

Coffee and geographical indication in food science perspective: a bibliometric analysis for future research

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Abstract. This study aimed to analyze the scope of geographical indication (GI) coffee using bibliometric review. A bibliometric approach was applied using data from 292 documents published between 2003 and 2024 using keywords coffee AND geographical AND indication OR origin. The analysis was conducted through Bibliometrix R package, VOSviewer, and Microsoft Excel 365, retrieving data from the Scopus database in October 2024. The results showed that interest in GI coffee grew from 2016, increased significantly in 2022 with over 40 publications. The research field of the top ten journals was mostly in the fields of food science and technology, with Food Chemistry as a top journal. Among all countries, Italy contributed to the most publications, meanwhile the most institutions contributor was the Slovak University of Agriculture in Nitra. Recent studies have increasingly focused on chemometrics, adulteration, and food quality. This review certainly serves as a reference for further research on GI coffee. This review certainly can provide a reference point for further research related to GI coffee.

1. Introduction

Coffee is a very valuable agricultural community that contributes significantly to the world economy [1]. Coffee production involves more than 70 countries in the world, with countries such as Brazil, Vietnam, Indonesia, and Colombia as the main producers [2]. According to ICO (2023), the total global coffee production in 2022 was approximately 10.3 million tonnes [3], with its global trade value estimated at more than USD 100 billion per year [2]. Besides being a major export commodity for many developing countries, coffee also creates jobs for millions of smallholder farmers around the world, most of whom depend on this crop as their main source of income [4]. The value of coffee products is not only determined by physical properties such as size and colour, but also by unique qualities influenced by geographical environmental factors, and cultivation methods in the region where the coffee is grown [5–7].

Many biological, chemical, and physical factors, including cultivar, coffee cherry maturity, geographic growing area, production, processing, roasting, and cup preparation, all contribute to the incredibly complex flavor of coffee [6]. These factors contribute to the distinct identify of coffee from specific regions, a

concept known as a geographical indication (GI). According to GI concept, the coffee is of high quality, has a good reputation (fame), and possesses other important qualities that are directly linked to its place of origin. GI is about legal protection and authenticity tied to cultural practices. Coffee with Geographical Indication (GI) status is generally priced at a premium compared to standard commercial coffee, attributed to its distinctive flavor profile and the value associated with its specific origin [7].

Numerous studies indicate that Geographical Indications (GIs) not only enhance authenticity but also offer consumers a sense of quality assurance. Baqueta *et al.* 2023 [8] revealed notable differences in the chemical and sensory profiles of *Canephora* coffee from Brazil, depending on the cultivation method and geographic location. This finding supports the idea that GI coffee holds strong market appeal, providing distinctive characteristics that set it apart from regular coffee. Geographical indications (GIs) play a significant role in maintain the quality and reputation of region-based products, including coffee [9]. Environmental conditions such as climate, altitude, and other geographical factors significantly affect the characteristics of coffee, including its distinctive flavor and aroma. GIs help identify and protect coffee quality

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in relation to its geographical origins and is supposed to bring additional value for the producers and quality assurance for the consumer [10]. This makes coffee with a specific GI more attractive in the global market, due to the unique flavors that come from the region of origin.

Geographical indications of coffee have been the focus of attention in recent decades, especially in relation to the quality, uniqueness, and added value they offer. Through geographical indications, coffee products can obtain legal protection that ensures that only coffee from certain regions can use the label, thus providing a competitive advantage in the international market [7]. In Indonesia, Geographical Indication (GI) regulation was formally proclaimed by the Indonesian government in 2007. This regulation defines GI as any indication that identifies a product or goods as coming from a specific region where its geographical environment factors, such as labor, nature, or a combination of both, are responsible for a particular product's or goods' reputation, quality, and characteristics. In Indonesia on October 2024, out of 158 geographically indicated products, 52 of them are coffee products: arabica (26 products), robusta (22 products), liberika (3 products), and excelsa (1 product) (46). However, to thoroughly understand how this aspect is studied and developed in the context of food science, a systematic scientific approach is required, one of which is through bibliometric analysis.

