metrics

MDPI

Article

Agri-Food Sector: Contemporary Trends, Possible Gaps, and Prospective Directions

José Roberto Herrera Cantorani [1,*], Meire Ramalho de Oliveira [2], Luiz Alberto Pilatti [3] and Thales Botelho de Sousa [4]

[1] Department of Physical Education, Federal Institute of Education, Science and Technology of São Paulo, Avenue Clara Gianotti de Souza, 5180-Jardim Agrochá, Registro 11900-000, SP, Brazil
[2] Department of Business, Federal Institute of Education, Science and Technology of São Paulo, Avenue Enio Pires de Camargo, 2971-Jardim Ribeirão, Capivari 13365-010, SP, Brazil; meire.oliveira@ifsp.edu.br
[3] Department of Production Engineering, Federal University of Technology—Paraná, R. Doutor Washington Subtil Chueire, 330-Jardim Carvalho, Ponta Grossa 84017-220, PR, Brazil; lapilatti@utfpr.edu.br
[4] Department of Production Engineering, Federal Institute of Education, Science and Technology of São Paulo, Avenue Clara Gianotti de Souza, 5180-Jardim Agrochá, Registro 11900-000, SP, Brazil; thales.botelho@ifsp.edu.br
* Correspondence: cantorani@ifsp.edu.br

Abstract: The agri-food sector is expanding, driven by growing global demand. At the same time, it faces the challenge of increasing its efficiency and adopting sustainable practices. This study aimed to map scientific production in this field, identifying trends, emerging themes, critical gaps, and future directions for research. A bibliometric analysis was conducted with 5141 papers published between 1977 and 2024, extracted from the Scopus and Web of Science databases. We applied keyword co-occurrence analysis, thematic analysis, thematic evolution, and three-field graphs using the metrics betweenness centrality, closeness centrality, and PageRank. The results revealed a significant growth in publications in the agri-food sector, especially after 2012, emphasizing the high centrality and relevance of themes such as sustainability, agri-food, and agriculture. Topics such as bioactive compounds, blockchain, and traceability were identified as areas of growing interest, and the circular economy stood out as an emerging topic. Italy, Spain, and France lead in scientific production and international collaboration. The most prominent journals were *Sustainability*, the *Journal of Cleaner Production*, and *Agriculture and Human Values*. Research in the sector is expanding, focusing on sustainability, the circular economy, and bioactive compounds. International collaborations and high-impact journals are pillars for advances in the sector.

Keywords: agri-food sector; food; sustainability; bibliometrics

Academic Editor: Siluo Yang

Received: 25 November 2024
Revised: 17 January 2025
Accepted: 1 February 2025
Published: 5 February 2025

Citation: Cantorani, J.R.H.; de Oliveira, M.R.; Pilatti, L.A.; de Sousa, T.B. Agri-Food Sector: Contemporary Trends, Possible Gaps, and Prospective Directions. *Metrics* **2025**, 2, 3. https://doi.org/10.3390/metrics2010003

1. Introduction

The agri-food sector is central to global challenges such as food security, sustainability, and adaptation to climate change, affecting human life, public health, and global economic systems [1,2]. With population growth and urbanization, the demand for food and resources continues to increase. At the same time, the availability of agricultural land decreases, resulting in an urgent need for technological solutions and resilient agricultural practices to ensure sustainable supply [3,4]. In addition, extreme weather events and changes in carbon dioxide levels intensify agri-food production challenges related to the quality and quantity of food produced [1].

The transition to more sustainable and efficient food systems is a priority. It has been made possible by the increasing integration of digital technologies, such as artificial intelligence, the Internet of Things (IoT), blockchain, and big data, in agricultural practices and supply chain management [5–7]. These technologies promote significant improvements in operational efficiency, traceability, and food waste reduction, contributing to constructing smarter and more sustainable agri-food systems, known as "Agri-Food 4.0" [8,9]. Studies show the importance of adhering to more sustainable practices and technological solutions capable of facing global challenges [10–12].

Despite significant progress, gaps persist in international scientific collaboration, food governance, and the impact of the financialization of the agri-food sector, especially in regions with more significant economic and social pressure [13,14]. Studies indicate that increased corporate investment in agricultural land in countries such as Canada and Australia has impacted farm ownership and control, raising concerns about the inequalities generated by this process [15]. At the same time, regulations and policies, such as those implemented in Europe and Qatar, demonstrate the importance of robust legislation for food safety and promoting sustainable production and consumption patterns [16–18].

Understanding scientific trends and identifying critical gaps in the agri-food sector is essential to address these challenges and seize the opportunities offered by technological innovations. This study uses a bibliometric analysis to map scientific production in the sector, covering 47 years (1977–2024) and 5141 papers from the Scopus and Web of Science (WoS) databases. The aim is to identify the main trends, emerging themes, research gaps, and future directions, providing a comprehensive overview of the state of the art in the field. By highlighting the centrality of topics, such as bioactive compounds, sustainability, traceability, and blockchain, the work seeks to advance science in the agri-food sector.

The paper's organization follows the IMRaD model, structuring the presentation of the results into well-defined sections and ensuring a logical exposition [19].

2. Materials and Methods

2.1. Data Collection Method and Procedure

The Scopus and WoS databases were the primary data sources for this academic investigation, providing comprehensive data on research related to the agri-food sector. A search expression was constructed with the terms "agri-food sector*" OR "agri-food system*" OR "agri-food industry*" OR "agro-food sector*" OR "agro-food system*" OR "agro-food industry*". The asterisk (*) was used at the end of the root of words that have variations to find all variations of that word. The searches were conducted on 21 November 2024. Both databases' "Topic" fields were used, allowing data to be retrieved in titles, keywords, and abstracts. This study did not impose any temporal delimitation. Additionally, there were no restrictions based on language; documents published in different languages were included in the analysis. The initial search yielded 4154 documents in WoS and 5594 in Scopus. After applying filters to focus solely on journal articles, these figures were reduced to 3464 documents in WoS and 4342 in Scopus. Materials such as proceedings papers, book chapters, and editorials were excluded from consideration. In the sequence, 2665 duplicate documents were identified and removed, leading to a final dataset of 5141 documents available for analysis.

The procedure of using only journal articles for bibliometric analysis is due to the uniformity of information. Journals follow standardized norms and guidelines regarding articles' structure and formatting, allowing a greater range of bibliometric analyses and more rigorous bibliometric analyses with less room for error. A highly relevant aspect regarding the provision and standardization of data is the presence of keywords as a standard in journal articles. Keywords are valuable indicators for identifying central themes and trends in a research area. Additionally, keywords with the same meaning (synonyms and the same terms in different languages) were identified and grouped. The most frequently used term was kept; the others were added to the primary term.

A bibliometric study employing mathematical and statistical methods was then conducted to evaluate the scientific knowledge generated, measure information flows, and analyze the quantitative aspects of production in the agri-food sector.

2.2. Data Analysis Method and Procedure

This study analyzed publication trends, identifying emerging and obsolete topics, the countries that contributed most, and research collaboration patterns. The research used networks to scientifically map fundamental knowledge clusters, highlighting the interrelationships between topics and the relevance of contributions from different areas.

In academics, keyword analysis is an appropriate strategy for defining topics and outlining central research subjects. This practice facilitates the visibility and dissemination of work within the scientific community [20–22], configuring itself as a valuable approach for identifying knowledge clusters in research areas. For this study, the keywords extracted from the Scopus and WoS databases were subjected to analysis using RStudio, Bibliometrix Rpackage, and Microsoft Excel software.

