2: Top 10 most prolific authors in coffee chemistry and sensory profiling research (2015–2024).

Rank	Author	Publications	Fractionalized Publications*
1	WANG X	14	2.97
2	WANG Y	11	1.57
3	NAVARINI L	10	1.66
4	ZHANG Y	10	1.32
5	SCHWAN RF	9	1.65
6	LIU X	8	1.47
7	LIU Y	8	1.23
8	RISTENPART WD	8	1.64
9	SOCCOL CR	8	1.36
10	BORÉM FM	7	1.13

*Fractionalized publications are weighted counts adjusted for multiauthor papers, reflecting proportional contribution.

Schwan RF, Soccol CR, and Borém FM stand out for their consistent contributions across multiple years, coinciding with increased publication clusters related to coffee fermentation and post-harvest processing. These temporal variations shown in Figure 2, complement the cumulative totals in Table 2 by showing how productivity evolved over time.

3.2.2 Institutions

At the institutional level, the Federal University of Lavras (Brazil) ranked first, with 102 publications, followed by the University of California (68), the Harvard T.H. Chan

School of Public Health (43), the National Cancer Institute (35), and the Federal University of Paraná – UFPR (31). These universities represent a dual emphasis: Brazilian institutions leading research in coffee chemistry and postharvest processing and U.S. institutions focusing on the epidemiological and public health dimensions of coffee science.

In addition to the five leading institutions, institutions such as Srinakharinwirot University (Thailand, 30 publications), Harvard Medical School (USA, 29), Universidad Autónoma de Madrid (Spain, 29), the University of Navarra (Spain, 27), and the University of Parma (Italy, 26) illustrate the global spread of coffee research. Table 3 summarizes the top institutions by publication volume.

3.3 Influential Sources and Seminal Publications

3.3.1 Core sources

The application of Bradford's law identified a small set of journals that constitute the field's core outlets. As shown in Figure 3, these include *Food Chemistry* (39 articles), *Food Research International* (35), *FOODS* (34), *Nutrients* (32), and *Coffee Science* (22). These journals together account for a disproportionate share of coffee chemistry and sensory profiling publications, confirming both the central role of general food science journals and the importance of specialized outlets, such as *Coffee Science*.

3.3.2 Seminal publications

The analysis of globally cited documents revealed a set of high-impact publications that have played a substantial

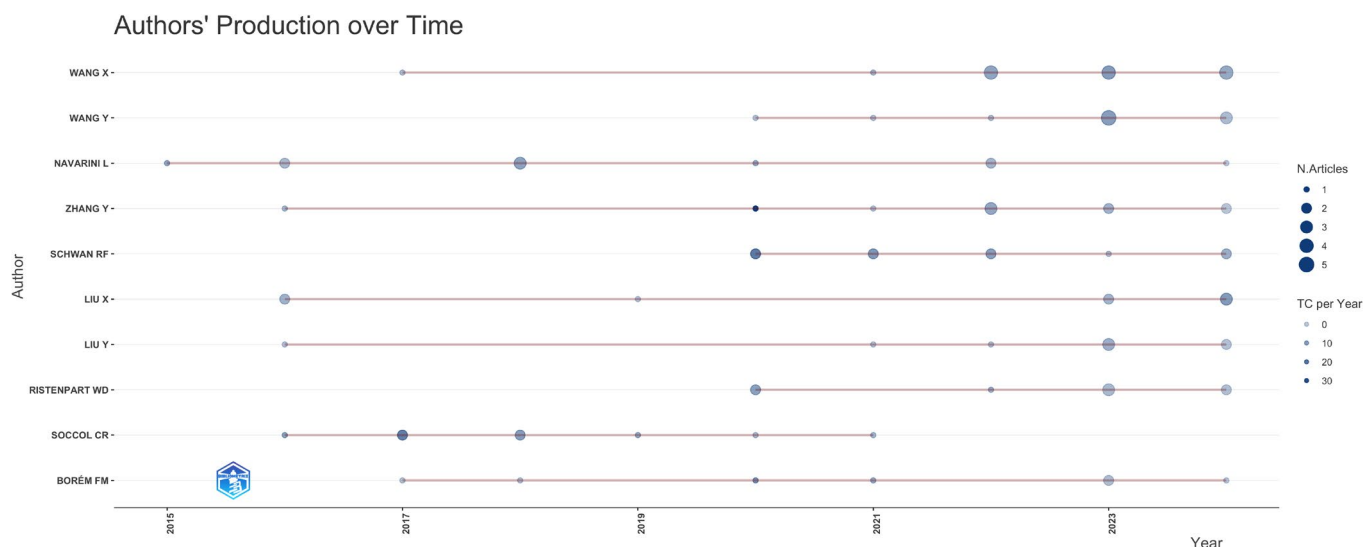


Figure 2: Longitudinal publication trajectories of the top authors in coffee chemistry and sensory profiling (2015–2024).

role in shaping contemporary research on coffee chemistry and sensory profiling (Table 4). Rankings were based on total global citations indexed in Scopus and processed through Bibliometrix.

The most highly cited document was Ceja-Navarro et al. (2015), *Nature Communications*, with 389 citations, which provided foundational insights into coffee-associated microbiomes and their functional roles in the coffee ecosystem. This was followed by Zhang et al. (2020, *Science of the Total Environment*), with 240 citations, whose work addressed environmental factors influencing coffee systems. The third most cited paper, Caporaso et al. (2018), *Food Research International*) with 225 citations, advanced analytical approaches in chemical composition profiling and sensory evaluation.