Bibliometric analysis is a research method used to identify publication patterns and research trends, as well as reveal collaboration networks among researchers, institutions, and countries involved in a particular research topic [11]. The purpose of this study was to investigate the development of research on geographical indication (GI) coffee. The study highlights trends, most authors, most affiliations, leading journals, institutions, countries, and collaborations. This analysis helps stakeholders such as producers, researchers, and policymakers understand the development of research on geographical indication (GI) coffee and research needed in the future.

2. Material and Methods

2.1 Data collection

The search and data retrieval for this study was conducted on October, 2024. Data were collected from 'Scopus' metadata using the keywords: coffee AND geographical AND indication OR origin. Scopus is a comprehensive database for academic articles, making it an excellent resource for research on a diverse array of subjects. Scopus stands out from other databases with its broad multidisciplinary coverage and comprehensive citation information, making it an invaluable resource for interdisciplinary research. The research was limited to the time span 2023-2024 to capture the latest trends and developments in geographical indication coffee research.

2.2 Selection of data-driven study

The initial search resulted a total of 351 documents. Only documents that discussed GI coffee in English were the focus of this research. They were 334 documents, consisting of 238 articles (75%), 31 conference papers (9%), 23 reviews (7%), and other (9%) including books, book chapters, editorials, short survey and data papers. Articles, conference paper and reviews are included, while books, book chapters, editorials, short surveys, and data papers were excluded. A total of 292 documents were extracted and downloaded in CSV and RIS formats. The rest of the retrieved documents were saved and exported as full records.

2.3 Data analysis

Microsoft Excel 365 was used to analyze annual publication trends, while the analysis and visualization of bibliometric data were performed using R software (version 4.4.1) with the bibliometrix package (version 4.1) and VOSviewer (version 1.6.20). These tools were chosen to guarantee precise and reliable data extraction and analysis processes. VOSviewer visualises bibliometric keyword occurrences to show authors' keywords that are often used in research and to aid analysis of research trends and important topics.

3. Results and Discussion

3.1 Overview of the research literature on coffee and geographical indication

Fig. 1 illustrates the fluctuation in the number of publications related to this topic from 2003 to 2024. During the period from 2003 to 2015, the number of publications remained stable and low, with fewer than 10 publications per year, indicating limited interest. From 2015 to 2016, there was a gradual increase, particularly in 2014, suggesting a growing research interest. A significant surge occurred between 2018 and 2022, maximum in 2022 at more than 40 publications, reflecting heightened scientific attention to this topic. After this peak, the number of publications decreased in 2023, although it stayed higher than in previous years (2018-2021), indicating a slight reduction in research intensity but continued interest.

Among them, the increase in awareness of environmental impacts and sustainable challenges around the world in general and in agricultural industries like coffee has become one of the triggers [12]. The abundance of articles in environmental journals indicates the growing importance of research on environmental conservation, sustainable agricultural practices, and coffee ecosystem preservation [12,13].

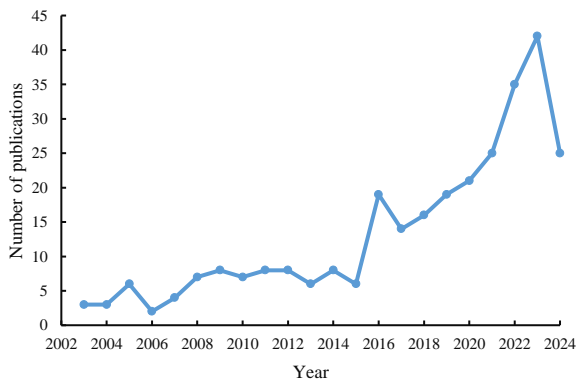


Fig. 1 Number of publications by year

Research on geographical indications (GIs) certification and its impact on the economy and global trade has grown due to the increasing recognition of GIs in coffee products, enhancing their economic value for producers in developing countries [14]. Technological advances in food analysis methods, such as the use of mass spectrometry and advanced chemical techniques, have also contributed to the increase in research [15]. Research focusing on the quality, food safety, and sensory characteristics of coffee is increasing rapidly caused by more advanced analytical methods [13,16]. In addition, the impact of the COVID-19 pandemic on the coffee supply chain and consumption has also spurred studies related to food security and changing consumption patterns, further strengthening interest in coffee research from food science, economic, and environmental perspectives [15].