The Bibliometrix package, developed in R, offers tools for bibliometric and scientometric analyses. This package works in an open-source environment and integrates statistical algorithms and data visualization tools, allowing detailed analyses [23].

The overview of the methodological procedures is illustrated in Figure 1.

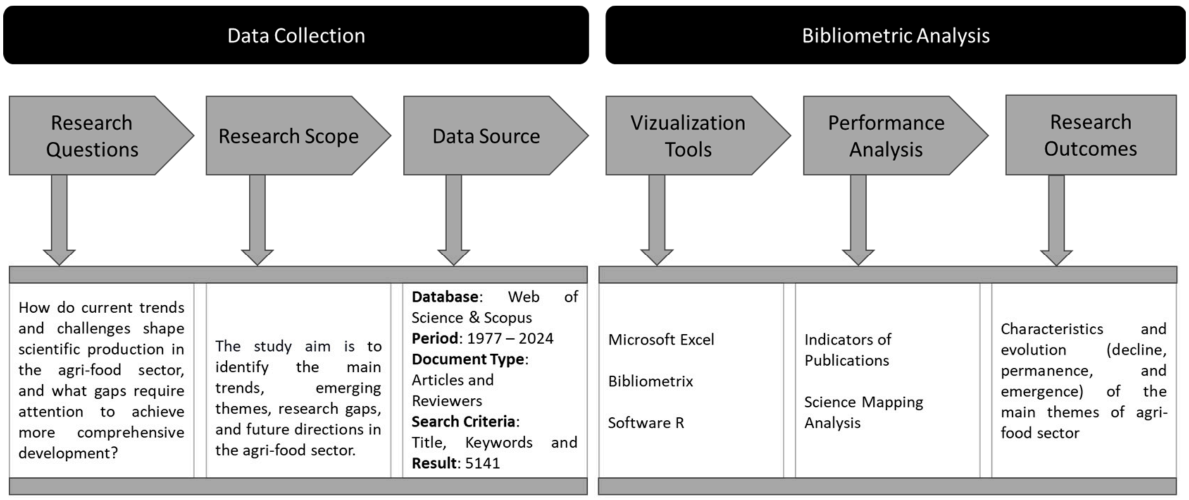

Figure 1. Methodological steps of the investigation. Source: own elaboration.

The methodological procedures adopted allowed for broad coverage without temporal or linguistic restrictions. Combining the WoS and Scopus databases ensured greater comprehensiveness and reliability in the results obtained. Another relevant aspect was the focus on the analysis of key terms, which allowed the identification of the most used terms and the mapping of trends and gaps in the field of study. This approach enriches the identification of patterns and provides a comprehensive view of the topic investigated.

3. Results

3.1. Evolution of Scientific Production

The descriptive analysis began with extracting 5141 documents, covering the period from 1977 to 2024. Figure 2 illustrates the growth of scientific production directed at the agri-food sector.

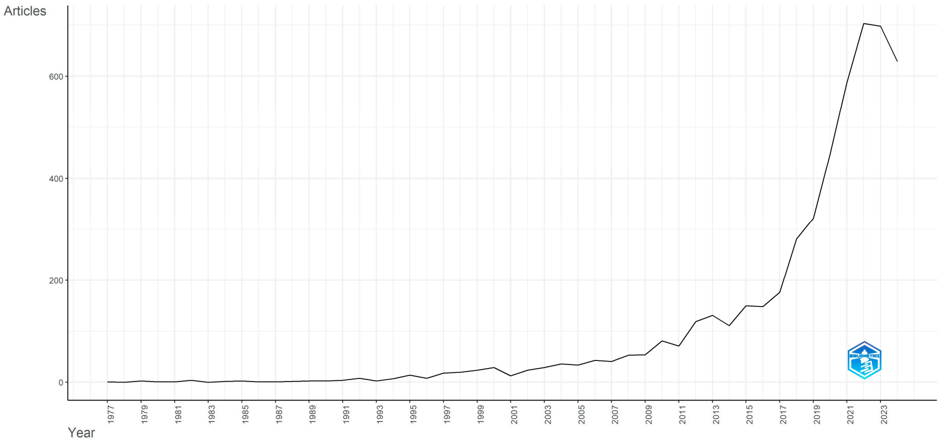

Figure 2. Annual distribution of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

3.2. Thematic Analysis

With the co-occurrence network (Figure 3), it is possible to visualize the main themes related to the agri-food sector in the period examined. Each circle represents a node—a keyword. The node's size indicates the frequency with which the term appears in the documents, while the lines indicate the strength of the relationship between the words—the thicker the line, the stronger the relationship [24]. The color of each node determines the creation of a cluster—the most significant ones are configured as a central indicator of the theme [25].

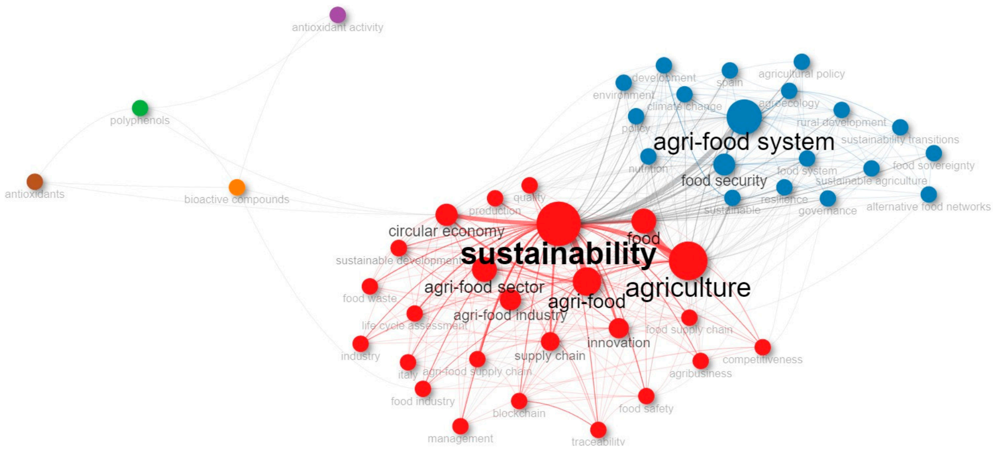

Figure 3. Keyword co-occurrence analysis of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

A co-occurrence network is structured based on the betweenness centrality, closeness centrality, and the PageRank of the terms that compose it, represented by the nodes. Each node's betweenness centrality, closeness centrality, and PageRank can be verified in Table S1 in the Supplementary Material.

Centrality is an essential concept in a network, as it allows the identification of dominant elements [26]. The betweenness centrality index measures the frequency with which a specific node appears on the shortest paths between two other nodes within the network, facilitating data flow between different segments. The higher the betweenness centrality value of a node, the more dependent the other nodes become on it to connect and exchange information. Betweenness can be used to assess the connectivity potential, reflecting the ability of a node to control communication between other nodes. This metric reflects the strategic importance of a node in disseminating information [27]. Closeness centrality measures the proximity of a node to other nodes in the network, indicating its global centrality. This indicator reflects the advantage of a node in terms of its strategic position in the network, allowing faster access to information and connections with other nodes [27]. PageRank is a metric used to measure the quality of a paper. This measure considers how often a given paper has been cited by others, demonstrating the overall significance—the popularity of that node [28].

