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a bibliometric review

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Review

Exploring Food Supply Chain Trends in the COVID-19 Era: A Bibliometric Review

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Abstract: Recently, the food supply chain (FSC) has been severely disrupted due to the COVID-19 pandemic, putting the vital flow of food products from farmers and producers to the ultimate consumers at risk. Furthermore, due to the pandemic, several food organizations have been prompted to rethink their strategies for the future. Although the literature on FSC research in the COVID-19 era is increasing, no attempt has been made to summarize this stream of research using bibliometric techniques. This paper fills this knowledge gap and looks at the current scholarly discourse around the FSC and COVID-19. Applying bibliometric techniques, 287 journal articles were extracted from Scopus and analyzed to determine the temporal evolution of FSC research, the most productive journals, researchers, countries, and the most relevant keywords and publications. To construct a keyword co-occurrence network and categorize the relevant literature, we used the computer program VOSviewer. The findings demonstrate the rapid expansion of FSC research during the COVID-19 pandemic. In addition, the top authors, publications, and nations for scientific output were also determined. Keyword co-occurrence network and detailed qualitative analysis both illustrate that FSC research revolves around six main themes: the impact of COVID-19 on the FSC and agriculture, FSC resilience, food waste and insecurity, fisheries and aquaculture, blockchain technology, and governance and innovation. This study represents the first effort to map worldwide FSC research in the COVID-19 era and draw on a comprehensive collection of journal articles and bibliometric approaches. It offers academics, practitioners, and decision-makers a snapshot of the state of the art in the FSC field and points to where further research is needed.

Keywords: food supply chain; food waste; food security; COVID-19; bibliometric

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1. Introduction

In recent decades, infectious diseases have posed significant challenges, particularly since the onset of the COVID-19 pandemic at the start of 2020 [1,2]. As of late 2019, when it was first detected in Wuhan, China, COVID-19 had claimed around six lives worldwide [3]. The World Health Organization (WHO) named it a new coronavirus illness due to the speed and intensity with which the virus spread worldwide. Without any question, the economic crisis caused by the COVID-19 pandemic has led to a global recession, the likes of which the world has not experienced since the Second World War. The scale of the effect is considerable, owing to globalization [4]. Many importing nations depend on food exporters to provide crucial food products [5]. As the severity of COVID-19 rises, food supply chain (FSC) disruptions are expected to be a catastrophe that will surpass the infectious virus [6–8].

A balanced diet constitutes a primordial source of sustenance and is required to provide the body with appropriate nutrients in order to increase resilience against illnesses. Healthy nutrition includes micronutrients [9] that can be obtained by balancing the consumption of animal-based and plant diets [10]. However, recent research in several countries (e.g., the United Kingdom, Greece, and Chile) indicated that individuals consumed more ultra-processed food products, i.e., those with a high concentration of sugars, fats, and salts during the pandemic [11]. Moreover, due to the global economic slowdown, low-income families are challenged by the difficulty of buying healthy and nutritious food products, which calls for social measures and protections [12].

Before COVID-19, developing nations already struggled with unstable and fragile FSC. For instance, Nordhagen et al. [13] estimates that one in three persons suffers from malnutrition, and one in nine people experiences starvation. These consequences are particularly pronounced in Africa and Asia [14–16]. The FSC disruptions and food scarcity directly affect the health and well-being of one-third of the global population.

To facilitate the containment of the coronavirus, authorities across the globe limited human-to-human contact and controlled social distance [17–19]. Such actions strained the midstream and downstream segments of the FSC, resulting in a total disruption [20]. The intermediary market actors play a major role in food distribution, especially in highly populated regions in Asia, whereby they are accountable for the marketability of food products and manage transaction costs made up of logistics activities [21–23]. Marketplaces were closed to prevent the transmission of the virus during the pandemic [20]. In addition to the absence of sellers and buyers, wholesale markets, cold storage facilities, and vegetable stores suffered from labor shortages and were consequently unable to load and unload food deliveries. The FSC disruption is mostly attributable to coercive limits on movement and the unprecedented shutdowns of borders [24].

In the past two years, the literature on the impact of COVID-19 on the FSC has increased significantly; however, a bibliometric study of the FSC trends in the COVID-19 era is lacking. Unlike traditional reviews, a bibliometric analysis enables researchers to structure, summarize, and quantitatively assess a particular domain's development using several publications [25]. Moreover, applying bibliometrics as a quantitative method ensures a non-predetermined and objective examination of an academic field [26]. Furthermore, bibliometric approaches permit the analysis of a vast array of textual resources; they are more data-driven and hence less biased [27]. The recent works by Erboz et al. [28] and Cordeiro et al. [29] have applied bibliometrics to analyze the general impact of pandemics and COVID-19 on supply chains without focusing on the FSC. As a result, this study focuses on a bibliometric analysis of COVID-19 and the FSC domain to better understand the bibliometric profile of FSC research, the main themes emerging from the literature, and future research directions. Consequently, the value of this work is to offer a timely review of FSC research in the COVID-19 era by employing a bibliometric analysis.

Addressing the aforementioned research gaps, the primary objective of this article is to explore the current status of FSC research in the COVID-19 era and to develop a research agenda for future studies. Our study also focuses on persuading interested researchers to undertake exhaustive, in-depth, and comprehensive works on emerging topics at the nexus of COVID-19 and the FSC. More specifically, this study fills the existing gap in the literature with several questions mainly concentrating on the current FSC research in the COVID-19 era. By doing so, we highlight the most productive scholars and journals that need to be tracked to determine the direction of this knowledge field. Furthermore, through the bibliometric approach, it is possible to identify the geographic distribution of publications in FSC and COVID-19. This is crucial, as it can indicate research progress as well as the technological development of different institutions and countries [30].

Moreover, identifying key thematic areas in the literature using bibliometric techniques has been left unaddressed. As a result, science mapping is essential to uncover the dynamics and structure of FSC research in the COVID-19 context. Finally, after socially, intellectually, and conceptually structuring the literature, we draw on the findings of the bibliometric

analysis to advance FSC knowledge and direct researchers to identify future research possibilities. Therefore, the following are our primary research questions:

- Who are the scholars, and what are the journals, academic institutions, and nations contributing to the literature on COVID-19 and the FSC?
- In the context of COVID-19 and the FSC, what are the main emerging research themes?
- What future research directions are needed to advance the literature related to FSC in the COVID-19 era?

This article is organized as follows. Section 2 provides the theoretical background of the review. Section 3 presents the research method applied. Next, the findings from the bibliometric analysis are disclosed. Section 5 presents the science mapping of the FSC knowledge base during the pandemic. Section 6 discusses the findings, followed by conclusions in Section 7.

2. Theoretical Background

2.1. FSC: Conceptualization and Potential Challenges

The FSC represents an important part of the global economy and has been a cornerstone of human society for thousands of years [31]. Conceptually, the FSC can be described as a sequence of activities and the interdependencies between them, beginning with agricultural inputs and ending with the final food products and their distribution [32]. Taking this description at face value, the FSC covers the whole life cycle of a food product, from production to final consumption. Academics have called for changes to the conventional FSC paradigm for several reasons. For instance, it is estimated that in the near future there will be 9.7 billion mouths to feed, up from the 7.8 billion nowadays [33]. This massive growth must be considered at every level of the food chain.

Moreover, water use is predicted to increase substantially, posing a sustainability challenge [34], especially as agriculture is the world's primary food source. Other ecologically negative impacts include greenhouse gas (GHG) emissions, the increased usage of pesticides and fertilizers, and pollution generated by production, processing, distribution, and transportation activities [35,36]. Additionally, more improvements in FSC traceability and transparency are needed in light of ongoing debates regarding food safety, quality, and security [37,38]. Academia and industry alike are called upon to enhance food traceability capabilities and real-time monitoring to avoid food loss and perishability throughout the FSC [39].

In addition to the aforementioned issues, the FSC is prone to several disruptions related to pandemics. For example, Ekici et al. [40] studied how best to organize the delivery of food products during a global influenza epidemic. The authors built heuristics to determine relatively optimal solutions for large instances with a facility location and resource allocation network for food distribution. Furthermore, Alders et al. [41] have presented an overview of poultry production in rural areas, discussing how the highly pathogenic avian influenza (HPAI) H5N1 pandemic has affected village poultry, their proprietors, and the merchants whose livelihoods are directly linked to these birds. The effects on food security, gender and culture, villages, biosecurity, village poultry value chains, marketing, genetic diversity, effective communication, poultry as part of livelihood plans, and other areas are also discussed. Their study examines chicken meat distribution in China and explains arrangements in poultry meat markets that accommodate small- and medium-scale producers while adapting to changes in live bird markets. The authors also analyze how live bird markets contribute to the spread of bird flu (H7N9) and how countermeasures (i.e., the closure of markets in diseased-affected regions) influence the chicken meat supply chain in China. Finally, Pendell et al. [42] evaluated the effect of the food and mouth disease on the economic situation of southwest Kansas and highlighted that the beef supply chain, dairy products, and other related businesses all suffered from the economic slump caused by the disease outbreak in this area. In conclusion, pandemics can significantly exacerbate FSC disruption, as all supply chain stages and activities are intertwined. Even the slightest interruption can have a devastating impact on the overall production and quality of food

products. More importantly, if any of these steps is compromised, many problems will emerge, putting the whole FSC at risk.