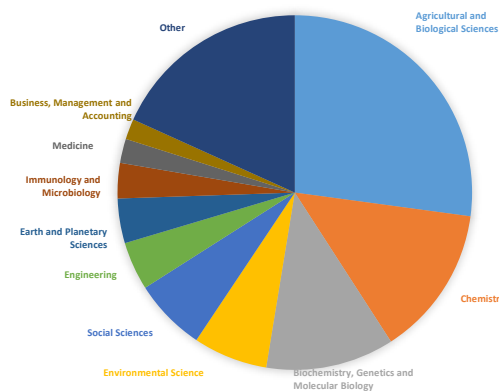


Fig. 2 Documents by subject area

Fig. 2 displays research on coffee and GI concentrated in a few disciplines, namely Agricultural and Biological Sciences, Chemistry, and also Biochemistry, Genetics and Molecular Biology reflecting an emphasis on the production of coffee across different geographic entities, coffee genetic traits, and chemical composition. In contrast, Social Sciences and Business, Management and Accounting are indispensable in discussing the socio-economic issues of GI, including intellectual property rights, branding strategies, and trade impacts [17]. This bibliometric analysis therefore digests the interdisciplinary nature of future research on coffee and GI [18].

The research on coffee GI has been growing in recent years. Near infrared (NIR) spectroscopy methods combined with chemometrics can distinguish new Brazilian *Canephora* coffees (Conilon and Robusta) GI [8]. However, the development of a new portable NIR method for this purpose is needed so that it can be implemented in small coffee cooperatives, industries, or regulatory bodies in the future that do not have high economic resources. Moraes-Neto *et al.* 2024 showed that UV-Vis spectroscopy, combined with PCA and PLS-DA, was able to differentiate green beans of Brazilian specialty *canephora* coffees based on their geographical indication. This method is more efficient than traditional analysis in specialty coffee authentication. This study also revealed that chlorogenic acid and caffeine play an important role in the differentiation of GI coffee [19]. These findings suggest that this technology is easy and inexpensive for GI coffee authenticity [20].

3.2 Most authors, cited documents, research field and affiliations

Based on **Fig. 3**, the most prolific author is Luciano Navarini with 14 publications, highlighting their dominant role in research related to coffee and geographical indications, particularly focusing on quality aspects and their impact in the global market [21–23]. Luciano Navarini *et al.* 2018 identified several minor chlorogenic acid isomers in roasted *Coffea arabica* using UHPLC-ESI-QqTOF-MS/MS. Four dimethoxycinnamoyl-quinic acid derivatives and two caffeoyl-feruloyl quinic acid derivatives had been identified by HR-MS/MS. These compounds were found in roasted Arabica coffee for the first time, and their existence is independent on the different geographical origins examined [21].

M.R. Baqueta has made significant contributions, though with a smaller number of publications, enriching the discussion about authentication and discrimination of coffee with spectroscopy and chemometric methods [19,24,25]. Interestingly, all authors' publications are the result of collaboration with other authors. This phenomenon emphasizes the important role of collaboration in academic research, especially in complex and multidisciplinary fields, where synergy between experts is needed to produce more comprehensive and impactful research.