Figure 4 represents the thematic evolution of research in the agri-food sector. In this figure, the most present research themes are observed in two distinct periods, 1977–2021 and 2022–2024, and the evolution of research themes from the first to the second period is also visible. Bibliometrix automatically defined the periods based on three main criteria. The first criterion considers the volume of data, making divisions based on the total number of publications and the temporal density of the available data, thus ensuring consistency for the analysis. The second criterion focuses on the frequency of keywords during the analyzed period, identifying the connection between the highlighted keywords and the respective predominant research themes. The third criterion analyzes the co-occurrence of different keywords in the same documents, allowing the identification of relationships between themes and the formation of subthemes within a given field of research. This integrated approach provides a more comprehensive and informed view of thematic evolution in the scientific literature.

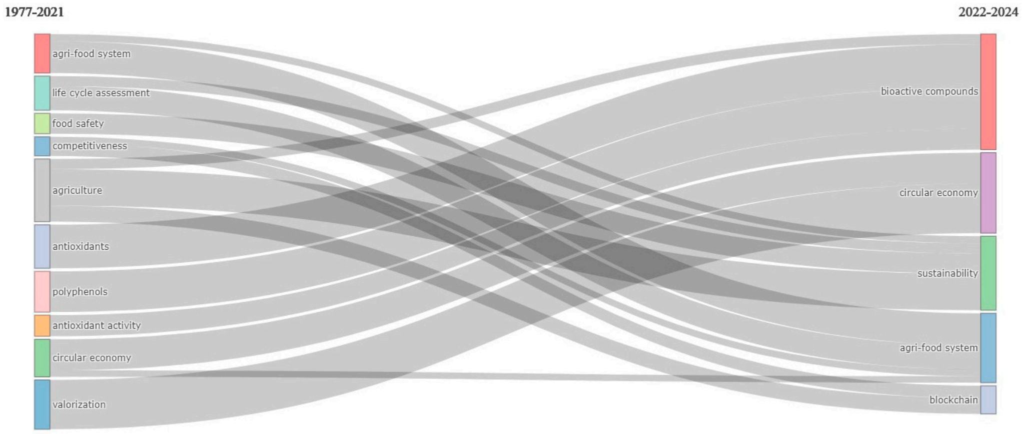

Figure 4. Thematic evolution of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

With the thematic map (Figure 5), it is possible to visualize the importance and development of research themes [29], as well as to evaluate the potential for evolution of the themes [30]. The diagram comprises two axes, centrality (*x*-axis) and density (*y*-axis), which divide it into four quadrants: motor themes, niche themes, emerging or declining themes, and basic themes. Centrality and density metrics are used to position research themes in this two-dimensional four-quadrant diagram [31]. Centrality corresponds to the degree of interaction between the network clusters and provides information about their significance [32]. Density indicates the internal strength of a cluster, portrays cohesion, and can be considered an indicator of the evolution of the theme [33]. The higher the centrality, the more critical the node in the network. The higher the density, the stronger the network's capacity to develop and sustain [34].

In the thematic map (Figure 5), the motor themes are located in the first quadrant (Q1); the niche themes—of limited importance to the field—are in the second (Q2); the themes that behave as emerging or in decline are in the third (Q3); and the basic and transversal themes are in the fourth (Q4) [33]. The size of the circles illustrates the number of documents on the themes that form the network in this cluster [31].

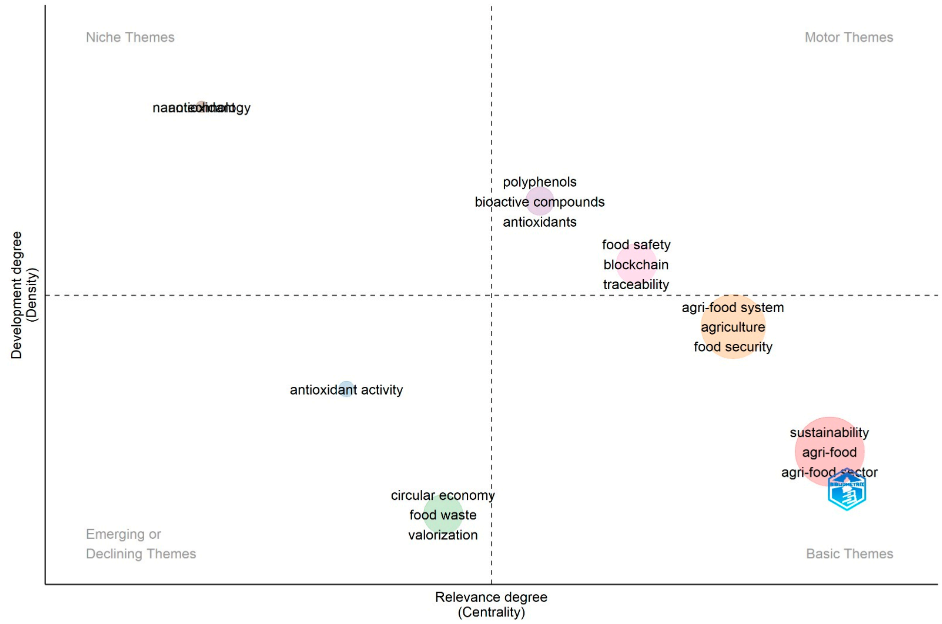

Figure 5. Thematic analysis of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

The themes, number of occurrences, connection to the respective cluster, and centralities can be verified in Table S2 in the Supplementary Material. The centrality and density of the clusters can be verified in Table S3 in the Supplementary Material.

Figure 6, a three-field plot based on the Sankey diagram, presents the connection between the most recurrent themes related to the agri-food sector and the institutions and countries that stand out in research on these themes. This diagram is used to visualize data flows [35]. These three elements are plotted with gray connections that show their relationship with each other. In the center are the themes that appear most in research related to the agri-food sector; on the left are the institutions in which these themes are researched; and on the right are the countries in which the themes are researched. The size of each rectangle indicates the number of papers associated with this element [36]. The width of the lines between the nodes is proportional to the number of existing connections [37].

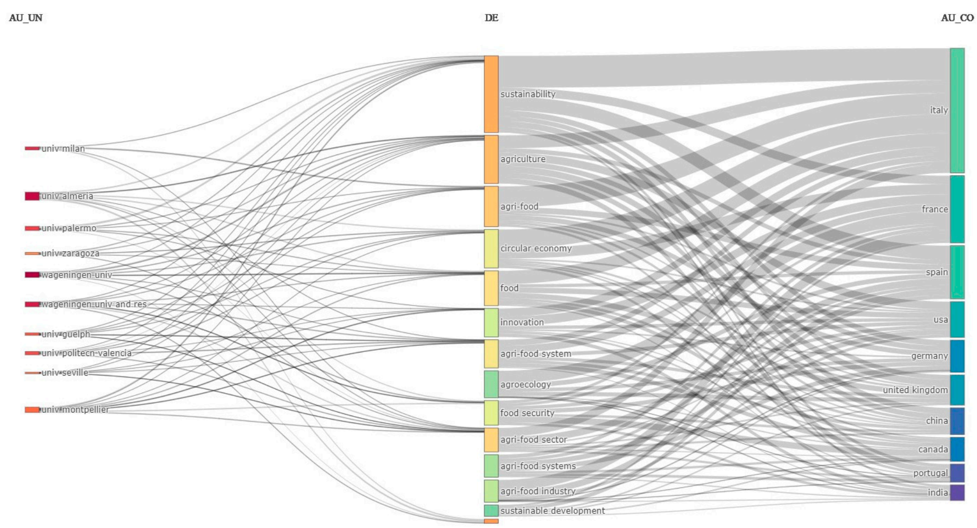

Figure 6. Three-field plot of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024. Legend: key-word authors (DE), institutions (AU_UN), countries (AU_CO).