Table 3: Top institutions by publication output (2015–2024).

Rank	Affiliation	Articles
1	FEDERAL UNIVERSITY OF LAVRAS	102
2	UNIVERSITY OF CALIFORNIA	68
3	HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH	43
4	NATIONAL CANCER INSTITUTE	35
5	FEDERAL UNIVERSITY OF PARANÁ (UFPR)	31
6	SRINAKHARINWIROT UNIVERSITY	30
7	HARVARD MEDICAL SCHOOL	29
8	UNIVERSIDAD AUTÓNOMA DE MADRID	29
9	UNIVERSITY OF NAVARRA	27
10	UNIVERSITY OF PARMA	26

Research on microbial dynamics also featured prominently. De Bruyn et al. (2017), *Applied and Environmental Microbiology*), with 215 citations, examined

the microbial ecology of coffee fermentation, while Sung et al. (2017), *(Carbohydrate Polymers)*, with 204 citations, contributed significant knowledge on coffee polysaccharides and carbohydrate chemistry.

Analytical and nutritional studies were also well represented. Król et al. (2020) *European Food Research and Technology*, with 186 citations, investigated polyphenols, antioxidant properties, and related quality parameters, whereas Grosso et al. (2016), *Molecular Nutrition & Food Research*), with 169 citations, explored associations between coffee consumption and human health outcomes. Marventano et al. (2016) *Clinical Nutrition* followed with 146 citations, examining links between dietary intake, coffee consumption, and metabolic health indicators. In addition, Dong W. et al. (2017) *Food Chemistry*, with 144 citations, contributed key findings on volatile compounds and aroma formation, while Dong X. et al. (2020) *Nutrients*, with 140 citations, evaluated coffee's bioactive compounds and their nutritional implications.

Collectively, these publications reflect the interdisciplinary nature of influential coffee research, spanning microbial ecology, environmental science, chemical and sensory analysis, nutritional epidemiology, and food chemistry. Their high citation counts demonstrate their central role in guiding scientific inquiry and shaping emerging themes in coffee science.

3.3.3 Intellectual structure

A document co-citation analysis was conducted using VOSviewer with a minimum co-citation threshold of 20 citations. The resulting network (Figure 4) revealed five distinct clusters, each representing a major research stream within coffee science.

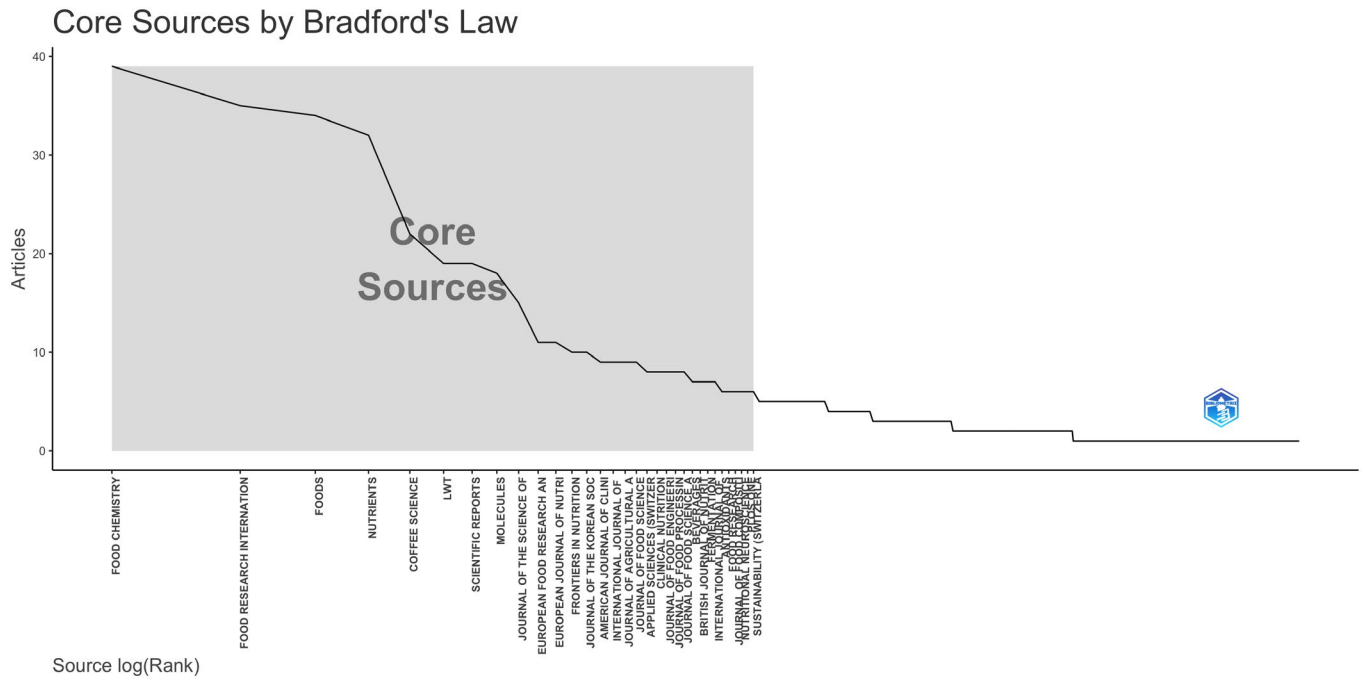


Figure 3: Core sources according to Bradford's Law.