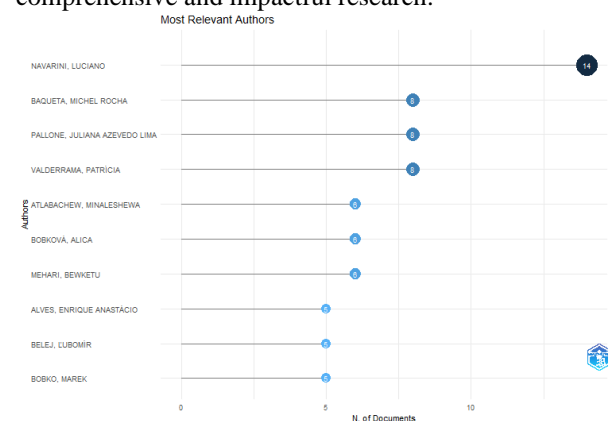


Fig. 3. Most relevant authors

Table 1 shows Coffee and geographical indications (GI) are highlighted in the top 10 most cited documents. The significance of food quality, authenticity of origin, and the effect of GI on food items are all emphasized in these documents. Growing interest in the ways that regional origin affects food qualities, particularly coffee, is shown in high citation counts, such as those by Davis *et al.* 2011 and Jeszka-Skowron *et al.* 2016 [5,26].

Jeszka-Skowron *et al.* 2016 used HPLC-DAD to analyze twelve samples of coffee from diverse geographical origins, including Robusta and Arabica. Robusta coffee extracts contain twice as much caffeine as Arabica, the highest concentration of 5-O-caffeoylquinic acid (5-CQA) was obtained for both coffees from Uganda. However, CUPRAC and F-C tests revealed that extracts of Vietnamese green coffee beans showed the best antioxidant activity [26].

The use of scientific approaches to validate GI claims is supported by studies such as Caporaso *et al.* 2018 on chemical analysis [27], Moraes-Neto *et al.* 2024 and Baqueta *et al.* 2023 [19,20] on food authenticity. Caporaso *et al.* 2018 analyzed the variability of volatile compounds of Arabica and Robusta roasted coffees analyzed by SPME-GC-MS. The results found that the composition of green coffee beans, which is influenced by species, origin, and post-harvest processes, determines the volatile profile of coffee in addition to the roasting level. Meanwhile Baqueta *et al.* 2023 used a combination of NIR spectroscopy with chemometrics as a tool to authenticate GI coffee [8].

The information that research related to coffee and geographical indications is spread across various scientific sources with different focuses is provided in **Table 2**. The source with the largest contribution is “IOP Conference Series: Earth and Environmental Science” with 18 documents, indicating that environmental aspects and sustainability in coffee production have great attention in academic studies. In addition, “Food Chemistry” and “Food Research International,” with 14 and 12 documents, respectively, show that research on the chemical composition and characteristics of coffee in relation to geographical indications is a major focus in this field. Furthermore, journals such as Food Control (11 papers) and Journal of Agricultural and Food Chemistry (10 documents) provide substantial contributions, demonstrating that food safety and agronomic qualities of coffee are key components of the linked study. European Food Research and Technology (7 documents) and the Journal of Food Composition and Analysis (6 documents) both stressed the significance of coffee chemical composition analysis in understanding the relationship between geographical origin and product quality.

Table 1. Top 10 Most Cited Documents

Author	Title	Year	Journal	Total Citations	TC per Year	Normalized TC
Jeszka-Skowron M [26]	Chlorogenic acids, caffeine content and antioxidant properties of green coffee extracts: influence of green coffee bean preparation	2016	Eur Food Res Technol	185	20,56	3,36
Davis Ap [5]	Growing coffee: Psilanthus (Rubiaceae) subsumed on the basis of molecular and morphological data: implications for the size, morphology, distribution and evolutionary history of Coffea	2011	Bot J Linn Soc	185	13,21	4,67
Alonso-Salces Rm [28]	Botanical and geographical characterization of green coffee (Coffea arabica and Coffea canephora): Chemometric evaluation of phenolic and methylxanthine contents	2009	J Agric Food Chem	184	11,50	3,83
Caporaso N [27]	Variability of single bean coffee volatile compounds of Arabica and robusta roasted coffees analysed by SPME-GC-MS	2018	Food Res Int	182	26,00	5,34
Belletti G [29]	Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies	2017	World Dev	165	20,63	3,63
Toledo Prab [30]	Related to Coffee Quality and Their Volatile Compounds	2016	Compr Rev Food Sci Food Saf	160	17,78	2,91
Risticvic S [31]	chromatographic-time-of-flight mass spectrometric methodology for geographical origin verification of coffee	2008	Anal Chim Acta	129	7,59	1,96
Giraud A [32]	Determination of the Geographical Origin of Coffee Beans Using Terahertz Spectroscopy Combined With Machine Learning Methods	2019	Food Control	123	20,50	3,26
Kamiloglu S [33]	Authenticity and traceability in beverages	2019	Food Chem	123	20,50	3,26
Wei F [34]	¹³ C NMR-based metabolomics for the classification of green coffee beans according to variety and origin	2012	J Agric Food Chem	120	9,23	3,19