3.3. Scientific Collaboration Between Countries

The contribution and scientific collaboration—in the agri-food sector—of the main countries over the last 46 years are shown in Figure 7, with the publications identified in two types: Single-Country Publications (SCPs), publications by authors from a single nation, and Multiple-Country Publications (MCPs), publications by authors from different countries. This distinction allows us to assess international cooperation and the role of each country in global scientific production.

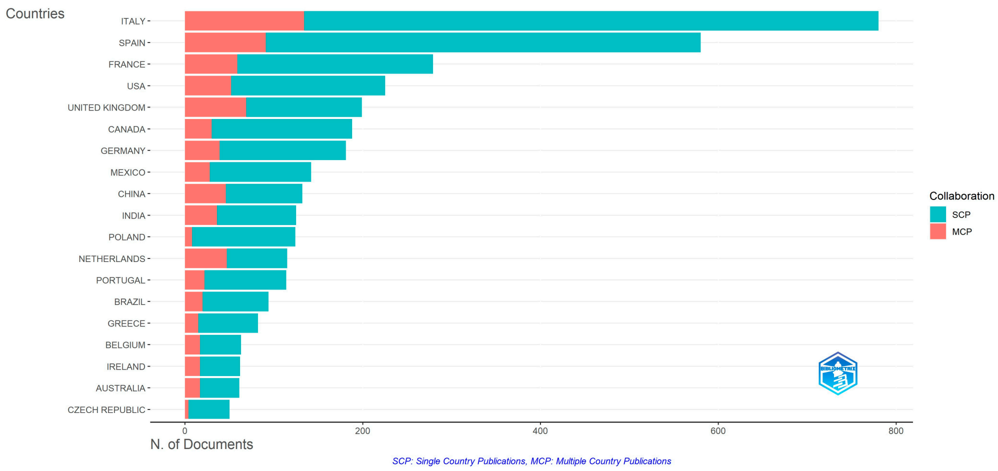

Figure 7. The countries of the authors of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

Table 1 presents the number of papers, SCPs, MCPs, total publication rates (frequency), and proportion of collaborations (MCP ratio), defined as the ratio between MCP documents and the total number of papers (SCP + MCP).

Table 1. Publications and corresponding authorships of scientific production in the agri-food sector—1977 to 2024.

Country	Number of Papers	Frequency	SCPs	MCPs	MCP Rate
Italy	780	0.152	646	134	0.172
Spain	580	0.113	489	91	0.157
France	279	0.054	564	3	0.005
USA	225	0.044	220	59	0.211
UK	199	0.039	173	52	0.231
Canada	188	0.037	130	69	0.347
Germany	181	0.035	158	30	0.16
Mexico	142	0.028	142	39	0.215
China	132	0.026	114	28	0.197
India	125	0.024	86	46	0.348
Poland	124	0.024	89	36	0.288
Netherlands	115	0.022	116	8	0.065
Portugal	114	0.022	68	47	0.409
Brazil	94	0.018	92	22	0.193
Greece	82	0.016	74	20	0.213
Belgium	63	0.012	67	15	0.183
Ireland	62	0.012	46	17	0.27
Australia	61	0.012	45	17	0.274
Czech Republic	50	0.01	44	17	0.279
Romania	45	0.009	46	4	0.08

Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

Figure 8 shows the central countries that collaborated in research in the agri-food sector.

Figure 8. Collaboration map of scientific production (between countries) in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

Table 2 shows the direction and frequency of collaboration between countries for research in the agri-food sector. Countries that had a minimum of 10 collaborations were considered.

Table 2. Direction and frequency of collaboration between countries regarding scientific production in the agri-food sector from 1977 to 2024.

From	To	Frequency
Italy	Spain	47
Italy	France	45
Italy	United Kingdom	38
United Kingdom	Netherlands	29
Italy	Netherlands	28
Germany	Netherlands	27
Italy	Germany	27
Italy	USA	27
Spain	France	26
Spain	Portugal	26
Italy	Belgium	25
USA	United Kingdom	23
USA	China	21
USA	Canada	20
France	United Kingdom	19
Netherlands	Belgium	19
United Kingdom	China	18
USA	India	18
France	Netherlands	17
Spain	United Kingdom	17
France	USA	15
United Kingdom	Ireland	15
Germany	Switzerland	14
Italy	Portugal	14
Spain	Germany	14
United Kingdom	Belgium	14
United Kingdom	India	14
USA	Netherlands	14

Table 2. *Cont.*

From	To	Frequency
France	Belgium	13
France	Canada	13
France	Germany	13
Spain	Mexico	13
United Kingdom	Australia	13
United Kingdom	Germany	13
France	Tunisia	12
Italy	Austria	12
Spain	USA	12
United Kingdom	Brazil	12
USA	Kenya	12
China	Australia	11
France	Portugal	11
Germany	Belgium	11
Italy	China	11
USA	Mexico	11
Germany	Austria	10
Italy	Switzerland	10
Netherlands	Chile	10
Netherlands	Switzerland	10
Spain	Brazil	10
Spain	Chile	10
Spain	Ireland	10
Usa	Belgium	10

Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

3.4. Most Relevant Sources

The documents analyzed—5141 papers in the agri-food sector—were published in 1737 journals. Figure 9 shows the ten journals that published the most research on this topic.

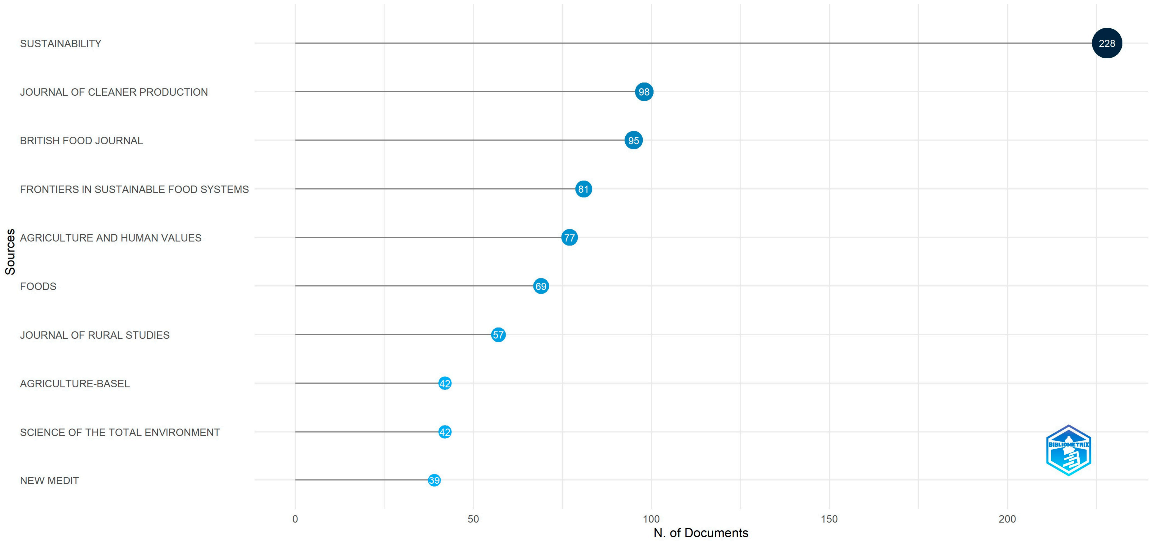

Figure 9. Most relevant sources of scientific production in the agri-food sector—1977 to 2024. Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

Table 3 shows the impact of the sources, considering the h-index of the journals, the total number of citations of papers in the agri-food sector published in these journals (TC), and the number of documents published (NP). Data on the number of citations were obtained from the Web of Science and Scopus databases and subsequently compiled and analyzed using RStudio and Bibliometrix Rpackage. Table 3 also includes the 20 most prominent journals based on combining these three metrics. The h-index is an academic impact metric that refers to the relevance of publications by a given author or a specific journal [31]. This metric is valued and recognized in academia, and it has become a valuable tool for comparing the impact of research [38] and journals [31].