Table 4: Most Globally cited publications in coffee chemistry and sensory profiling (2015-2024).

Rank	Reference	DOI	Total Citations	Topic / Contribution
1	Ceja-Navarro et al. (2015), <i>Nature Communications</i>	10.1038/ncomms8618	389	Coffee microbiome; functional microbial roles in coffee ecosystems
2	Zhang et al. (2020), <i>Science of the Total Environment</i>	10.1016/j.scitotenv.2020.137015	240	Environmental impacts affecting coffee quality and chemistry
3	(Caporaso et al., 2018), <i>Food Research International</i>	10.1016/j.foodres.2018.03.077	225	Chemical composition profiling; sensory and analytical methods
4	De Bruyn et al. (2017), <i>Applied and Environmental Microbiology</i>	10.1128/AEM.02398-16	215	Microbial ecology during coffee fermentation
5	Sung et al. (2017), <i>Carbohydrate Polymers</i>	10.1016/j.carbpol.2017.04.037	204	Coffee polysaccharides; carbohydrate chemistry and structure
6	Król et al. (2020), <i>European Food Research and Technology</i>	10.1007/s00217-019-03388-9	186	Polyphenols, antioxidant properties, and coffee quality
7	Grosso et al. (2016), <i>Molecular Nutrition & Food Research</i>	10.1002/mnfr.201500620	169	Coffee consumption and human health outcomes
8	Marventano et al. (2016), <i>Clinical Nutrition</i>	10.1016/j.clnu.2016.03.012	146	Diet, coffee intake, and metabolic health
9	Dong W. et al. (2017), <i>Food Chemistry</i>	10.1016/j.foodchem.2017.04.156	144	Aroma compounds; volatile chemical analysis
10	Dong X. et al. (2020), <i>Nutrients</i>	10.3390/nu12030840	140	Bioactive compounds; nutritional implications of coffee

The first cluster (blue) encompasses epidemiological and nutritional studies evaluating the health effects of coffee consumption. Key works include Poole et al. (2017) and Ding et al. (2014), which synthesize evidence from cohort studies on chronic disease and mortality.

The second cluster (red) groups earlier public health and toxicology-oriented research, such as Cano-Marquina et al. (2013) and Vignoli et al. (2011), focusing on coffee's safety, composition, and general health implications.

The third cluster (green) represents the core of coffee chemistry and sensory science, anchored by Sunarharum et al. (2014) and Caporaso et al. (2018). These studies examine volatile compounds, chlorogenic acids, flavor formation, and sensory profiling.

The fourth cluster (orange) consists of research on processing and post-harvest transformations, including roasting chemistry and fermentation dynamics, represented by Flament (2002) and Farah (2002).

The fifth cluster (purple) comprises foundational aroma and analytical chemistry studies, including Illy and Viani (2005) and Caprioli et al. (2014), which established early chromatographic and spectrometric approaches to characterize flavor compounds.

Together, these clusters illustrate a highly interdisciplinary intellectual landscape connecting health research, chemical composition, flavor science, and processing technology.

Figure 5 depicts a historiograph of influential documents, mapping citation flows among key publications and illustrating how research themes have evolved over time. The historiograph was generated using Bibliometrix with a minimum global citation threshold of 20, enabling the identification of the most influential citation pathways. The visualization produces three distinct clusters, each representing a different developmental trajectory within coffee science.

The first cluster (green) represents research on sensory perception and consumer studies. This includes works such as

Steen et al. (2017) and Giacalone et al. (2019), which examine sensory evaluation methods, consumer preferences, and behavioral responses to coffee flavor attributes. These studies highlight the emergence of consumer-centered sensory science as a growing research direction.

The second cluster (red) is centered on epidemiology and health outcomes, led by influential works by Loftfield et al. (2015, 2018) and Kim et al. (2019). This trajectory traces the consolidation of evidence linking coffee consumption to health markers such as mortality, metabolic disease, and liver function. The citation flow within this cluster reflects an iterative accumulation of evidence through large-scale cohort studies and supporting analyses.

The third cluster (blue) encompasses research on coffee production systems and quality assessment, represented by works such as Tolessa et al. (2017) and Worku et al. (2018). These studies examine post-harvest practices, processing methods, and chemical determinants of cup quality, forming a methodological bridge between agronomic practices and sensory outcomes.

Overall, the historiograph reveals an intellectual structure composed of three parallel but interconnected research streams: (1) sensory and consumer science, (2) coffee and health epidemiology, and (3) production–processing–quality research. These trajectories demonstrate how the field has expanded from foundational health and chemical studies toward more integrated perspectives that link consumer perception, health implications, and production practices.