Meanwhile, the journals Foods and Journal of Mass Spectrometry each included five documents, demonstrating that instrumental analytical methods such as mass spectrometry are being utilized to identify the specific chemical components of coffee by place of origin. This indicates that in-depth studies on coffee from various regions continue to grow, especially in understanding the relationship between geographical factors, chemical composition, and the sensory quality and safety of the final product.

Table 2. Top 10 most relevant sources

Sources	Number of documents
IOP Conference Series: Earth And Environmental Science	18
Food Chemistry	14
Food Research International	12
Food Control	11
Journal Of Agricultural And Food Chemistry	10
European Food Research And Technology	7
Journal Of Food Composition And Analysis	6
Foods	5
Journal of Mass Spectrometry	5

Based on **Fig. 4**, which shows the most productive countries in terms of lead author contributions related to bibliometric studies, Italy is the most productive country with the highest number of publications, followed by Brazil and Indonesia. The contributions from these countries can provide important insights related to the development of coffee research as a product with geographical indication (GI). Geographical indications on coffee are becoming increasingly relevant in coffee-producing countries such as Indonesia and Brazil, which are also two of the five largest coffee-producing countries in the world [3].

Italy is the world's third largest importer of green coffee, after the United States and Germany. In Europe, it is the second largest producer, exporter, and consumer of roasted coffee after Germany [35]. According to research by Piñeiro *et al.* 2024, the registration of geographical indications (GIs) has an impact on the quality of imported coffee. The study found that using GIs enhance import quality primarily in countries with weaker domestic manufacturing standards. However, in nations with high domestic production quality, GIs may hinder import quality improvements, as local producers focus on quality competition rather than price, making imported coffee a more affordable alternative for consumers [36].

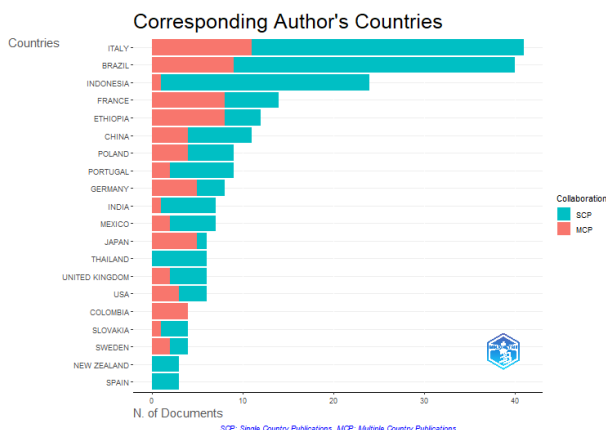


Fig. 4. Most productive countries (SCP: Single Country Publications, MCP: Multiple Country Publication)

The data in **Fig. 4** shows that Indonesia as one of the coffee producer countries, publishes documents without collaboration with authors from other countries known as SCP (single country publication) at a much greater percentage than collaborating with authors from other countries or MCP (Multiple Country Publication) with a percentage of only 4%. While countries such as France (57%) and Ethiopia (67%) do publications with collaboration with other countries more than publications without collaboration, namely 57% and 67% respectively.