2.2. Main Review Studies on COVID-19's Impact on the FSC

Recently, a few review studies have discussed this topic from different perspectives. For example, Alabi et al. [43] provides a general review of the effects of COVID-19 on food security and disruptions of global FSCs. The research shows that COVID-19 has stronger effects on food security and global FSCs due to disruptions leading to increased food insecurity in the United States and Canada. The findings also demonstrate that the pandemic has disrupted the global FSC in many ways, including labor shortages, limited food accessibility, restricted transportation of commodities, changes in customer demand, the closure of food production plants, uncertainty regarding food safety and quality, restrictions on food trade, and transportation delays. Brooks et al. [44] conducted a review to examine food fraud and authenticity across the FSC and the effects of food fraud on consumers and producers. The findings indicate that the prevalence of food fraud varies by industry, making it challenging to assess and detect.

Rizou et al. [45] summarize the potential transmission routes of COVID-19 via food products, FSCs, and surfaces and conclude that it is necessary to modify bioanalytical protocols for food safety applications in the post-lockdown era. The findings also indicate that public health officials do not believe that COVID-19 is being transmitted via the food industry, and they have ignored the priority of tracing the virus in the food sector and its environs.

Nasereldin et al. [46] review the primary challenges facing global FSC resilience and provide strategies and recommendations to reduce the pandemic's effect on food production and delivery systems. The findings illustrate that despite the efforts to contain COVID-19, the spread of the virus remains a danger to the global FSC due to its effects on the economy, the severe restrictions it has placed on people's ability to get food, the scarcity of agricultural labor, and people's reluctance to travel.

Aday and Aday [2] assess the impact of the pandemic on the food and agriculture sector and provide a summary of the necessary recommendations to mitigate and manage the pandemic's impact. Anderson et al. [47], too, review the effects of COVID-19 on meat and poultry supply chains and find that pandemic-induced disruptions to the meat supply chain and the economic difficulties related to these disruptions have led to a greater interest in enhancing FSC resilience and robustness.

Hamid and Mir [48] review the challenges facing the agri-food sector during the pandemic and deduce that due to the inelastic nature of demand, the need for food products has remained relatively constant around the globe. On the global scale, supply chain stability and food security have been largely dismal for emerging and less developed nations owing to their lack of protection from global pandemics or shocks. Vargas-Ramella et al. [49] take a multidisciplinary look at how the COVID-19 pandemic has affected the FSC, including how it has impacted food safety and security, risk assessment of human–animal interactions, and how it has caused logistical and protocol changes in the food industry. The literature also includes other related reviews that offer insights into the intersection of COVID-19 and the FSC [50–58]. However, none of the previous reviews has applied bibliometric techniques to investigate FSC trends in the COVID-19 era. Instead, current works adopt a traditional or systematic literature review approach to analyze the literature. As a result, they are prone to bias, subjectivity, and a lack of comprehensiveness [59]. On the other hand, these pitfalls can be sidestepped by studying research trends using bibliometric approaches [60].

3. Research Method

Our goal is to conduct a comprehensive and impartial review of the existing literature in order to identify potential research gaps [61,62]. A literature review can be considered a valuable scholarly contribution [63], as it advances theory in certain study domains and

paves the way for future studies to be undertaken on this subject [64]. The impartiality and reliability of the current study is guaranteed by the meticulous execution of a number of specific steps [62]. Structured literature reviews involve the steps of assessing, searching and identifying information resources, applying mind mapping, developing conceptual frameworks, and summarizing the literature [65]. To collect data and conduct a thorough evaluation of a certain study subject, Fahimnia et al. [66] suggested a five-step approach. The process involves:

- Selecting the appropriate keywords and database
- Performing the initial search
- Refining the results
- Compiling basic statistics
- Analyzing the data

We have adopted this five-step method throughout our investigation because it is a widely accepted procedure in bibliometric studies [66].

3.1. Formulating the Search Keywords

We assured coverage of food, supply chain management, and COVID-19-related aspects by using relevant search terms. As such, we referred to the search queries used by other authors to retrieve the relevant literature. For example, in the study of Erboz et al. [28], food was used synonymously with other terms in the search query, including beverage, dairy, fruit, vegetable, meat, beef, fish, drinks, and perishable [67]. The keywords related to supply chain management included supply, chain, inventory, logistics, supply network, and value chain [33]. Finally, various designations were used to reflect the keyword COVID-19, such as pandemic, coronavirus, and sars-cov-2 [68].

3.2. Preliminary Search Results

The search was performed on the 28 June 2022. We used the Scopus database because of the breadth of information it provides. Compared to the Web of Science (WoS) database, Scopus indexed more academic journals—approximately 42,180—and has a huge overlap with WoS, which totals 84% of the documents indexed [69]. In addition, the Scopus database is the best option for rapidly developing research topics such as COVID-19's impact on the FSC. This database also helps to compile leading journals in the SCM field that are not indexed in WoS, including the *International Journal of Supply Chain Management* and *IEEE Engineering Management Review*. The search string employed was in the title, abstract, and keywords fields of Scopus, since these fields often include the terms representing a certain work [70]:

TITLE-ABS-KEY ("food*" OR "beverage*" OR "dairy" OR "fruit*" OR "vegetable*" OR "meat" OR "beef" OR "fish" OR drinks OR "perishable") AND ("supply" AND "chain*" OR "inventory" OR "logistic*" OR "supply network" OR "value chain") AND ("covid-19" OR pandemic OR coronavirus OR "sars-cov-2").

The search yielded 948 documents, all of which were scholarly publications written in English.

3.3. Search Result Refinement

Out of the 948 documents founds, only publications from the fields of social sciences, business, management, accounting, economics, and decision sciences were selected. The restriction to these subject areas prevents discrepancy in research findings, guarantees a more in-depth exploration of these areas, and allows for better generalization and systematization [71]. Furthermore, choosing precise subject areas helps maintain the review's relevance and concision [72].

Books, chapters, conference papers, editorial notes, white papers, and periodicals, among others, were omitted to ensure academic rigor and the high quality of the selected publications [73]. Selected articles were those published between 2019 and June 2022. Consistent with previous research [28], we took 2019 as the starting year because the

outbreak of COVID-19 in China occurred at the end of this year [74]. These criteria resulted in a refined collection of 287 articles for the final analysis. All of these articles were relevant to the scope of the present study after being screened based on their titles, abstracts, and, if necessary, the full text. Figure 1 depicts the review process.

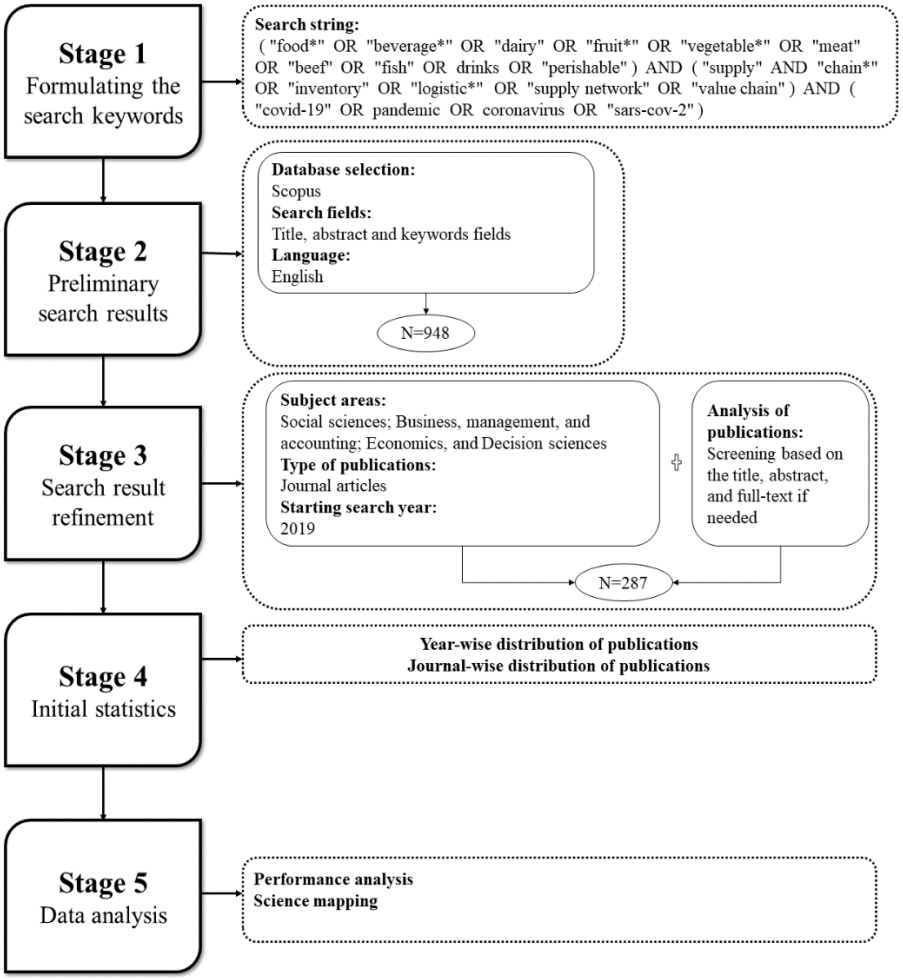

Figure 1. Review process.