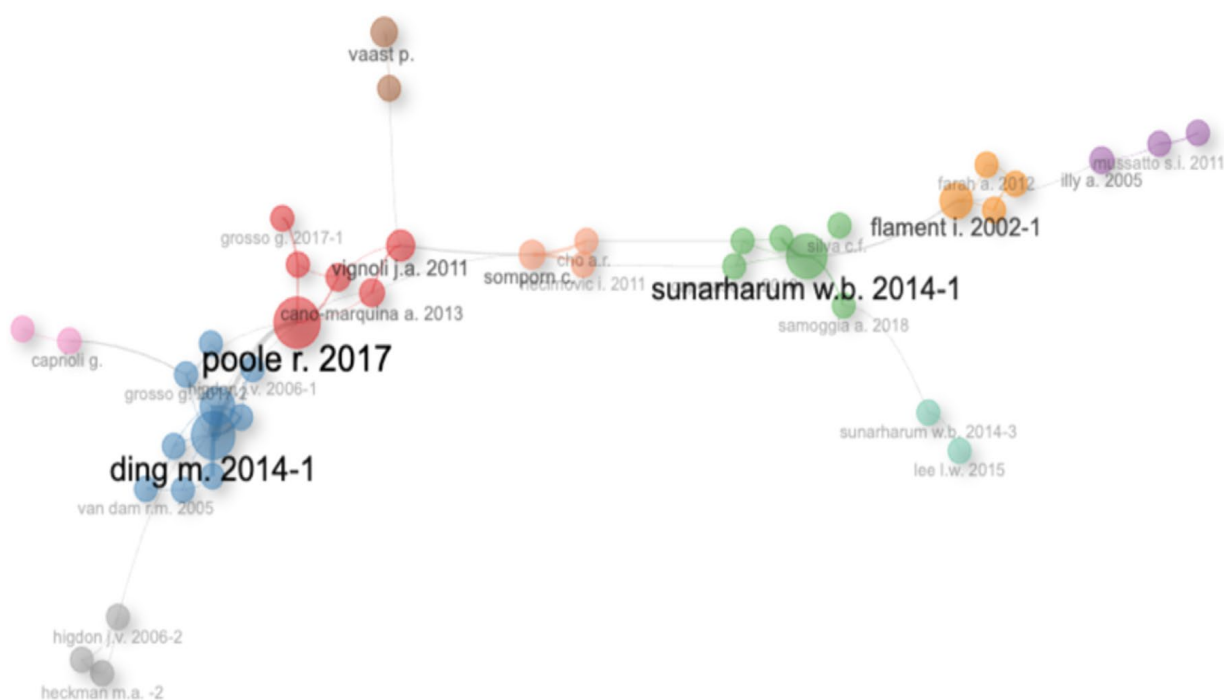


Figure 4: Cocitation network of sources/documents.



Figure 5: Historiograph of influential publications.

3.4 Thematic Structure and Emerging Trends

3.4.1 Co-occurrence network

Analysis of 3,389 author keywords and 7,775 Keywords Plus produced a dual-cluster structure (Figure 6).

- Cluster A (health outcomes), shown in blue, is anchored by terms such as *coffee*, *caffeine*, *humans/human*, *adult*, *female*, and *male*, along with study descriptors such as *controlled study* and *prospective study*. This cluster reflects the strong presence of biomedical and epidemiological research linking coffee intake to human health.

- Cluster B (chemistry and processing), shown in red, comprises terms such as *Coffea arabica*, *chlorogenic acid*, *chemistry*, *plant extract*, *antioxidants*, *fermentation*, and *extraction*. This cluster represents the research stream on chemical composition, sensory attributes, and postharvest processing methods.

The central node “**coffee**” connects both clusters, underscoring the field’s dual emphasis on biomedical outcomes and chemical/processing science.

3.4.2 Thematic map

The strategic thematic map (Figure 7) plots keyword clusters according to their centrality (relevance to the field) and density (development level), producing four quadrants that reflect the structural positioning of themes in the literature.

The upper-right quadrant (motor themes) contains topics that are both highly developed and highly relevant. In this map, the cluster composed of “*coffee*,” “*article*,” and “*caffeine*” occupies this position, indicating that these terms remain the conceptual core of research in the field. Their strong centrality reflects the broad, interdisciplinary nature of coffee studies, while high density suggests sustained methodological and thematic development around caffeine chemistry, consumption studies, and general coffee science.

The lower-left quadrant (emerging or declining themes) includes topics with low centrality and low density. The cluster consisting of “*chemistry*,” “*Coffea*,” and “*chlorogenic acid*” falls within this area. This positioning suggests two potential interpretations. First, these terms may represent emerging themes, reflecting renewed interest in detailed chemical and phytochemical analysis, particularly as advanced analytical tools (e.g., FTIR, metabolomics) gain prominence. Alternatively, they may be viewed as declining stand-alone themes, as chemical studies increasingly integrate with broader research topics such as sensory science, health effects, and processing technologies.

The upper-left quadrant (niche themes) and lower-right quadrant (basic themes) appear unpopulated in this map. This pattern indicates that, within the 2015–2024 dataset, no keyword clusters simultaneously demonstrated high density with low centrality (niche themes) or high centrality with low density (basic or transversal themes). This suggests a field organized around a dominant central topic (“*coffee*”) with fewer specialized subdomains achieving cluster-level cohesion during the study period.

Overall, the thematic map reveals a structural concentration around general coffee research and caffeine-related studies, while foundational chemical terms (e.g., *chlorogenic acids*, *Coffea*) appear less central but may serve as evolving entry points for new analytical and phytochemical research.

3.4.3 Trend topics

Temporal keyword analysis (Figure 8) illustrates how research priorities evolved across the study period. Early in the decade (2016–2018), topics such as *espresso coffee*, *food intake*, and *insulin resistance* dominated. In later years (2020–2024), interest shifted toward coffee quality, fermentation processes, and the integration of advanced analytical techniques such as Fourier transform infrared (FTIR) spectroscopy. This progression reflects a broadening of the research focus from primarily health-oriented investigations to quality- and process-driven inquiries supported by sophisticated instrumentation.