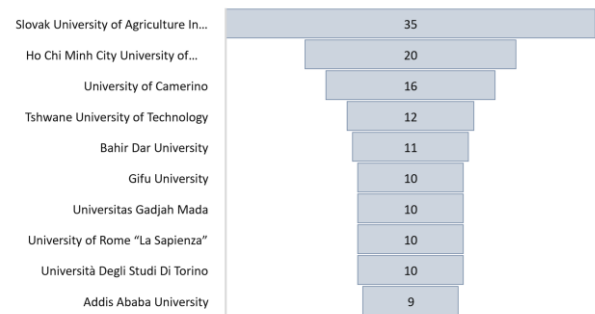


Fig. 5. Most relevant affiliations

Based on the bibliometric analysis of 292 articles, it can be identified that there are several university affiliations that are the main research centers in this topic (**Fig. 5**). Based on the data presented, the Slovak University of Agriculture is the institution with the highest number of publications, reaching 35 publications. This suggests that the university has a strong focus on coffee and geographical indications research, as well as a significant contribution to developing the scientific literature in this field. Research at this university seems to focus on agro-economic and quality aspects of coffee products related to geographical indications.

Research in Slovak University of Agriculture in Nitra focuses on the evaluation of coffee quality parameters and beverage preparation methods [43], chemical composition, coffee properties and health effects [37], Effect of roasting on total polyphenols and antioxidant activity of coffee [38] and authentication [39].

In second place, Ho Chi Minh City University of Technology and University of Camerino contributed 20 and 16 publications, respectively. These two universities also play an important role in the development of research related to the topic, indicating the attention from the Southeast Asian region and Europe to issues such as the protection of geographical indications and their impact on the quality and economic value of coffee.

Ho Chi Minh research highlights determination of bioactive compounds and antioxidant [43], authentication with spectroscopy, and chemometric [40], and the potential of cascara kombucha as a novel substrate for kombucha manufacturing while also recycling coffee byproducts, boosting ecologically friendly and sustainable agricultural development [41].

Based on the country collaboration map shown in **Fig. 6**, it can be seen that the research on “Coffee and Geographical Indication in Food Science Perspective” involves extensive international cooperation. Countries with darker colors, such as Brazil, show a higher intensity of collaboration, especially with countries in North America and Europe. Brazil, as one of the world's largest coffee producers [3], has a central role in this research, which is in line with its interest in the topic of coffee geographical indications. This collaboration highlights the importance of interdisciplinary research in analyzing the geographical characteristics and quality of coffee across different regions.

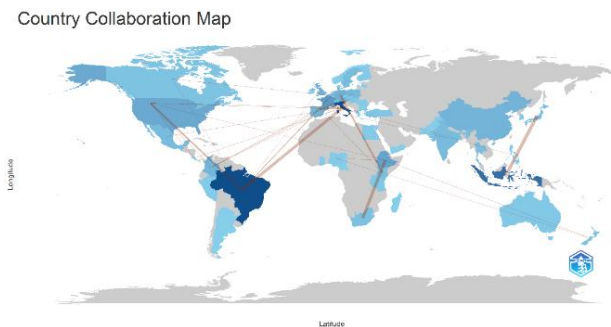


Fig. 6. Country collaboration map

This collaboration map shows how coffee producing and consuming countries are working together to deepen the understanding of the relationship between geographical characteristics and coffee quality, and opens up opportunities for further collaboration for in-depth research on geographical indications from a food science perspective.

Several keynote authors and works emerge in the development of "Coffee and Geographical Indication" (**Fig. 7**). The most prominent works among these are those done by [28] and [42], which helped a lot in establishing this now-growing foundation in this field. These studies are highly connected to each other through strong citations, revealing that earlier works have indeed acted as important references for all other researchers who afterwards focused their investigation into the geographical and chemical features of coffee. For instance, Alonso-Salces' work has been a milestone in those dealing with the authentication of coffee according to geographical origin and analysis of the chemical composition. Later studies, such as Giraudo *et al.* 2019 and Babova *et al.* 2016 [32] and synthesized the conclusions of earlier works by applying sophisticated data analysis and larger data.