3.4. Initial Statistics

The upward trend in the number of articles on COVID-19 and the FSC is shown in Figure 2. Over the whole of 2020, 62 papers were published; however, the number of articles increased substantially in 2021, exceeding 150 publications in that year. Through the first six months of 2022, 73 articles had been published. The top ten journals accounted for 44.5 per cent of the total published papers (128 of 287) (see Table 1). *Sustainability* tops the list of most productive journals publishing on COVID-19 and the FSC. The *Canadian Journal of Agricultural Economics* ranks second with thirteen papers, followed by *Global Food Security* and *Foods* with 11 and 10 papers, respectively. In terms of journal influence, the *Canadian Journal of Agriculture Economics* received the highest number of citations (897), followed by *Sustainability* (483), *Food Security* (358), and *Global Food Security* (280). The publications from these journals have improved FSC research and promoted its advancement in the COVID-19 era. Overall, these journals are the most productive in COVID-19 research from the FSC perspective.

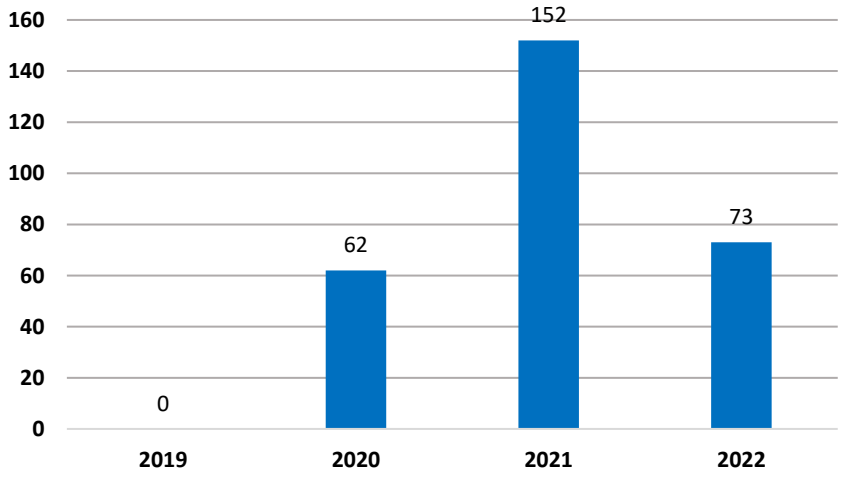

Figure 2. Annual distribution of publications.

Table 1. Top 10 most productive journals.

Journal	No. of Articles	No. of Citations	Impact Factor
Sustainability	50	483	3.889
Canadian Journal of Agricultural Economics	13	897	11.353
Global Food Security	11	280	9.027
Foods	10	62	5.561
Food Security	9	358	7.141
Applied Economic Perspectives and Policy	8	162	4.89
Marine Policy	8	72	4.315
International Journal of Logistics Management	7	29	5.446
China Agricultural Economic Review	6	145	4.265
British Food Journal	6	11	3.224

3.5. Data Analysis

A two-step process was applied to analyze data. To begin, we used BibExcel to conduct the bibliometric analysis, which revealed information on the authors' impact, affiliations, home countries, keywords, and citation data. VOSviewer software was then used to implement science mapping. VOSviewer is a popular and efficient tool for visualizing extensive scientometric maps [75].

First, reference co-citation analysis was carried out to identify the early and most important works in the FSC literature during the COVID-19 pandemic [76]. This approach is also helpful in determining the growth and development of a research field, thereby benefitting researchers interested in identifying potential research prospects through reference co-citation analysis [77]. Second, we analyzed journal citations to reveal the relationship between different journals and fields. A journal co-citation occurs when a single document references two journals [78]. Third, institution co-citation analysis was performed to identify the most influential academic institutions that have contributed substantially to the growth and progress of FSC research in the COVID-19 era. Fourth, the analysis of countries' co-authorships gives an idea about the state of research collaboration and communication between nations as well as active counties [79]. Fifth, we carried out country-specific bibliographic coupling to determine how countries use comparable material in their publications and concentrate on a similar subject. Bibliographic coupling occurs between two countries when their publications cite the same research works [80]. Sixth, we performed an article

co-citation analysis to offer insights into the intellectual structure of the research field [81]. A network is formed when papers are connected based on their shared citations by future works. It has been demonstrated that frequently cited papers have a bigger impact on their field than those cited less frequently. If two papers are frequently co-cited, they probably contain similar or related ideas. Groups of linked papers covering the same study topics can be identified by counting and assessing the frequency with which two publications are mentioned in the same publication [81]. A document co-citation network represents the frequency with which works jointly cite two publications in a certain dataset. Finally, a keyword co-occurrence network was generated to capture keywords that appear together in at least two different publications over a certain time frame. Therefore, very frequent and central keywords can be used to identify major research foci or orientations throughout a certain time period [82]. The keyword co-occurrence network is formed this way: each term is represented by a node in the network, and the links between the nodes are made up of the co-occurrence of the terms.

4. Performance Analysis

A bibliometric study employs mathematical methods to organize and summarize the published literature [83]. As a result, it is a helpful approach to assess the current state of a knowledge domain by looking at various indicators such as seminal research works, influential authors, journals, institutions, and geographies [66,84]. Most of the recent research in the SCM field has relied on bibliometric analysis to examine how the discipline has progressed [28].

4.1. Author Productivity

The top ten most prolific authors on COVID-19 and the FSC are shown in Table 2. Kazancoglu Y. has the most articles on the list (5), followed by Mangla S.K. (4). All the remaining authors published three articles, respectively. Multiple criteria decision-making methods and mathematical modeling [85–89] were the main research methods that the most productive authors employed.

Table 2. Top 10 most productive authors.

Author	No. of Articles
Kazancoglu Y.	5
Mangla S.K.	4
Richards T.J.	3
Belton B.	3
Fan S.	3
Chenarides L.	3
Luthra S.	3
Ali I.	3
Mor R.S.	3

4.2. Affiliation Data

The top 10 most productive institutions in the field of COVID-19 and the FSC are listed in Table 3. WorldFish comes in first with eight articles, followed by the International Food Policy Research Institute and China Agricultural University with six articles each. Compared to the list of the top ten most productive contributors, it is not surprising that the top five researchers represent the top five institutions listed in the table. The countries in which the selected articles originated are shown in Table 4. The United States (66 articles), India (42 articles), the United Kingdom (41 articles), and China (37 articles) account for

over 65 per cent of all publications. Regarding the number of citations, the United States, Canada, and China have the highest impact.

Table 3. Top 10 most productive institutions contributing to COVID-19 and FSC research.

Institution	No. of Articles	Country
WorldFish	8	Malaysia
International Food Policy Research Institute	6	United States
China Agricultural University	6	China
Wageningen University & Research	5	Netherlands
University of Saskatchewan	5	Canada
Chinese Academy of Agricultural Sciences	5	China
Yasar Universitesi	5	Turkey
The University of British Columbia	4	Canada
University of Guelph	4	Canada
Nanjing Agricultural University	4	China

Table 4. Top 10 most productive countries.

Country	No. of Articles	(%)	No. of Citations
United States	66	23.00	1225
India	42	14.63	477
United Kingdom	41	14.29	424
China	37	12.89	611
Canada	25	8.71	879
Australia	20	6.97	298
Malaysia	17	5.92	245
Italy	16	5.57	300
Bangladesh	11	3.83	203
Germany	11	3.83	92

4.3. Keyword Frequency Analysis

Using BibExcel we analyzed the most popular search terms (Table 5). Looking at the keywords in the 287 selected publications, the top 20 most common keywords were identified. Our findings show that the most frequently used keywords are linked to those that were entered into the search engine (cf. Figure 1). These keywords include COVID-19, food supply chain (FSC), food security, resilience, supply chain (SC), and pandemic. Besides these, other relevant keywords reflecting topical issues included sustainability, food system, food waste, blockchain, and disruption.

4.4. Citation Analysis

Since citations are a major indicator of the quality of a scientific publication [90], we conducted a citation analysis of high-quality and influential publications. To some degree, the articles with high citations constitute the research trends and hotspots in the scientific field [91]. The top ten most cited publications, together with the research method used and the key findings, are listed in Table 6. According to the findings, Hobbs [92] holds the top position with 243 citations. This study offers an early evaluation of the impacts of COVID-19 on FSC and supply chain resilience. Following this is Singh et al. [93], which has been cited 189 times. In this study, the authors developed a simulation model of the public distribution system network with several scenarios to assess disruptions in the FSC.

Table 5. Top 20 most frequent keywords.