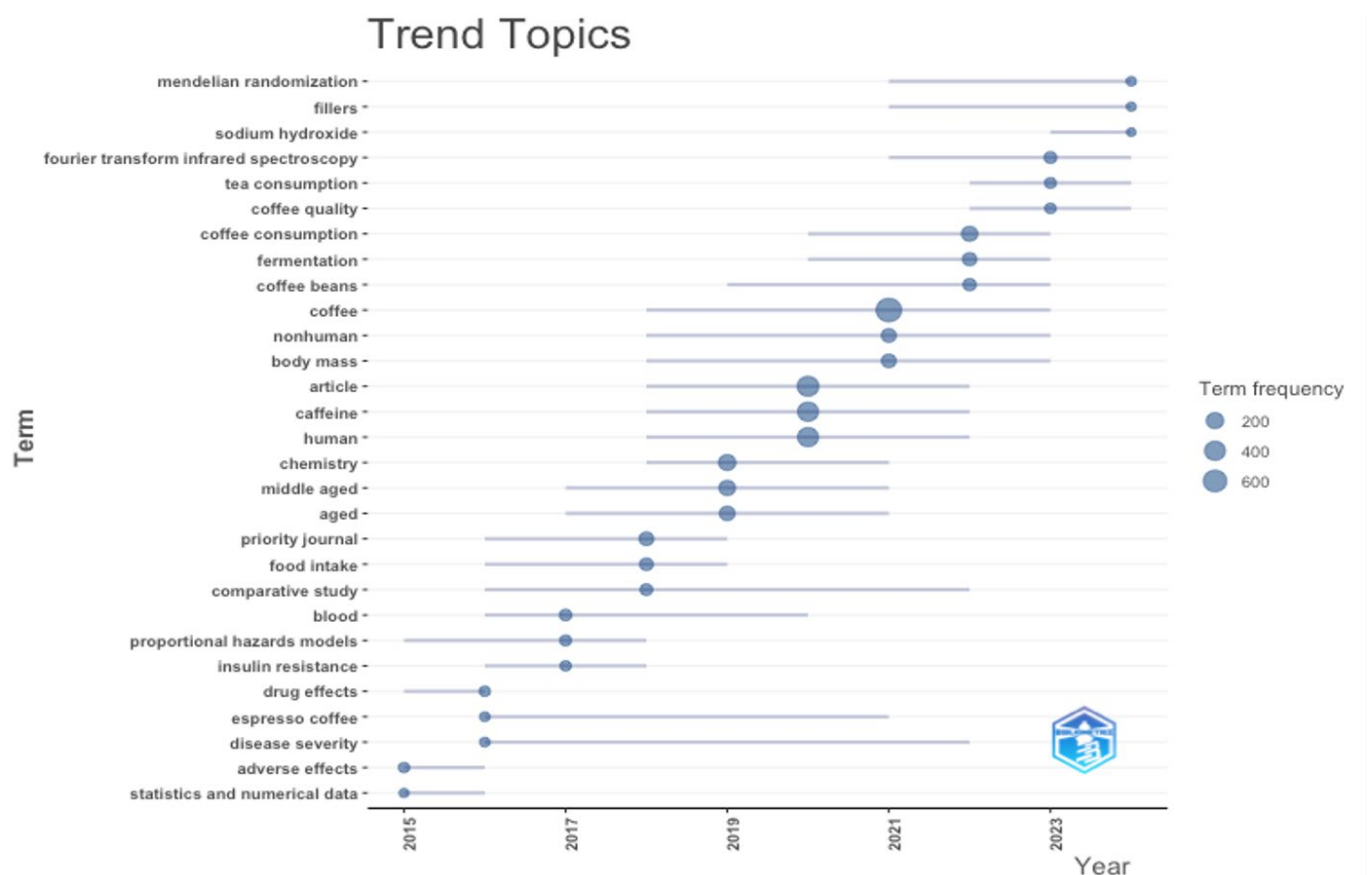


Figure 8: Trend topics in coffee research (2015–2024).

3.5 Collaboration Networks

3.5.1 Countries

Country-level analysis confirms that research output is led by Brazil (135 publications), followed by the USA (128) and China (102). While Brazil and the USA primarily produced single-country publications (SCPs), the USA also demonstrated strong international engagement, with 25.8% of its output classified as multicountry publications (MCPs). Italy exhibited one of the highest levels of international collaboration (33.8% MCP ratio), whereas Korea's publication profile was predominantly domestic (5.9% MCP ratio). These trends are summarized in Table 4.

The global collaboration map (Figure 9) highlights a strong North America–Europe axis of coauthorship, with Brazil anchoring Latin America and increasing participation observed from Asian countries, such as China and Korea.

3.5.2 Authors and institutions

The author-level collaboration network (Figure 10) reveals dense intracountry clusters, particularly among Brazilian fermentation and chemistry-focused teams and U.S. public health researchers. While cross-country ties are evident, they are less frequent, suggesting that collaboration remains more nationally

concentrated than globally integrated. At the institutional level, hubs such as the Federal University of Lavras (Brazil) and the University of California (USA) act as connectors, linking national research groups into broader international networks.