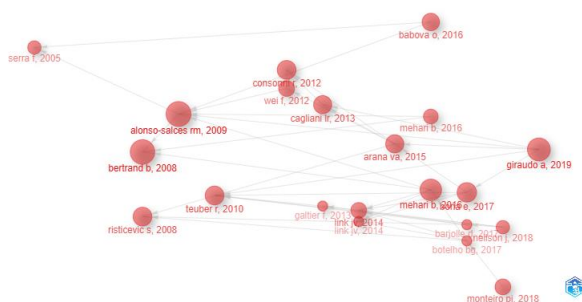


Fig. 7. Co-authorship network

Their findings showed that new methods of coffee authentication, emerging recently, were based on new technologies of chemical analytics and multidisciplinary approaches. Other author linkages show how research develops from foundation studies into more advanced detailed applied studies. This historiograph makes clear the way research into geographical indications of coffee has evolved through time and what key contributions by researchers have been in shaping knowledge of today.

3.3 Hotspots and development trends through an analysis of keyword clustering

Thematic maps are categorized into four quadrants according to centrality and density, reflecting the significance and progress of research topics. Based on the thematic map shown in **Fig. 8**, there are several main themes that are the center of attention in the research on “Coffee and Geographical Indication”. In the upper right quadrant (Motor Themes), the topics “coffee,” “article,” and “chemistry” show a high level of development and are very central to this study. This indicates that the chemistry aspect of coffee research, particularly with regard to chemical composition, quality analysis, and characteristics influenced by geographical indications, is highly relevant and growing.

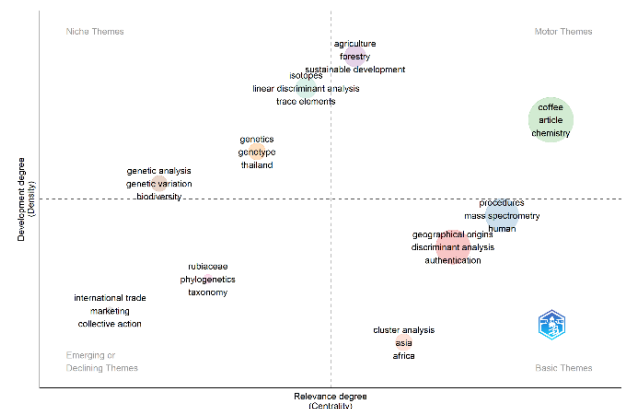


Fig. 8. Thematic map of coffee and geographical indication.

On the other hand, in the lower right quadrant (Basic Themes), themes such as “geographical origin,” “discriminant analysis,” and “authentication” show high relevance but lower levels of development. This suggests that these themes are fundamental to the study of geographical indications in coffee, which involves identifying the geographical origin and authenticating coffee products based on their origin. While these topics have significant relevance, the method development and application aspects still have room for further exploration.