Keyword	Frequency
COVID-19	179
Food Supply Chain (FSC)	47
Food Security	43
Resilience	28
Supply Chain (SC)	25
Pandemic	21
Sustainability	21
Food System	19
Food Waste	11
Blockchain	10
AgriFood Supply Chain (AFSC)	9
Lockdown	9
China	8
Food Insecurity	8
Supply Chain Resilience	8
Supply Chain Management (SCM)	8
Value Chain (VC)	8
Agriculture	7
Disruption	7
Food Policy	7

Table 6. Top 10 most cited articles.

Article	No. of Citations	Research Method	Key Findings
Hobbs [92]	243	Conceptual research	The COVID-19 pandemic impacts FSCs and food resilience. The pandemic leads to demand-side shocks manifesting in consumer panic-buying behaviors and sudden changes in consumption patterns. From the supply-side perspective, the pandemic resulted in labor shortages, interruptions to transportation networks, and the restriction of product flows.
Singh et al. [93]	189	Simulation	A resilient supply chain is imperative to reduce the impact of the pandemic and develop a responsive FSC capable of adapting to changing demands and supporting decision makers in delivering food products.
Richards and Rickards [94]	127	Conceptual research	The emergence of COVID-19 had a substantial effect on the Canadian fruit and vegetable markets. Produce growers and distributors were compelled to move supplies almost completely from the food service channel to the retail channel due to the lockdown. It is expected that permanent changes in the online food-purchasing habits of consumers, shortage in labor markets, and higher concentrations of fresh produce will occur in the long term.
Kansiime et al. [95]	118	Survey	The COVID-19 crisis has resulted in income shocks, worsened food security and dietary quality, and led to lower food intake for income-poor households.

Table 6. *Cont.*

Article	No. of Citations	Research Method	Key Findings
Gray [96]	111	Conceptual research	The study finds that agricultural access to bulk ocean freight, rail travel, and trucking has enhanced during the COVID-19 crisis, aided by the reduced need for these transportation services by other economic sectors. Moreover, it was found that consumers' broad adoption of physical distancing measures has dramatically boosted the demand for delivery services and retail food pickup.
Lal [57]	93	Conceptual research	The COVID-19 pandemic has exacerbated food insecurity in urban areas due to the disruption in the FSC, the worsening of economic and physical obstacles that limit access to food, and the dramatic rise in food waste caused by labor shortages.
Chowdhury et al. [97]	85	Case study	The results reveal that COVID-19 has had severe short-term effects, such as a lack of working capital, product expiry, and constrained operations of distributors. Multiple performance measures, including return on investment (ROI), the company's contribution to the gross domestic product (GDP), and employee size, are predicted to fall over the long run.
Pu and Zhong [98]	82	Conceptual research	The findings indicate that excessive regulations would obstruct the flow of agricultural output, impede vital production inputs, disrupt production cycles, and ultimately weaken production.
Deaton and Deaton [99]	78	Conceptual research	The COVID-19 pandemic has created an income shock that increases the incidence of food insecurity among households. The pandemic increased household anxiety about the capability of national food systems to guarantee food supply.
Di Vaio et al. [100]	77	Systematic literature review	In the context of the COVID-19 pandemic, the results shed light on the importance of artificial intelligence and digital technologies to develop sustainable agri-food business models, maximize productivity, reduce product emissions and costs, and optimize resource consumption.

Additionally, Richards and Rickards [94], the third most-cited paper, analyzes the impact of COVID-19 on Canadian fruit and vegetable markets. Table 7 lists the top ten cited authors in the area of COVID-19 and the FSC. According to the results, Hobbs is the most frequently cited scholar, followed by Singh and Kumar.

Table 7. Top ten most cited authors.

Author	Citations
Hobbs J.E.	448
Singh S.	189
Kumar R.	189
Panchal R.	189
Tiwari M.K.	189
Richards T.J.	161
Deaton B.J.	156
Rickard B.	130
Kansiime M.K.	118
Tambo J.A.	118

5. Science Mapping

5.1. Reference Co-Citation Analysis

Reference co-citation analysis can identify areas of potential future research based on the cited publications [101]. The network considers references co-cited at least once (Figure 3). As a result, 43 references and 1,246 links were used to generate four clusters. Based on the number of nodes, the red cluster is the most important, comprising 15 studies that mainly focus on the impact of the COVID-19 pandemic on FSC systems and agriculture [2,99,102]. The second cluster (in green) contains 14 studies that examine the mitigation strategies and measures necessary to increase FSC resilience [103–105]. The third cluster (in blue) consists of nine studies discussing the risks of the COVID-19 pandemic to global food security [106–109]. Finally, the fourth cluster (in yellow) includes five studies that scrutinize the impact of the pandemic on seafood systems [110–112].

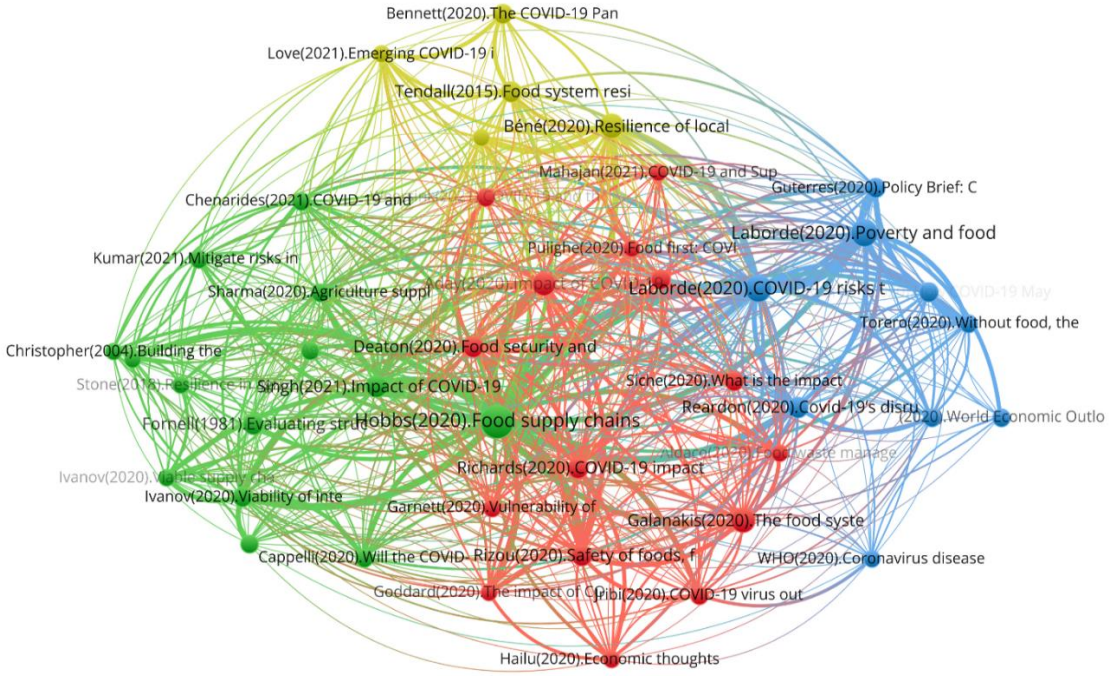

Figure 3. Reference co-citation network.

5.2. Journal Co-Citation Analysis

According to Tsay et al. [113], journal publications are the most important way for academics to disseminate their findings. Journal co-citation analysis is a powerful approach for revealing the overarching structure of a research field and pinpointing the primary publishing avenues responsible for the field's intellectual growth and progress [114]. For this study, the journal co-citation network is depicted in Figure 4. The node's size in the map corresponds to the number of publications of the journals included in the sample. Overall, the network contains 68 nodes and 1,146 edges in the field of FSC research. Three clusters of journals construct the network. The first cluster includes journals focusing on supply chain management, logistics, and operations research (e.g., the *International Journal of Logistics Management*, *Operations Management Research*, the *International Journal of Logistics Research and Applications*, *Supply Chain Management*). The green cluster includes journals related to food sciences and agriculture (e.g., *Global Food Security*, *Foods*, *Food Policy*, *Agricultural Economics*). Finally, the blue cluster contains journals with sustainability and country-specific foci (e.g., *Sustainability*, the *Canadian Journal of Agricultural Economics*, the *China Agricultural Economic Review*, the *American Journal of Agricultural Economics*).