These patterns are further supported by country-level publication and collaboration metrics (Table 5). Brazil and the United States lead in total research output, with 135 and 128 publications, respectively. However, differences in international collaboration are evident. The United States demonstrates a relatively higher proportion of multi-country publications (MCP = 33; MCP ratio = 25.8%) compared to Brazil (MCP = 27; MCP ratio = 20.0%), indicating stronger engagement in global research networks. European countries such as Italy also exhibit high international collaboration (MCP ratio = 33.8%), while Asian countries such as China and Korea show more nationally concentrated outputs, as reflected in their lower MCP ratios.

3.6 Synthesis of Key Bibliometric Indicators

The bibliometric profile of research on coffee chemistry and sensory profiling from 2015–2024 as shown in Table 6 highlights both the rapid growth of the field and its strong collaborative base. A total of 1,244 documents were published in 610 distinct sources, authored by 6,792 contributors. The field recorded an annual growth rate of 13.43%, confirming rapid expansion across the decade.

Overall, the dataset accrued 25,451 citations, with an average of 20.46 citations per document, indicating moderate to strong impact. The number of references cited totaled 54,852, underscoring the breadth of literature integration. The average document age of 4.52 years reflects a corpus that is both recent and highly relevant.

Collaboration is a defining feature of the field: only 28 single-authored papers (produced by 24 authors) were identified, while the average number of coauthors per document was 6.5. Notably, 26.53% of the publications involved international collaboration, indicating a significant degree of cross-border research exchange.

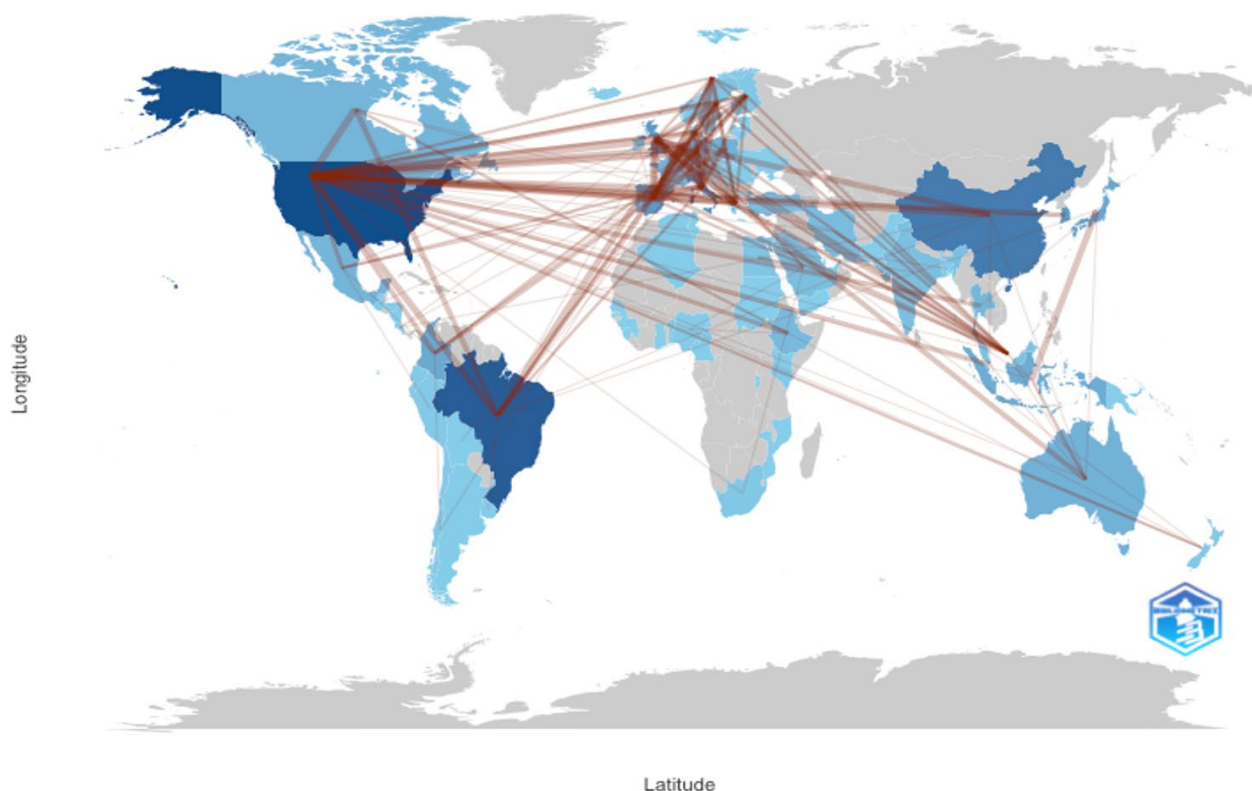


Figure 9: Global collaboration world map.