Table 3. Source impact of scientific production in the agri-food sector—1977 to 2024.

Element	h-Index	TC	NP
Sustainability	37	4347	228
Journal of Cleaner Production	36	3982	98
Agriculture and Human Values	23	2243	77
Journal of Rural Studies	21	1804	57
Trends in Food Science & Technology	19	1585	26
Sociologia Ruralis	15	1418	30
Science of the Total Environment	20	1402	42
Food Policy	13	1370	27
British Food Journal	20	1334	95
Bioresource Technology	8	1169	8
Agronomy for Sustainable Development	15	1155	21
Journal of The Science of Food and Agriculture	10	1025	16
Journal of Peasant Studies	15	955	22
Agroecology and Sustainable Food Systems	13	952	29
Foods	17	900	69
Journal of Environmental Management	16	855	24
Food and Bioprocess Technology	10	820	10
Applied Sciences-Basel	12	775	28
Food Security	12	773	16
Nanotechnology, Science and Applications	1	739	1

Source: own elaboration using RStudio, Bibliometrix Rpackage, and Excel software 2016, 2024.

4. Discussion

The results of this study provide information on the diversity and evolution of research in the agri-food sector over the last four decades. The analysis revealed significant publication growth, especially since 2012 (Figure 2). Between 1977 and 1994, scientific production was stable and relatively low. From 1995 onwards, there was an increase in scientific production on the subject, becoming exponential after 2012. The peak of production occurred in 2022, with 703 documents published. The average annual growth rate in the period was 23%.

The research topics were analyzed using the analysis procedures of keyword co-occurrence analysis, thematic evolution, thematic analysis, and three-field plots. In the procedures of keyword co-occurrence analysis and thematic analysis, the metrics betweenness centrality, closeness centrality, and PageRank were evaluated.

The analysis of the co-occurrence network (Figure 3) reveals the importance of sustainability, agriculture, and agri-food in cluster 1 and agri-food system, food security, and agroecology in cluster 2. These two clusters are the most relevant of the entire network, comprising six clusters. Cluster 1, with 26 nodes, is the main one; cluster 2, with 19 nodes, is equally relevant. Clusters 3, 4, 5, and 6 comprise only one node each: polyphenols, antioxidant activity, bioactive compounds, and antioxidants, respectively.

The analysis of betweenness centrality (Table S1) shows that sustainability (betweenness = 218.37164), the circular economy (betweenness = 167.82183), and agriculture (betweenness = 133.62723) are themes strongly connected to other research themes. They function as a link or "bridge" between several studies, evidencing their relevance.

The closeness centrality analysis (Table S1) reveals that the themes sustainability (closeness = 0.01851), agriculture (closeness = 0.01724), and food (closeness = 0.01612) occupy a central position in the network.

The PageRank analysis (Table S1) found that sustainability (0.09229), agriculture (0.07870), and agri-food systems (0.05608) have the most significant connections and are, therefore, the most influential in the network.

The thematic evolution graph (Figure 4) shows dominant themes in research in the agri-food sector in two distinct periods, from 1977 to 2021 and from 2022 to 2024. From 1977 to 2021, the most researched themes were agriculture, antioxidants, valorization, and agri-food systems. In 2022–2024, the predominant themes were bioactive compounds, the circular economy, sustainability, and agri-food systems. The first period is the most fragmented, with a greater variety of themes, and in the second period, these themes condensed, reflecting a greater emphasis on issues related to sustainability, the circular economy, and the environment. More precisely, the analysis of thematic evolution allows for identifying themes that stood out in an initial period and that, over time, were incorporated into themes that became more prominent in the most recent period. This dynamic reveals how research areas connect and transform as discoveries and interactions emerge. It is possible to identify, for example, that study topics such as agriculture, competitiveness, food safety, and life cycle assessment have become strongly associated with studies on sustainability in the most recent period. In this case, it is revealed that sustainability has gained prominence in the current scenario.

Using the thematic map (Figure 5), the driving themes, niche themes, themes that behave as emerging or declining, and basic and transversal themes were identified. This identification allows an analysis of research dynamics, highlighting how specific themes are developing or losing relevance while revealing interrelationships between themes that may indicate future trends.

In quadrant Q1 (motor themes), there are two clusters: cluster 4, composed of three nodes, polyphenols, bioactive compounds, and antioxidants; and cluster 5, which is more robust, consisting of 21 nodes, with emphasis on food safety, blockchain, and traceability nodes. The position of these clusters reflects high centrality and density (Table S3), which indicates strong cohesion and correlation between the research. This condition suggests that these themes are mature, well developed, and essential for the area, even though the number of publications is moderate.

Quadrant Q2 (niche themes) is composed of cluster 6 and cluster 8, both with only one node, antioxidant and nanotechnology, respectively. These clusters' low centrality and high density (Table S3) indicate that they are well-defined topics with little general relevance but well developed for specific audiences and small interest groups. The small number of publications reinforces this niche character.

In quadrant Q3 (emerging or declining themes) is cluster 2, with the node antioxidant activity, and cluster 3, with the nodes circular economy, food waste, and valorization. These clusters have low density and centrality (Table S3), showing potential for growth, especially cluster 3, which has a moderate number of publications and is approaching Q4, suggesting a possible transition to essential themes in the future.

In quadrant Q4 (basic themes), cluster 1 (30 nodes) and cluster 5 (23 nodes) are used. In cluster 1, the nodes sustainability, agri-food, and agri-food sector stand out, while in cluster 5, the nodes agri-food system, agriculture, and food security stand out. The clusters in this quadrant have high centrality (importance) and low density (development) (Table S3). These themes are considered essential and transversal and represent the basis for research in the agri-food sector. The research themes in this quadrant are considered relevant but still under development. Cluster 5 is very close to the transition line to quadrant 1 (motor themes), indicating the potential to become a motor theme.

The analysis specifically directed to the nodes (themes of each cluster) verifies that some themes are highlighted in the three metrics: betweenness centrality, closeness centrality, and PageRank (Table S2). The themes that stand out are sustainability (betweenness centrality = 1381.560279, closeness centrality = 0.002132196, PageRank = 0.042749648), agriculture (betweenness centrality = 1337.212284, closeness centrality = 0.002207506, PageRank = 0.03842499), and food (betweenness centrality = 1269.779501, closeness centrality = 0.002114165, PageRank = 0.02410805). These three themes simultaneously occupy the central position of the network (closeness centrality), the bridge position (betweenness centrality), and the prominent position in PageRank, which gives influence and relevance to the themes in their academic or research context. Nodes with these characteristics influence the flow of the system [39] and the connection between other subjects [40]. These nodes have the most significant connections; they are the most influential nodes [41]. The values for betweenness centrality, closeness centrality, and PageRank of all themes can be seen in Table S2 in the Supplementary Material.