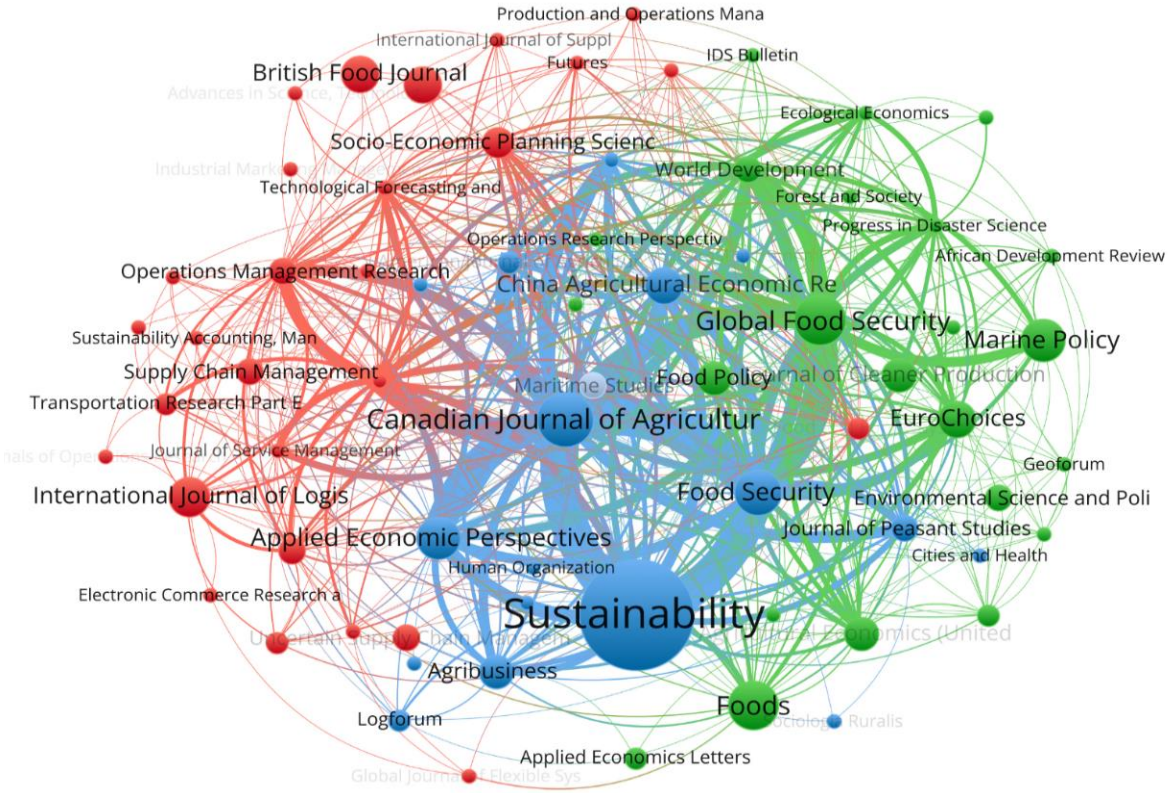

Figure 4. Journal co-citation network.

5.3. Institution Co-Citation Analysis

Initially, FSC research in the COVID-19 context was concentrated on research institutes and centers (e.g., WorldFish, the International Food Policy Research Institute). With time, and in tandem with the unfolding of the pandemic, universities took an active interest, assembling teams of scholars and researchers who accelerated the progress of FSC research in the COVID-19 era. We generated an institution co-citation network to identify the top influential institutions contributing to this research strand (Figure 5). Results specify that the University of Saskatchewan is the most influential institution, followed by WorldFish and the National Institute of Industrial Engineering. Interestingly, no institutions from Malaysia or Italy made it into the top ten most influential institutions in the field, although these countries are among the top nations based on research productivity. We may infer from this analysis that research is both extensive and comprehensive, with a wide variety of institutions and nations concentrating on the same issues. This finding, however, also calls attention to the need for stronger collaboration and coordination across institutions to enhance research quality and output.

5.4. Countries' Co-Authorships

Figure 6 depicts the countries' co-authorship network. Table 8 presents the countries with at least six publications that are included in the network. Total link strength was determined for each of the 86 countries based on the number of co-authored publications with each other country. We chose the ten countries with the highest total link strength and found some interesting patterns. The countries in the graph are organized into four clusters, and there are a total of 1096 links and 1498 total link strengths. The United States, the United Kingdom, and Malaysia are found on the top, with 51, 45, and 46 countries of co-authorship networks, respectively.

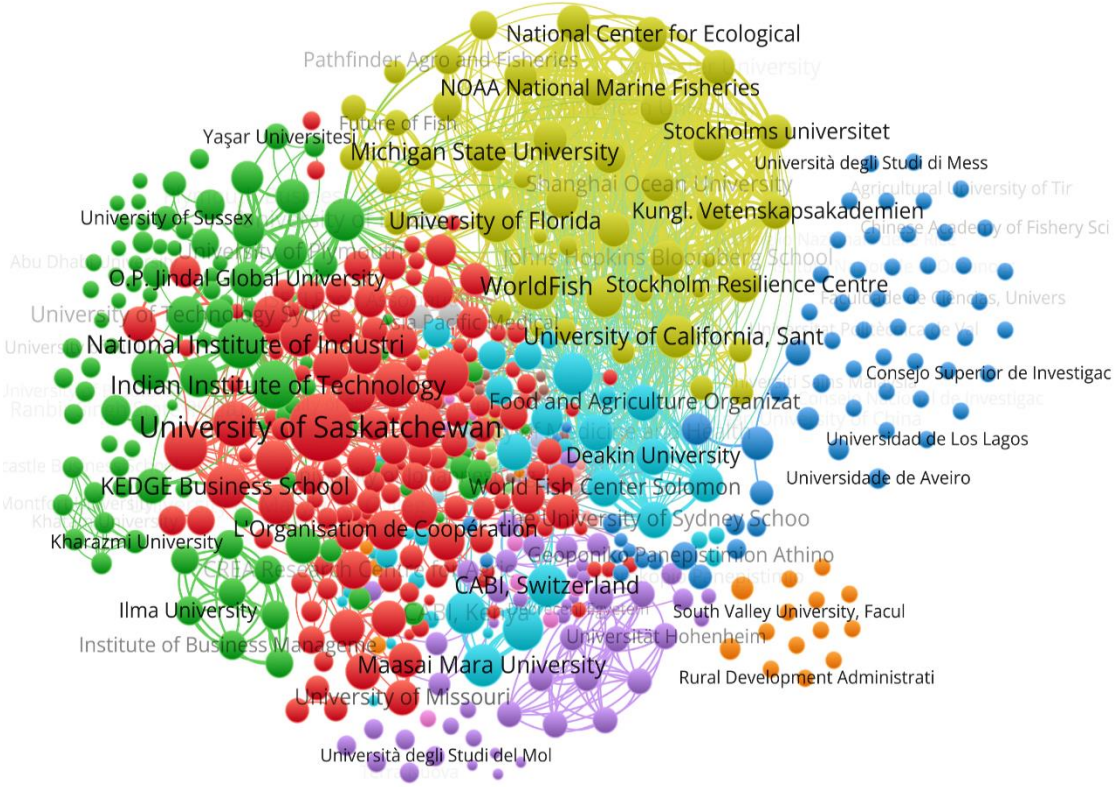

Figure 5. Institution co-citation network.

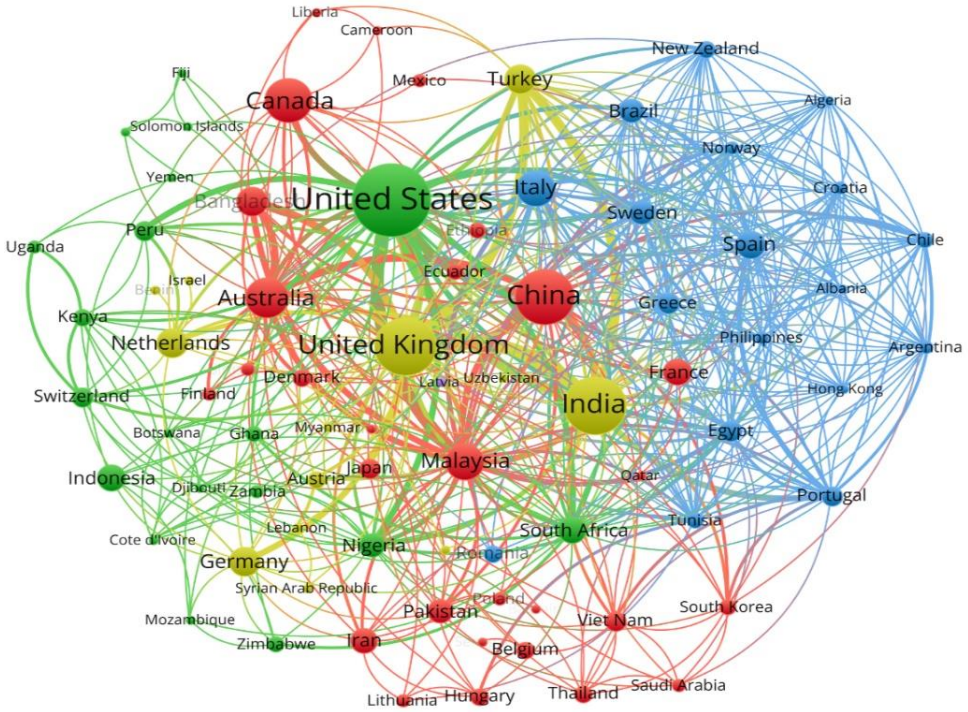

Figure 6. Countries' co-authorship network.

Table 8. Top 10 countries according to country co-authorship network.