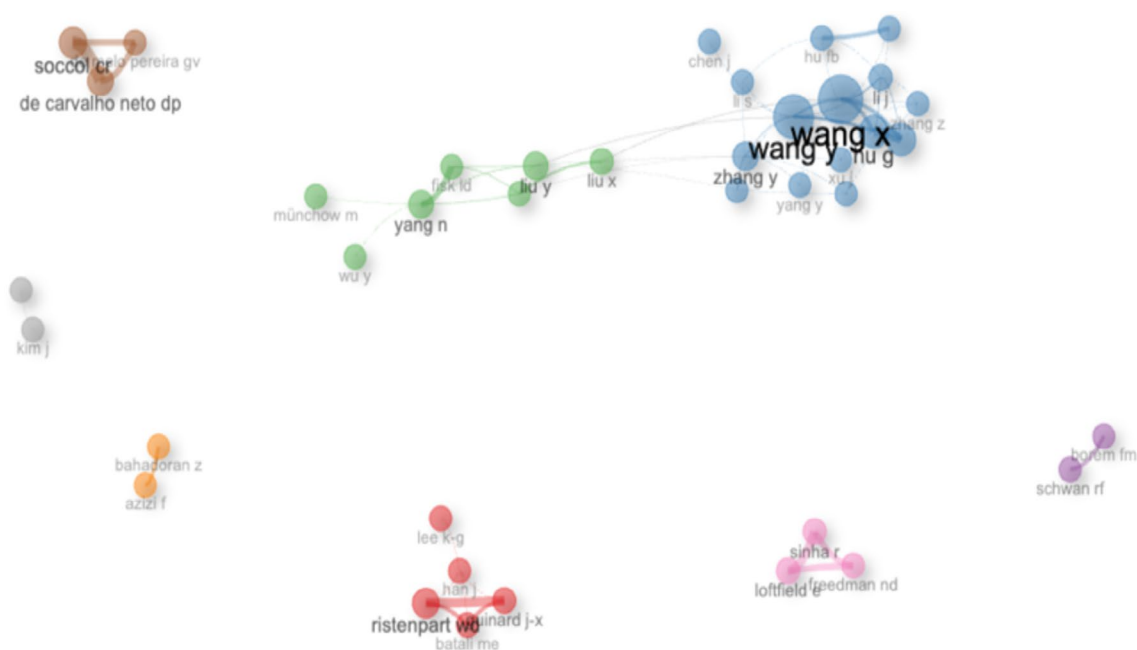


Figure 10: Author collaboration network.

Table 5: Top countries by publication output and collaboration (2015–2024).

Country	Publications	SCP	MCP	MCP Ratio (%)
Brazil	135	108	27	20.0
USA	128	95	33	25.8
China	102	89	13	12.7
Italy	74	49	25	33.8
Korea	68	64	4	5.9

Table 6: Summary of the main bibliometric indicators (2015–2024).

Indicator	Value	Observation
Total documents	1244	Scopus dataset
Sources	610	Journals, proceedings, books
Annual growth rate (%)	13.43	Rapid field expansion
Total citations	25451	Across dataset
Average citations/document	20.46	Moderate to strong impact
References cited	54852	Strong literature integration
Average document age (years)	4.52	Recent contributions dominate
Authors	6792	Large contributor base
Single-authored documents	28	Minimal solo contributions
Authors of single-authored docs	24	Very small proportion of authorship
Coauthors per document	6.5	High collaboration intensity
International co-authorship (%)	26.53	Significant cross-border linkages

4 DISCUSSION

The purpose of this study was to map and analyze global research activity in coffee chemistry and sensory profiling from 2015 to 2024. The preceding results provided a comprehensive overview of publication trends, influential authors and documents, thematic structures, and collaboration networks. In this section, we interpret these patterns in relation to the study's objectives and situate them within the broader scientific and industry contexts of coffee research. By connecting the quantitative indicators with conceptual and methodological developments, the discussion highlights the implications of the field's growth, fragmentation, and emerging research directions.

4.1 Overview of Key Findings

This bibliometric analysis highlights the rapid expansion of research on coffee chemistry and sensory profiling over the past decade, with an annual growth rate of 13.43% and 1,244 publications. Brazil and the United States emerged as the most productive contributors, reflecting the dual role of producing and consuming nations. Thematic

mapping confirmed two dominant research orientations: one focused on health outcomes, and the other focused on coffee chemistry, processing, and sensory evaluation. Collaboration networks remain strong within countries but show uneven levels of international integration. Recent years have revealed increasing interest in fermentation technologies and the adoption of advanced tools such as FTIR spectroscopy for rapid, nondestructive quality assessment.

4.2 Alignment with Existing Literature: Leadership and Trends

The prominence of Brazil in this bibliometric analysis is consistent with its long-standing position as the world's largest coffee producer. Previous studies have similarly identified Brazil, particularly the Universidade Federal de Lavras (UFLA), as a global leader in coffee science (Pereira *et al.*, 2020; Borém, 2020). Our findings confirm this pattern, but extend the literature by demonstrating that Brazil's leadership is not only in production-focused research but also in the development of microbial and biochemical approaches to controlled fermentation, which have become increasingly central in recent years. This expansion into advanced chemical–sensory research suggests a thematic evolution from traditional agronomic studies toward more value-added, quality-oriented innovation.

In contrast, the United States' research profile remains strongly aligned with health outcomes, dominated by institutions such as the University of California, Harvard T.H. Chan School of Public Health, and the National Cancer Institute. Prior evidence has consistently shown that coffee-related epidemiological research is led by US-based cohorts and meta-analyses (Lopez-Garcia *et al.*, 2019; Grosso *et al.*, 2017). The present analysis corroborates this trend but further reveals that the health-oriented research stream has grown more rapidly than chemistry-focused work over the 2015–2024 period, indicating a shift in global scientific interest toward population-level health implications of coffee consumption.

This persistent divergence between producing-country research (chemistry, processing, fermentation) and consuming-country research (health, toxicology, population studies) reflects deeper structural segmentation in the field. While earlier literature (Samoggia & Riedel, 2018) has described this divide in broad terms, our findings empirically map this separation into distinct co-citation clusters, indicating limited intellectual integration between the two streams. This segmentation has implications for innovation: chemical and sensory studies rarely cite epidemiological research, and vice versa, potentially limiting opportunities for integrated understanding of how coffee composition relates to health effects.