The thematic map showed that sustainability, agriculture, and food are central themes that are more consolidated and developed. However, it also showed that new and important research topics exist, such as polyphenols, bioactive compounds, antioxidants, food safety, blockchain, and traceability. These topics are essential for structuring the area, driving the advancement of research, and highlighting relevant trends in the field.

The main trends in the agri-food sector reflect a convergence towards the importance of technological advancement, sustainability, and global challenges. The growing relevance of food safety, traceability, and bioactive compounds points to innovations that meet the demand for safe, nutritious, and high-quality food, even with climate change and increasing urbanization [5,42–44]. Industry 4.0 technologies, such as artificial intelligence, big data, blockchain, and 3D printing, emerge as pillars to face these challenges, promoting greater efficiency in the production chain, reducing waste, and increasing transparency [5,8,9,45–48]. In addition, the sustainable intensification of livestock production and the development of resilient agricultural practices are essential to ensure global food security [1,3,4]. The trends indicate a sector in transformation, driven by the integration of technological solutions and sustainable practices, focusing on meeting population demands and mitigating environmental impacts.

The Sankey diagram (Figure 6) highlights the interactions between research institutions, the most frequently used search terms, and the countries involved. In the left column, the research institutions are listed, with the University of Almeria, Wageningen University, and the University of Montpellier as the most connected. The most frequently used terms are listed in the central column, with sustainability, agriculture, and agri-food leading the field. In particular, sustainability has been the most researched topic and reflects a growing concern with environmental issues, indicating a trend of studies in this area. In the right column, the last element represents the countries with the highest research volume, with Italy, France, and Spain, members of the European Union (EU), standing out. This interest may be associated with the fact that the food and beverage industry is the most prominent representative of the EU manufacturing sector in terms of employment and value added, with a significant trade surplus. In the last 10 years, EU food and beverage exports have doubled in value, reaching EUR 182 billion [49], demonstrating a very significant market and justifying the increase in research on the subject. These connections indicate academic interest and economic and environmental relevance, potentially stimulating new research.

With the analysis of the corresponding authors (Figure 7 and Table 1), it was found that the majority of researchers on the subject are from Italy (780 papers, 646 SCPs and 134 MCPs), followed by researchers from Spain (580 papers, 489 SCPs and 91 MCPs) and France (279 papers, 220 SCPs and 59 MCPs). Although these countries lead in scientific production (Italy: 15.2%, Spain: 11.3%, and France: 5.4%), the UK surpasses France in the number of absolute international collaborations (MCPs).

An MCP rate above 50% reflects more robust collaborations, bringing benefits such as infrastructure and knowledge sharing [50]. Based on this indication, it would be interesting for countries to maintain rates above 50% when analyzing the MCP ratio. However, this is not the reality among the most productive countries (Table 1).

In scientific collaboration between countries, it is observed that there are 3280 partnerships around the world (Figure 8 and Table 2). In this criterion, Italy and Spain stand out with 47 collaborative productions. In addition, the data show a solid relationship between Italy and France, with 45 collaborations (Table 2), and Italy and the UK, with 38 collaborations (Table 2). Figure 7 also reveals significant interactions between other European countries, highlighting the collaborative solid network in the region.

As for the primary sources, a plurality of journals address the topic, with 1737 different sources (Figure 9), with emphasis on *Sustainability*, the *Journal of Cleaner Production*, and the *British Food Journal*. MDPI's *Sustainability* is an open-access journal that covers sustainability in environmental, cultural, economic, and social dimensions [51], while Elsevier's *Journal of Cleaner Production* addresses cleaner production and environmental issues [52]. The *British Food Journal* is the third most relevant, exploring interdisciplinary themes in the food industry [53].

The disparity in publication volume between the most prominent journal, *Sustainability*, and the other journals (Figure 9) can be attributed to two main factors. The first concerns the journals' editorial policies, which can be classified as open-access and subscription journals. Open-access journals prioritize a higher volume of publications as a strategy to expand their visibility and reach a wider global audience [54,55], and this type of editorial policy may be a factor indicative of *Sustainability*'s large publication volume. The second factor is related to the thematic flexibility of these journals. *Sustainability* has a broad scope, addressing sustainability from several dimensions, such as economic, social, environmental, and cultural. As a multidisciplinary journal, it accepts papers from different areas, including social sciences, public policy, technology, and education. The *Journal of Cleaner Production*, which ranks second in the volume of publications on the topic, has a hybrid editorial policy, offering open-access and subscription options. Although also interdisciplinary, this journal has a narrower focus, concentrating on clean production, the circular economy, and strategies to mitigate environmental impacts in industrial processes and production systems. This approach may be limiting for authors whose work deals with sustainability more broadly.

Among the ten journals with the largest volume of publications in the agri-food sector, the following have open-access editorial policies: *Sustainability*, *Frontiers in Sustainable Food Systems*, and *Foods and Agriculture-Basel*. The *Journal of Cleaner Production*, the *British Food Journal*, *Agriculture and Human Values*, the *Journal of Rural Studies*, *Science of the Total Environment*, and *New Medit* operate under a hybrid model, offering open-access and subscription options.

The total number of citations was used as a metric to assess the impact of sources (Table 3). The journals that stood out most in citations of papers in the agri-food sector were *Sustainability* (4347 citations in 228 documents), the *Journal of Cleaner Production* (3982 citations in 98 documents), and *Agriculture and Human Values* (2243 citations in 77 documents). These journals also have high relevance in terms of the h-index. *Sustainability* has an h-index of 37, the *Journal of Cleaner Production* has an h-index of 36, and *Agriculture and Human Values* has an h-index of 23, evidencing their importance for research in the agri-food sector. These findings align with the findings of Miranda and Garcia-Carpintero [56], who highlight the predominance of publications in the first quartile among citations in the Scopus database, evidencing the relevance of the impact factor.

5. Conclusions

This study comprehensively analyzes trends and gaps in the agri-food sector over the past 47 years, highlighting its evolution and growing relevance in the global scientific agenda. The results reveal a significant increase in academic production and the consolidation of central themes, such as sustainability, the circular economy, and agri-food systems, which occupy strategic positions in the research network.

In addition, emerging topics of great relevance were identified, such as bioactive compounds, food safety, and blockchain, which point to new opportunities for research and technological innovation. These findings highlight the need to integrate digital solutions and sustainable practices to address complex challenges such as climate change, food security, and resource management.

Regarding the methodological limitations of this study, the papers were extracted from only two databases, which may have excluded relevant works from other sources. In addition, only papers were included, excluding conference papers, book chapters, and other formats, which, although less relevant to impact research, may raise essential questions. The data were extracted from the Scopus and WoS databases, the world's two most critical scientific databases, to overcome the reported limitations.

The bibliometric analysis enabled the mapping of the leading scientific contributions. It also offered concrete future research directions, emphasizing strategies combining productivity and sustainability in the agri-food sector. Despite methodological limitations, such as the exclusion of alternative data sources, this study provides a robust and guiding overview for academics, policymakers, and professionals in the sector.

By advancing the integration of Industry 4.0 technologies and sustainable practices, the agri-food sector can consolidate its role as an essential pillar for global food security and sustainable economic development. Emerging topics, such as food waste and the circular economy, must be better explored. Regarding Industry 4.0 technologies, blockchain, and traceability, the studies need to be explored better because they drive themes in this research area. Thus, this work is a basis for further analysis and fostering collaborations that drive scientific and technological progress.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/metrics2010003/s1, Table S1: Keyword co-occurrence analysis; Table S2: Thematic map themes; Table S3: Thematic map clusters.