No.	Co-Authorship Country	Cluster	Links	Total Link Strength	Publications
1	United States	2	51	108	66
2	United Kingdom	4	45	90	41
3	Malaysia	1	46	83	17
4	India	4	38	80	42
5	China	1	36	67	37
6	Australia	1	29	46	20
7	Turkey	4	29	46	11
8	South Africa	2	34	44	9
9	Italy	3	32	41	16
10	Egypt	3	30	40	6

5.5. Countries' Bibliographic Coupling

This research uses country bibliographic coupling to determine which countries emphasize FSC research most during the COVID-19 pandemic. Figure 7 displays the results of the countries' bibliographic coupling network. Each node in the network represents a country, and each color corresponds to a cluster. The end output consists of six different clusters. With 66 documents, 1225 citations, and a total link strength of 8114, the United States ranks top on the list. Countries appearing in the same cluster tend to concentrate on similar issues. Furthermore, the number of clusters suggests that FSC issues faced by various nations during the COVID-19 pandemic are different.

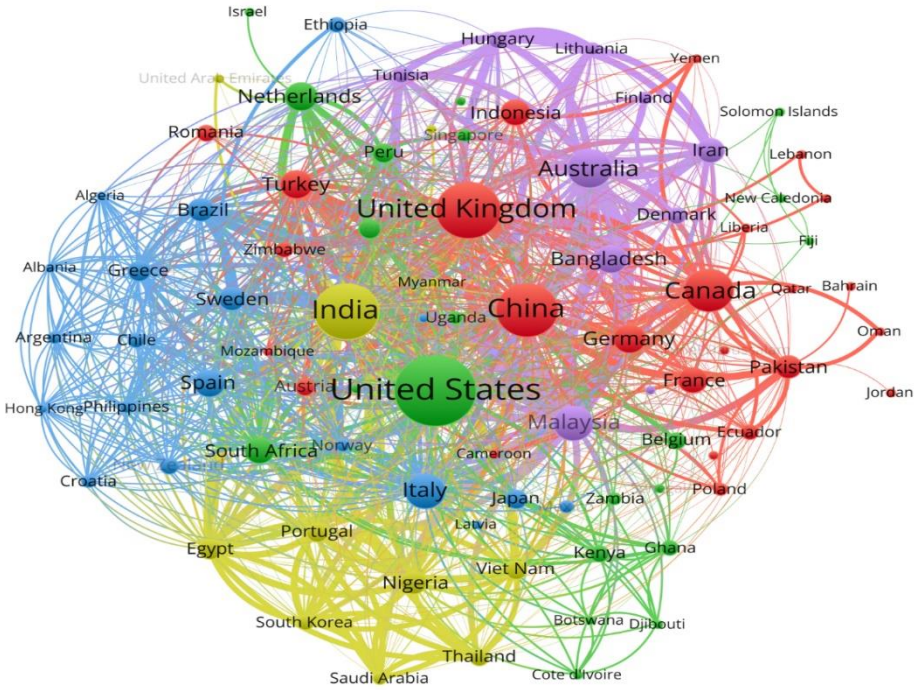

Figure 7. Countries' bibliographic coupling network.

5.6. Article Co-Citation Analysis

Co-citation is the appearance of two different authors or sources in the reference list of the same publication [115]. When two papers are regularly cited together, it suggests that they share similar topics or substance. As a result, co-citation analysis represents a

technique for measuring the contextual similarity of several studies related to the same subject, methodology, theory, or empirical field [116]. Using BibExcel to analyze co-citations, we identified 119 pairs of articles that are co-cited with each other. In total, five thematic clusters were generated (see Figure 8). To identify the theme of each cluster, two of the authors independently engaged in the reading of the articles' titles and abstracts to reduce bias [117] and resolve any disagreement through a discussion [118].

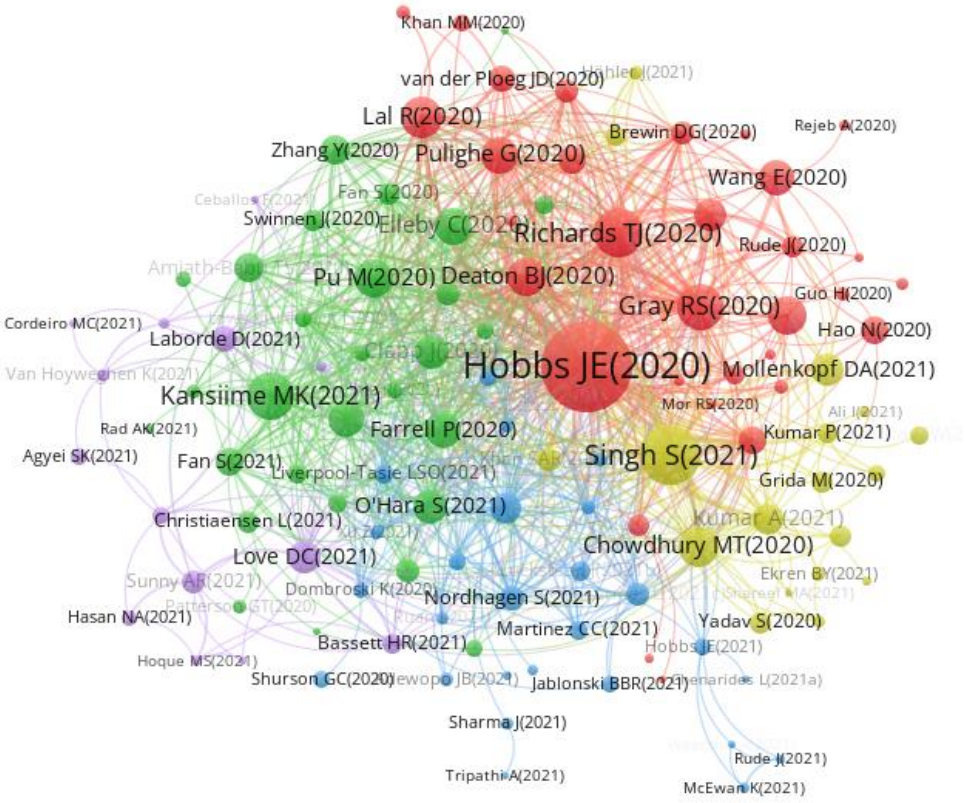

Figure 8. Co-citation analysis of selected articles.

The red cluster contains studies that mainly focus on the impacts of COVID-19 on the FSC and urban agriculture [92,96,119,120]. The green cluster includes studies on the implications of the pandemic on household income and food security [95,98,110]. The blue cluster focuses on the FSC disruptions in developing countries brought on by the COVID-19 pandemic [13,121–123]. The yellow cluster revolves around risk mitigation strategies to increase FSC resilience [89,124–126]. Finally, the purple cluster contains studies discussing the impact of COVID-19 on seafood systems [111,127–129].

5.7. Keyword Co-Occurrence Network

The study of keyword co-occurrence networks enables scholars to discover the essential topics addressed in a certain research field [130]. According to Huang et al. [26], a keyword co-occurrence represents a valuable scientometric tool that allows one to visualize and exhibit commonalities among frequently co-occurring terms or subjects in the academic literature. With the support of this approach, researchers can acquire a general idea of the substance of a publication and key information pertaining to methodologies, theories, viewpoints, and objectives. To perform the analysis, we considered the keyword field, because it is more precise than the title and abstract fields, which can contain irrelevant words and phrases (e.g., verbs, adverbs). Further, the major themes and sub-themes of the publications' content are usually tagged in the keyword field [131].

We pretreated and modified the original keywords as needed in order to construct the keyword co-occurrence network. For example, we merged keywords such as "food supply

chain" and "food supply chains", "consumer behavior" and "consumer behaviour". After cleaning up the data, we used VOSviewer to set the minimum keyword co-occurrence threshold to two and visualize the keyword co-occurrence network. As seen in Figure 9, 67 nodes were distributed among six distinct clusters. Nodes in the figure represent individual keywords, with a node's size reflecting the frequency with which that keyword appears in the literature.