At the same time, the growing involvement of European and Asian institutions—such as the University of Parma,

Universidad Autónoma de Madrid, and Srinakharinwirot University—suggests a geographic diversification that earlier bibliometric reviews did not capture. These emerging contributors appear to bridge the structural divide by engaging in hybrid themes, such as sensory evaluation linked to nutritional studies or processing techniques linked to metabolomic profiling. This trend points to a gradual thematic convergence and the development of interdisciplinary niches, although integration remains partial.

Overall, the results of this study both confirm established global patterns and extend the literature by revealing how research orientations have evolved over the past decade. The field remains structurally segmented, but new actors and emerging methodological approaches (e.g., FTIR spectroscopy, chemometrics, controlled fermentation) suggest a gradual shift toward more interconnected, multidisciplinary research trajectories.

4.3 Thematic Insights: Techniques and Interdisciplinarity

The increasing adoption of spectroscopic techniques such as FTIR reflects a shift toward rapid, low-cost, and nondestructive quality evaluation. FTIR and near-infrared (NIR) methods have been applied successfully to authenticate geographical origin, distinguish defective beans, assess roast levels, and predict sensory quality when combined with chemometric models (Barbin et al., 2018; Craig et al., 2020). This methodological shift complements but does not replace traditional cupping, offering reproducibility and speed that can support quality assurance and specialty coffee certification.

The persistent divide between health-oriented and chemistry/processing-oriented research underscores a missed opportunity for greater interdisciplinarity. For example, understanding how processing variables (fermentation and roasting) affect the bioavailability of chlorogenic acids and other bioactive compounds could integrate chemical and epidemiological insights (Farah & de Paula Lima, 2019; Moon et al., 2009). Bridging this gap would enhance the translational relevance of coffee research, linking farm-to-cup processes with both sensory experience and health outcomes.

4.4 Collaboration Patterns and Geographical Gaps

The collaboration networks presented in this study reveal uneven patterns of international integration that help explain disparities in scientific visibility across regions. The co-authorship network, for example, shows that European countries—particularly Italy, Germany, and Spain—form dense, highly interconnected clusters. This aligns with previous findings that EU funding mechanisms promote cross-border consortia and shared research infrastructures

(Hoekman et al., 2009). The high centrality of these European networks enhances the global visibility of their publications, as multicountry collaborations are associated with higher citation impact and broader dissemination.

In contrast, Korea's publication output, although substantial, appears primarily domestically clustered within the network analysis. This limited international integration likely contributes to lower global visibility compared with similarly productive countries. Such patterns underscore how collaborative positioning within the global network—not just publication volume—shapes a country's influence in coffee science.

A significant gap identified in the analysis is the limited international presence of African coffee-producing countries. Despite Ethiopia's status as the genetic center of *Coffea arabica* and the contributions of countries like Uganda, Rwanda, and Kenya to global biodiversity and production, these nations remain on the fringes of the co-authorship and country collaboration networks. This supports earlier observations of structural inequities related to research funding, laboratory infrastructure, and access to high-visibility publishing platforms (Jezeer et al., 2018). Their peripheral position in the network likely worsens the underrepresentation seen in publication counts, as weaker collaboration links reduce opportunities to participate in high-impact research collaborations.

Linking these findings to broader bibliometric patterns, the geographical gaps in collaboration partially explain why research leadership remains concentrated in a few hubs—Brazil in processing and chemistry, and the United States and parts of Europe in epidemiology and health research. The limited integration of key producing regions suggests untapped scientific potential, especially in areas such as genetic diversity, local processing practices, and terroir-specific sensory attributes. Strengthening international partnerships with African and other underrepresented producers would not only enhance global inclusivity but also enrich the scientific understanding of coffee quality, resilience, and biodiversity.

4.5 Concluding Integration

The global research landscape in coffee chemistry and sensory profiling is dynamic, growing, and becoming increasingly sophisticated. The field's vitality rests on its ability to embrace interdisciplinary approaches, integrate advanced analytical methods, and expand collaborative networks to underrepresented regions. By connecting health, processing, and sustainability research, coffee science can evolve into a more holistic and inclusive discipline—one that links microbial and chemical transformations at the origin with sensory experiences and health outcomes in the cup.

5 CONCLUSIONS

This bibliometric study charts global research in coffee chemistry and sensory profiling (2015–2024), showing rapid growth fueled by advances in analytical techniques, quality research, and health studies. Two main but weakly connected streams, chemical/sensory and epidemiological, highlight the need for stronger interdisciplinary collaboration. Brazil, the United States, and China lead in output, while Europe exhibits strong collaboration networks. Overall, the findings underscore the importance of integrative frameworks and strategic partnerships to promote more interconnected and globally inclusive coffee science.

6 AUTHORS' CONTRIBUTION

Conceptual Idea: Magwilang, E; Cue, E.; Tawanna, R.; Methodology design: Magwilang, E.; Tawanna, R.; Data collection: Lawagey, D.; Claudio, A.; Data analysis and interpretation: Magwilang, E.; Tawanna, M.; Lawagey, D.; Claudio, A.; Writing and editing: Magwilang, E; Cue, E.; Claudio, A.; Tawanna, R.; Lawagey, D.

7 DATA AVAILABILITY STATEMENT

Data available upon request to authors

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