Author Contributions: Conceptualization, J.R.H.C. and M.R.d.O.; methodology, J.R.H.C. and M.R.d.O.; software, J.R.H.C. and M.R.d.O.; validation, J.R.H.C., M.R.d.O. and L.A.P.; formal analysis, J.R.H.C., M.R.d.O. and L.A.P.; investigation, J.R.H.C. and M.R.d.O.; resources, J.R.H.C., M.R.d.O. and L.A.P.; data curation, J.R.H.C. and M.R.d.O.; writing—original draft preparation, J.R.H.C. and M.R.d.O.; writing—review and editing, J.R.H.C., M.R.d.O., L.A.P. and T.B.d.S.; visualization, J.R.H.C. and M.R.d.O.; supervision, J.R.H.C.; project administration, J.R.H.C. and M.R.d.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author(s).

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Kumar, L.; Chhogyel, N.; Gopalakrishnan, T.; Hasan, M.K.; Jayasinghe, S.L.; Kariyawasam, C.S.; Kogo, B.K.; Ratnayake, S. Chapter 4—Climate change and future of agri-food production. In *Future Foods*; Bhat, R., Ed.; Academic Press: Cambridge, MA, USA, 2022; pp. 49–79.
2. Webb, R.; Buratini, J. Global challenges for the 21st century: The role and strategy of the agri-food sector. *Anim. Reprod.* **2016**, *13*, 133–142. [CrossRef]
3. Akanmu, A.O.; Akol, A.M.; Ndolo, D.O.; Kutu, F.R.; Babalola, O.O. Agroecological techniques: Adoption of safe and sustainable agricultural practices among the smallholder farmers in Africa. *Front. Sustain. Food Syst.* **2023**, *7*, 1143061. [CrossRef]
4. Shah, F.; Wu, W. Soil and Crop Management Strategies to Ensure Higher Crop Productivity within Sustainable Environments. *Sustainability* **2019**, *11*, 1485. [CrossRef]
5. Lei, M.; Xu, L.; Liu, T.; Liu, S.; Sun, C. Integration of Privacy Protection and Blockchain-Based Food Safety Traceability: Potential and Challenges. *Foods* **2022**, *11*, 2262. [CrossRef]
6. Juan Manuel, V.-C.; Brambila-Paz, J.J.; Verónica, P.-C.; Rojas-Rojas, M.M.; María del Carmen, L.-R.; José Miguel, O.-S. Trends in science, technology, and innovation in the agri-food sector. *Tapuya Lat. Am. Sci. Technol. Soc.* **2022**, *5*, 2115829. [CrossRef]
7. Camanzi, L.; Troiano, S. The evolutionary transformation of modern agri-food systems: Emerging trends in consumption, production, and in the provision of public goods. *Agric. Food Econ.* **2021**, *9*, 24. [CrossRef]
8. Misra, N.N.; Dixit, Y.; Al-Mallahi, A.; Bhullar, M.S.; Upadhyay, R.; Martynenko, A. IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry. *IEEE Internet Things J.* **2022**, *9*, 6305–6324. [CrossRef]
9. Torky, M.; Hassanein, A.E. Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges. *Comput. Electron. Agric.* **2020**, *178*, 105476. [CrossRef]
10. Borsellino, V.; Schimmenti, E.; Hamid El, B. Agri-Food Markets towards Sustainable Patterns. *Sustainability* **2020**, *12*, 2193. [CrossRef]
11. Debesh, M.; Muduli, K.; Lukas, S.; Sujoy Kumar, J.; Manidatta, R. Combating of Associated Issues for Sustainable Agri-Food Sectors. *Sustainability* **2023**, *15*, 10096. [CrossRef]
12. Yadav, S.; Malik, K.; Moore, J.M.; Kamboj, B.R.; Malik, S.; Malik, V.K.; Arya, S.; Singh, K.; Mahanta, S.; Bishnoi, D.K. Valorisation of Agri-Food Waste for Bioactive Compounds: Recent Trends and Future Sustainable Challenges. *Molecules* **2024**, *29*, 2055. [CrossRef] [PubMed]
13. Guía-García, J.L.; Charles-Rodríguez, A.V.; Reyes-Valdés, M.H.; Ramírez-Godina, F.; Robledo-Olivo, A.; García-Osuna, H.T.; Cerqueira, M.A.; Flores-López, M.L. Micro and nanoencapsulation of bioactive compounds for agri-food applications: A review. *Ind. Crops Prod.* **2022**, *186*, 115198. [CrossRef]
14. Kotsanopoulos, K.V.; Arvanitoyannis, I.S. The Role of Auditing, Food Safety, and Food Quality Standards in the Food Industry: A Review. *Compr. Rev. Food Sci. Food Saf.* **2017**, *16*, 760–775. [CrossRef]
15. Magnan, A. The financialization of agri-food in Canada and Australia: Corporate farmland and farm ownership in the grains and oilseed sector. *J. Rural Stud.* **2015**, *41*, 1–12. [CrossRef]