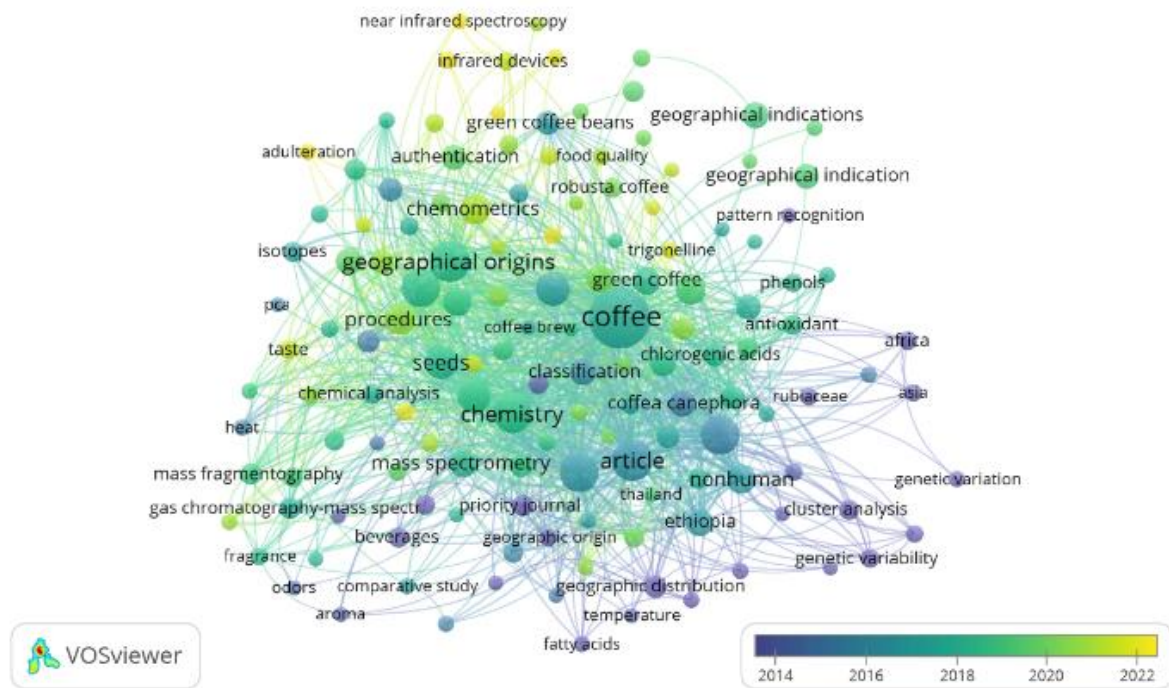


Fig. 9. Keyword co-occurrence networks

Fig. 9 shows a bibliometric analysis of GI coffee research in the last 20 years. The colors of the nodes and lines indicate the temporal progression of the research topics, with a spectrum from blue (older) to yellow (newer). “Coffee”, “geographical origins”, “chemistry”, and “geographical indications” are the primary keywords that predominate, according to the network visualization of the author’s keywords that are often used in research pertaining to coffee and “Geographical Indication”. This shows that geographical origin is an important factor in coffee research, especially in determining the chemical compounds and sensory of coffee [44].

The keywords “authentication”, “chemometrics” “infrared spectroscopy”, and “adulteration” reflect the increasing use of non-destructive techniques to assess coffee quality and confirm the importance of validating product authenticity in the global coffee industry [8,19], while “chlorogenic acids” and “antioxidant” indicate recent research in the field of GI coffee has paid greater attention to the health benefits of coffee. These developments signal that future coffee research will be increasingly oriented towards a multidisciplinary approach combining analytical technologies, geographic authentication, and bioactive characteristics.

4. Strengths and limitations

This study will help researchers to understand the topic more clearly and carry out new paths. However, certain limitations must be acknowledged. The exclusion of papers outside the Scopus database may affect the results, though Scopus remains one of the most reputable sources for bibliometric analysis.

Additionally, the study only considers English-language literature, introducing a potential source bias. Despite these limitations, this paper effectively reviews the current research landscape, emerging trends, and key hotspots in food science research.

5. Conclusion

This study reveals a significant increase in publication since 2016 on coffee and geographical indications (GIs), reflecting growing global interest in this topic. Food Chemistry is the leading journal in this field, while Luciano Navarini was the most relevant author, and Italy was the most author’s countries. As the second-largest producer of roasted coffee in Europe, Italy places great emphasis on the quality of the green coffee beans it imports. Current research mainly concentrates on the chemical properties, bioactive compounds, health benefits, and the discrimination and authentication of coffee. The study of GI coffee has progressed rapidly, particularly in quantitative chemical analysis, discrimination between GI and non-GI coffee, determination of GI coffee markers, and authentication techniques. Despite these advances, further research is needed to improve the accuracy and efficiency of these approaches for practical applications. Additionally, investigation into coffee quality in producing countries other than Brazil such as Vietnam and Indonesia, the world's second and third largest coffee producers remain limited. To bridge this gap, global collaboration between coffee-producing and importing countries is essential for improving quality, establishing robust quality standards, and promoting sustainable trade.

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