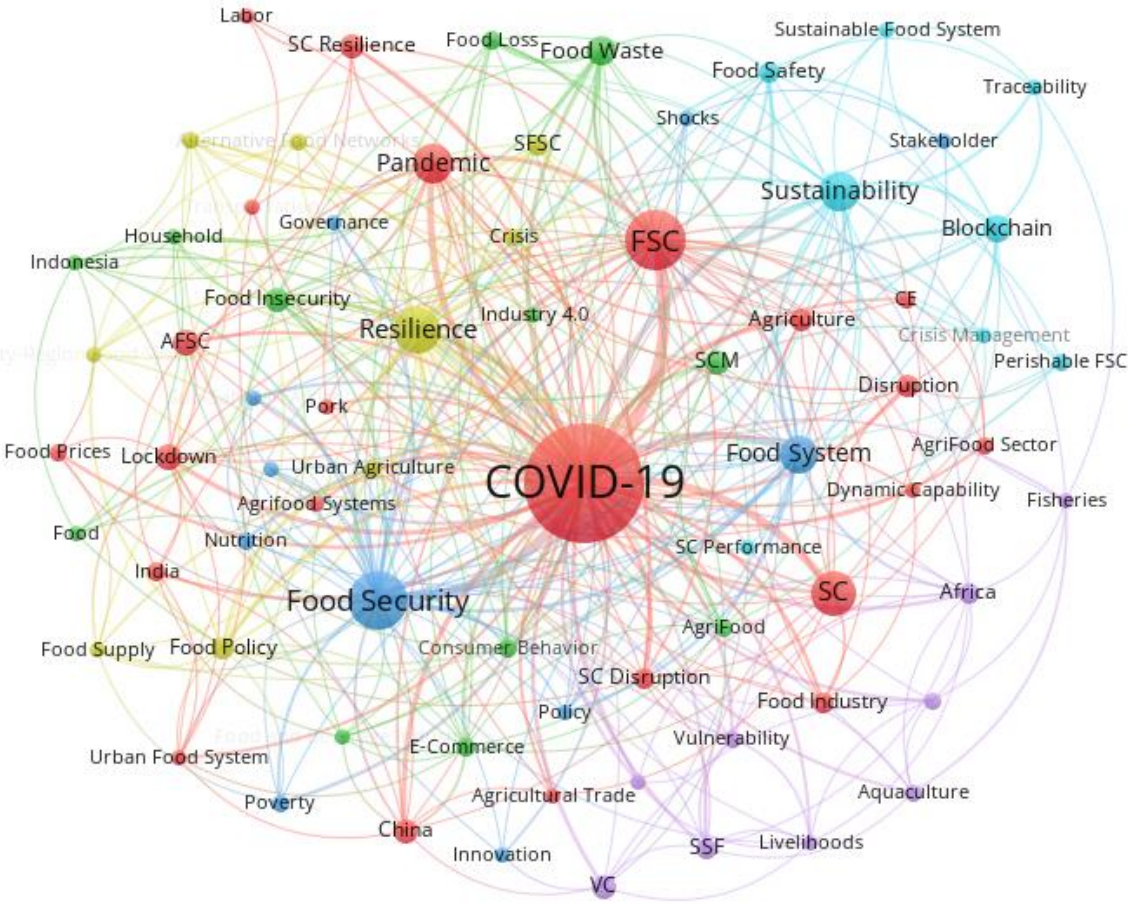

Figure 9. Keyword co-occurrence network.

Simply put, a more frequent occurrence of a keyword pair corresponds to a larger node. Keywords that appear together often are clustered closely to one another in the network. Thus, the keywords used by the authors were categorized into six clusters with a relative level of importance (see Table 9).

5.7.1. The Impact of COVID-19 on the FSC and Agriculture

Table 9 shows that cluster 1 focuses on the impact of COVID-19 on the FSC and agriculture. The most important keywords in this cluster include "COVID-19", "FSC", "Food Security", "SC disruption", "Lockdown", "Agriculture", etc. Generally, food systems integrate all the phases of food production, from cultivation to final consumption [132]. Access to market factors such as logistics resources and labor force is crucial for FSCs to operate in a global and complex environment [133]. Due to the unique characteristics of food products, the FSC is highly vulnerable to several uncertainties associated with demand, weather, and business markets [105,134]. The current COVID-19 pandemic represents one of the most severe public health challenges that have detrimentally influenced FSCs and food security [24,135,136]. Specifically, COVID-19 has disrupted the regular operations of the FSC by affecting both the upstream and downstream parts of the food chain [20]. Vital farming inputs such as seeds, insecticides, and fertilizers are disrupted as farmers

have experienced increasing sourcing challenges due to limitations on the flow of materials, thereby resulting in less production and food-processing inefficiencies [134]. According to Béné [134], the production and distribution of food products have become challenging and expensive due to transport restrictions, workforce migration, and the adoption of social distancing. The work performance also slowed down even in areas where farmers could find sufficient adequate and qualified numbers of laborers owing to social distancing practices [18,137]. Béné [134] highlighted that lack of available workers and movement restrictions have led to a rise in the difference between wholesale and retail prices during the first lockdown phase. Similarly, Jiang et al. [138] pointed out that a higher transportation cost, a scarcity of available labor, and the unpredictability of logistics contributed to a sharp increase in food prices. Consequently, the lockdowns, alongside domestic and international restrictions, have exacerbated FSC disruptions and led to food shortages and food security issues [136].

Table 9. Top 10 most frequent keywords in each cluster.

Cluster 1 (The Impact of COVID-19 on the FSC and Agriculture)	Cluster 2 (FSC Resilience)	Cluster 3 (Food Waste and Insecurity)	Cluster 4 (Fisheries and Aquaculture)	Cluster 5 (Blockchain Technology)	Cluster 6 (Governance and Innovation)
COVID-19 (187)	SC Resilience (36)	Food Waste (11)	VC (8)	Sustainability (21)	Food System (19)
FSC (80)	Food Policy (7)	Food Insecurity (8)	Africa (6)	Blockchain (10)	Nutrition (4)
Food Security (43)	SFSC (6)	SCM (8)	SSF (6)	Food Safety (6)	Governance (3)
SC Disruption (13)	Alternative Food Networks (4)	E-Commerce (5)	Aquaculture (4)	Perishable FSC (4)	Innovation (3)
Lockdown (9)	Crisis (4)	Food Loss (5)	Food and Nutrition Security (4)	Crisis Management (3)	Policy (3)
China (8)	Local Food Systems (4)	Agri-Food (4)	Vulnerability (4)	SC Performance (3)	Shocks (3)
Agriculture (7)	Poverty (4)	Food (3)	Fisheries (3)	Sustainable Food System (3)	Stakeholder (3)
Food Industry (6)	Urban Agriculture (4)	Food and Beverage Industry (3)	Livelihoods (3)	Traceability (3)	
Consumer Behavior (5)	City-Region Food System (3)	Household (3)			
India (5)	Food Supply (3)				

The fundamental reason that the COVID-19-induced disruptions have significantly harmed FSCs is the inability of FSC stakeholders to withstand these disruptions and the limited adaptability to such rapidly changing circumstances. Overall, the pandemic has placed a massive burden on local and global FSCs due to the constrained availability of agricultural inputs, labor forces, and the disruption of processing plants. The prolonged pandemic provides an opportunity to assess the weaknesses of the FSC and devise plans to develop a more resilient food system. As a result, FSCs with fragile structures should be more resilient to fight the impact of the pandemic. This implies that the FSC stakeholders should capitalize on the technical and system changes brought on by the pandemic to promote innovation and hopefully strengthen resistance against potential shocks [139]. Though the impact of COVID-19 on the FSC has been widely acknowledged in previous studies [92,124], there are still some research gaps that need to be filled. For example, more attention should be paid to the influences of COVID-19 and mitigation strategies that can be applied to various food organizations, ranging from small to medium to large companies [97]. In addition, FSC policies to better control the ripple effect [124] in the event of a pandemic are worthy of further study. This is essential, as addressing COVID-19 disruptions and achieving a long-term recovery plan is becoming a major priority for organizations suffering immense challenges in their FSCs due to the pandemic [138]. A

further intriguing research avenue is the development of capabilities to recover from COVID-19 using emerging technologies to increase FSC resilience.

5.7.2. FSC Resilience

The second cluster revolves around the importance of developing FSC resilience to combat the COVID-19 pandemic. Conceptually, resilience is defined as the ability of a system to absorb disturbance and restructure while experiencing a change to substantially preserve the same structure, function, feedback, and identity [140]. Due to the critical importance of FSC resilience during disruptive events [141], organizations must develop skills to proactively enhance the appropriate degree of preparedness, reaction, and recovery capability throughout the pre-disruption and post-disruption phases [97,103]. In this context, Kazancoglu et al. [139] argues that FSCs with weak structures must be more robust and regularly develop resistance against potential shocks and crises. The authors illustrate the importance of innovative digital technologies such as the IoT and big data analytics to absorb the effects of the pandemic and make food systems more resilient. Xu et al. [142] highlight that those diverse strategies could be implemented to build resilient FSCs, including enhancing flexibility, establishing redundancy, diversifying sources, increasing supply chain agility, raising transparency, reorganizing the FSC, strengthening collaborative relationships with business partners, and information sharing. Keywords such as "Food Policy" and "SFSC" (short food supply chain) are highly frequent in this cluster. As a response to changing consumer needs, the innovative organizational initiatives of food producers, and food policy development, SFSCs have been widely acknowledged as a solution to increase food system resilience and ensure the availability of food products [143]. SFSCs involve a wide variety of market-driven initiatives, such as community-supported agriculture, on-farm direct sales, farm shops, farmers' markets, restaurant procurement schemes, and digital platforms offering unique farmers' products [144]. The reduced distances with the FSC are intended to provide economic advantages, contribute to social and cultural objectives (e.g., food safety, environmental protection), and strengthen cultural relationships via a cooperative and communitarian consumption pattern [145]. These FSC networks also integrate information inside their products, helping customers to understand food production methods and fostering a greater relationship of trust between producers and customers [146]. As a result, during the COVID-19 pandemic, the focus of food policy should be devoted to developing local SFSCs to increase the affordability and availability of sustainable food alternatives [147].