16. Tarek Ben, H.; Hamid El, B.; Mohammed, A.-M. Agri-Food Markets in Qatar: Drivers, Trends, and Policy Responses. *Sustainability* **2020**, *12*, 3643. [CrossRef]
17. Marsden, T.; Moragues Faus, A.; Sonnino, R. Reproducing vulnerabilities in agri-food systems: Tracing the links between governance, financialization, and vulnerability in Europe post 2007–2008. *J. Agrar. Chang.* **2019**, *19*, 82–100. [CrossRef]
18. Papaioannou, G.; Mohammed, A.-M.; Despoudi, S.; Saridakis, G.; Papadopoulos, T. The role of adverse economic environment and human capital on collaboration within agri-food supply chains. *Int. J. Inf. Manag.* **2020**, *52*, 102077. [CrossRef]
19. Pilatti, L.A.; Herrera Cantorani, J.R.; Cechin, M.R. Cómo desarrollar la estructura IMRaD en el artículo original (How to develop the IMRaD structure in original paper). *Retos* **2023**, *49*, 914–925. [CrossRef]
20. Valtakoski, A. The evolution and impact of qualitative research in Journal of Services Marketing. *J. Serv. Mark.* **2020**, *34*, 8–23. [CrossRef]
21. Donthu, N.; Kumar, S.; Mukherjee, D.; Pandey, N.; Lim, W.M. How to conduct a bibliometric analysis: An overview and guidelines. *J. Bus. Res.* **2021**, *133*, 285–296. [CrossRef]
22. Pattnaik, D.; Kumar, S.; Burton, B. Thirty Years of The Australian Accounting Review: A Bibliometric Analysis. *Aust. Account. Rev.* **2021**, *31*, 150–164. [CrossRef]
23. Aria, M.; Cuccurullo, C. bibliometrix: An R-tool for comprehensive science mapping analysis. *J. Informetr.* **2017**, *11*, 959–975. [CrossRef]
24. Taqi, M.; Gurkaynak, N.; Gençer, M. Marketing concept evolution: A bibliometrics co-occurrence analysis. *Mark. Manag. Innov.* **2019**, *2*, 185–197. [CrossRef]
25. Donthu, N.; Kumar, S.; Ranaweera, C.; Pattnaik, D.; Gustafsson, A. Mapping of Journal of Services Marketing themes: A retrospective overview using bibliometric analysis. *J. Serv. Mark.* **2022**, *36*, 340–363. [CrossRef]
26. Mukhtar, M.F.; Anuar, S.H.H.; Abas, Z.A.; Hussin, M.S.F.; Sulaiman, S.A. Bibliometric Analysis of the Global Trend in Centrality Measures. *Int. J. Acad. Res. Bus. Soc. Sci.* **2024**, *14*, 1078–1098. [CrossRef] [PubMed]
27. Zhong, X.; Liu, J.; Gao, Y.; Wu, L. Analysis of co-occurrence toponyms in web pages based on complex networks. *Phys. A Stat. Mech. Appl.* **2017**, *466*, 462–475. [CrossRef]
28. Kumar, A.; Singh, R.K.; Singh, D. Supply chain resilience in developing countries: A bibliometric analysis and future research directions. *Benchmarking* **2024**, *31*, 2217–2238. [CrossRef]
29. Helal, M.A.; Anderson, N.; Wei, Y.; Thompson, M. A Review of Biomass-to-Bioenergy Supply Chain Research Using Bibliometric Analysis and Visualization. *Energies* **2023**, *16*, 1187. [CrossRef]
30. Katakidis, A.; Kodonas, K. A scientometric, bibliometric, and thematic map analysis of hydraulic calcium silicate root canal sealers. *Restor. Dent. Endod.* **2023**, *48*, e41. [CrossRef] [PubMed]
31. Cantorani, J.R.H.; Oliveira, M.R.d. Forty-five years of disability and rehabilitation research: Review of the journal Disability and Rehabilitation through bibliometric analysis. *Disabil. Rehabil.* **2024**, *46*, 1–15. [CrossRef]
32. Zheng, J.; Gu, Y.; Li, P.; Luo, L.; Wu, G. Research evolution and thematic breakthroughs in project leadership: A bibliometric analysis. *Eng. Constr. Archit. Manag.* **2023**. *ahead-of-print*. [CrossRef]
33. Tatlıyer Tunaz, A. Bibliometric analysis of quantitative genetics research in animal science in the last decade. *Mustafa Kemal Üniversitesi Tarım Bilim. Derg.* **2023**, *28*, 363–378. [CrossRef]
34. Agbo, F.J.; Oyelere, S.S.; Suhonen, J.; Tukiainen, M. Scientific production and thematic breakthroughs in smart learning environments: A bibliometric analysis. *Smart Learn. Environ.* **2021**, *8*, 1. [CrossRef]
35. Lupton, R.C.; Allwood, J.M. Hybrid Sankey diagrams: Visual analysis of multidimensional data for understanding resource use. *Resour. Conserv. Recycl.* **2017**, *124*, 141–151. [CrossRef]
36. Rusydiana, A.S. Bibliometric analysis of journals, authors, and topics related to covid-19 and islamic finance listed in the dimensions database by biblioshiny. *Sci. Ed.* **2021**, *8*, 72–78. [CrossRef]
37. Koo, M. Systemic Lupus Erythematosus Research: A Bibliometric Analysis over a 50-Year Period. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7095. [CrossRef]
38. Hassan, W.; Duarte, A.E. Bibliometric analysis: A few suggestions. *Curr. Probl. Cardiol.* **2024**, *49*, 102640. [CrossRef] [PubMed]
39. Makkizadeh, F.; Sa'adat, F. Bibliometric and thematic analysis of articles in the field of infertility (2011–2015). *Int. J. Reprod. BioMed.* **2017**, *15*, 719–728. [CrossRef] [PubMed]
40. Marteleto, R.M. Análise de redes sociais—Aplicação nos estudos de transferência da informação. *Cienc. Inf.* **2001**, *30*, 71–81. [CrossRef]
41. Zhang, P.; Wang, T.; Yan, J. PageRank centrality and algorithms for weighted, directed networks. *Phys. A Stat. Mech. Appl.* **2022**, *586*, 126438. [CrossRef]
42. Wallace, C.A.; Sperber, W.H.; Mortimore, S.E. *Food Safety for the 21st Century: Managing HACCP and Food Safety Throughout the Global Supply Chain*; Wiley: Hoboken, NJ, USA, 2018.

43. Qian, J.; Wu, W.; Yu, Q.; Ruiz-Garcia, L.; Xiang, Y.; Jiang, L.; Shi, Y.; Duan, Y.; Yang, P. Filling the trust gap of food safety in food trade between the EU and China: An interconnected conceptual traceability framework based on blockchain. *Food Energy Secur.* **2020**, *9*, e249. [CrossRef]
44. Lin, X.; Chang, S.-C.; Chou, T.-H.; Chen, S.-C.; Ruangkanjanases, A. Consumers' Intention to Adopt Blockchain Food Traceability Technology towards Organic Food Products. *Int. J. Environ. Res. Public Health* **2021**, *18*, 912. [CrossRef]
45. Pandey, P.C.; Pandey, M. Highlighting the role of agriculture and geospatial technology in food security and sustainable development goals. *Sustain. Dev.* **2023**, *31*, 3175–3195. [CrossRef]
46. Hassoun, A.; Boukid, F.; Pasqualone, A.; Bryant, C.J.; García, G.G.; Parra-López, C.; Jagtap, S.; Trollman, H.; Cropotova, J.; Barba, F.J. Emerging trends in the agri-food sector: Digitalisation and shift to plant-based diets. *Curr. Res. Food Sci.* **2022**, *5*, 2261–2269. [CrossRef]
47. Tapia-Quirós, P.; Montenegro-Landívar, M.F.; Reig, M.; Vecino, X.; Cortina, J.L.; Saurina, J.; Granados, M. Recovery of Polyphenols from Agri-Food By-Products: The Olive Oil and Winery Industries Cases. *Foods* **2022**, *11*, 362. [CrossRef]
48. Gutiérrez-Del-Río, I.; López-Ibáñez, S.; Magadán-Corpas, P.; Fernández-Calleja, L.; Pérez-Valero, Á. Terpenoids and Polyphenols as Natural Antioxidant Agents in Food Preservation. *Antioxidants* **2021**, *10*, 1264. [CrossRef] [PubMed]
49. European Comission. The Agri-Food Industrial Ecosystem. Available online: https://single-market-economy.ec.europa.eu/sectors/agri-food-industrial-ecosystem_en (accessed on 1 November 2024).
50. Dusdal, J.; Powell, J.J.W. Benefits, Motivations, and Challenges of International Collaborative Research: A Sociology of Science Case Study. *Sci. Public Policy* **2021**, *48*, 235–245. [CrossRef]
51. MDPI. Sustainability—About. Available online: https://www.mdpi.com/journal/sustainability/about (accessed on 10 November 2024).
52. Elsevier. Journal of Cleaner Production. Available online: https://www.sciencedirect.com/journal/journal-of-cleaner-production (accessed on 10 November 2024).
53. Emerald Publishing. British Food Journal (BFJ). Available online: https://www.emeraldgrouppublishing.com/journal/bfj (accessed on 10 November 2024).
54. Gasparyan, A.; Yessirkepov, M.; Voronov, A.; Koroleva, A.; Kitas, G. Comprehensive Approach to Open Access Publishing: Platforms and Tools. *J. Korean Med. Sci.* **2019**, *34*, e184. [CrossRef] [PubMed]
55. Momeni, F.; Mayr, P.; Fraser, N.; Peters, I. What happens when a journal converts to open access? A bibliometric analysis. *Scientometrics* **2021**, *126*, 9811–9827. [CrossRef]
56. Miranda, R.; Garcia-Carpintero, E. Comparison of the share of documents and citations from different quartile journals in 25 research areas. *Scientometrics* **2019**, *121*, 479–501. [CrossRef]