Some of the frequent keywords in the cluster also include "Alternative Food Networks", "Local Food Systems", "Poverty", and "Urban Agriculture". Alternative food networks have emerged and expanded, allowing consumers to participate in a diverse movement toward sustainable food production, consumption, and distribution. Alternative food networks incorporate the three pillars of sustainability: freshness, locality, and efficiency [148]. Additionally, alternative food networks have alleviated worries about local food networks dying out due to the expansion of global and centralized food delivery networks [149,150]. Finally, the interruptions in the FSC caused by the pandemic provide the necessary impetus to revitalize urban agriculture, which aims to maximize total food production in urban areas by converting vacant lands into agricultural farms [151]. With the shift to the development of SFSCs, there is an immense interest in examining the resilience of local food system actors, particularly small-scale producers, and their role in the transition of agri-food systems to sustainability [17]. Hence, the study of how local and domestic food networks can contribute to the development of macroeconomic shock resistance is encouraged for future research [127]. The definitions of strategies and innovative policies to support adopting urban agriculture practices during lockdown situations are also important; therefore, future studies should explore the characteristics of urban actors engaged in this livelihood strategy [151].

5.7.3. Food Waste and Insecurity

Cluster 3 refers to a critical research theme related to the intensification of food waste and insecurity during the COVID-19 pandemic. According to several scholars, food waste represents the largest contributor to inefficient resource consumption and the failure to realize global food sustainability and security [84,152]. The transition from dining out to online meal delivery services during the pandemic has resulted in a rise in food waste and the use of plastic food containers [153]. Food waste has increased in homes during COVID-19 for a number of reasons, including excessive quantities of food, unappealing taste, poor quality, and staleness. Due to the significant resources needed for producing wasted food products, food waste has become an obstacle to developing sustainable food systems. Adelodun et al. [154] argue that a substantial portion of greenhouse gas emissions is associated with the handling and disposing of wasted food products. For example, França et al. [155] found that landfills in Rio de Janeiro, Brazil, released 138.51 CO2eq. tons of emissions per day from food waste, with a possible 90% decrease when considering both food waste reduction and alternative waste treatment. As a result, when food waste is reduced or eliminated, greenhouse gas emissions can be reduced by up to 8.2 per cent, as stated by [156]. To address the food waste issue, the EU Platform on Food Losses and Food Waste disseminated the food waste and loss prevention measures made by European countries in response to the COVID-19 pandemic [56]. Similarly, several governments have warned households that no significant food shortages were reported and provided advice on preparing for such a scenario by planning, shopping, and stocking food, thereby increasing food security. During the lockdown, if community-based groups and private charities are mobilized to distribute food, they can assist in reducing food waste while also providing essential support to those in need. Several municipalities and cooperatives [157,158] have undertaken a similar strategy by redistributing unsold food from restaurants and schools to low-income and disadvantaged populations. During the pandemic, these alternate supply routes have been beneficial and appreciated because of the possibility of food surpluses or food waste and losses due to the closure of catering businesses, restaurants, hotels, and schools [56]. Overall, the unexpected increase in food demand caused by the COVID-19 pandemic has significantly disrupted FSCs, underscoring the need to educate consumers. The examination of this cluster suggests that there is still a lot of potential for research on recycling and capturing food waste sources' economic value during the COVID-19 pandemic [152]. There is also a need to investigate the impact of COVID-19 on food waste reduction strategies in developing countries, in which the levels of food waste are picking up, and existing data and the ability to overcome this problem are limited [153]. Finally, another interesting avenue for future research is the ways in which organizations can use data collected on food waste and by-products to support decision-making processes.

5.7.4. Fisheries and Aquaculture

The fourth cluster focuses on the impact of the COVID-19 pandemic on the fisheries and aquaculture sectors. Keywords such as "VC" (value chain), "Africa", "SSF" (small-scale fisheries), and "Aquaculture" are thus included in this cluster. The severe impacts of the COVID-19 crisis have demonstrated the vulnerabilities of the fishery industry, such as its reliance on tourists and the absence of diverse market choices for harvested produce [159]. As an external stressor, the pandemic has adversely impacted the fisheries' value chains, leading to lower catches and, therefore, lower incomes for fishermen [160]. Furthermore, the local production and availability of inputs are severely affected. Khan et al. [161] argue that low dock landings from reduced fishing activities and loss of employment and income due to lockdowns and social distancing are a few examples of the many negative effects of the pandemic on fishery systems. Evidence of productivity constraints includes post-harvest loss, food waste, and inadequate fishing inputs and feeds for farming/fishing activities. In addition, the food supply has been impacted by a lack of labor for onshore and offshore activities, rising food costs, and interruptions in shipping traffic. In African and Southeast Asian nations, populations rely heavily on fisheries and aquaculture for economic survival.

As a result, small-scale fisheries have been particularly vulnerable to the pandemic due to the decline in fishing capacity and consumer demand [52]. By disrupting fish demand and supply, production, distribution, and labor, the pandemic puts the livelihood of small-scale fisheries in danger [50]. Waiho et al. [162] stated that due to COVID-19's detrimental effects on the market for fish and fishery products, hatcheries have been forced to shut down, feed importers have been halted, and numerous value chain organizations have been losing money since the beginning of the culture season. As a result, integrating aquaculture and fisheries industries via an ecosystem-based approach is necessary to mitigate the limited availability of fish and seafood caused by the pandemic [111]. Though there is a growing body of research on the effects of COVID-19 with an emphasis on local case studies in the fisheries and aquaculture sector in countries including China, Indonesia, Malaysia, Thailand, and the United States, there is a lack of global perspective. Understanding how the pandemic impacts the aquaculture sector and the fish supply chain and to what degree the various stakeholders can be supported to overcome this predicament is critical, given the importance of fish as a food source. Given that the aquaculture supply chain involves many actors, from the raw material suppliers to the fish farmers, merchants, processors, importers, and exporters, it is important to comprehend the implications and issues affecting each of these parties. Existing research addressed a wide range of pertinent topics, including the overall impact of the pandemic on small-scale fisheries' performance [159], resilience [52], vulnerability [160], and consumption patterns. However, there is a lack of comprehensive research that assists small-scale fisheries in devising appropriate distribution strategies in different economic, political, geographic and cultural contexts [21]. Finally, more studies are required to evaluate the fishers' knowledge and prevention measures for overcoming the COVID-19 pandemic [163].

5.7.5. Blockchain Technology

The fifth cluster topic refers to blockchain technology's role in increasing sustainability and food safety in the FSC. As one of the cutting-edge technologies in the Industry 4.0 era, blockchain is defined as "*a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records*" [164]. The technology can potentially increase operational excellence by providing complete visibility and tracking of food products across the entire FSC, from harvesting through processing, warehousing, transportation, and retailing [165]. The use of blockchain can have a number of positive effects on the FSC, including increased food safety and security, better quality management, less illegal counterfeiting, and more sustainable supply chain management [88]. The technology can also reduce the need for middlemen, improve inventory management and replenishment practices, and lower transaction costs [166]. Amentae and Gebresenbet [167] argue that a blockchain-based food system ensures food quality and process safety traceability because the technology enables trusted track, trace, and provenance information to the focal company. Iftekhar and Cui [168] point out that existing systems cannot offer sufficient trustworthy information to deal with the existing dangers of the COVID-19 pandemic due to transparency, auditability, and data lock-in issues. However, incorporating blockchain in the FSC helps stakeholders maintain accurate and tamper-proof information readily available at all points in the FSC. Similarly, Rejeb et al. [33] highlights that blockchain can enable consumers to acquire all necessary information and trace food products from their origin. As a result, blockchain plays a critical role in enhancing food traceability and transforming the digitalized FSCs [169]. During COVID-19, the technology can serve as a means to ensure real-time monitoring of food products and to determine their origin and location. Furthermore, the transparent nature of blockchain aids in building confidence between FSC suppliers, consumers, producers, and third parties, which is especially important during the COVID-19 pandemic when cooperation between industry stakeholders is essential. By implementing preventive measures, minimizing waste and operating costs, and improving inventory management, blockchain is expected to help food organizations to become more efficient [166].

To advance an understanding of the potential of blockchain in the context of pandemics and crisis management, future research is needed to examine how governance mechanisms and data standardization issues can be overcome to facilitate the successful integration of blockchain in the FSC [145]. Future studies may also provide additional insights into the combination of blockchain and other technologies (e.g., the internet of things, artificial intelligence, additive manufacturing, etc.) that can improve automation and integration and further enhance the blockchain's capabilities to achieve operational excellence in the perishable food supply chain [165]. Finally, an investigation of technology acceptance by consumers may inform food organizations and industry stakeholders about the enablers and barriers to blockchain adoption during the COVID-19 pandemic and similar crises.

5.7.6. Governance and Innovation

The last cluster discussed the topic of governance and innovation within food systems. It details how the COVID-19 pandemic has resulted in different proposals for novel food governance mechanisms [18]. According to Jiang et al. [138], nations must increase policy communication, restructure the global agricultural and food governance system, and build an efficient collaboration mechanism between local and global governance. Chi Ffoleau and Dourian [144] state that FSC governance is a critical factor in impact assessment; thereby, there is a need to develop new forms of agri-food governance to ensure sustainability, create power balances, and promote fair trading in the FSC. Similarly, Khan et al. [161] asserts that responsible governance of tenure security and access can reduce gender inequalities and resolve women's inequalities in the aquaculture value chain. The cornerstone of effective FSC governance is innovation, since more investment in agricultural research and development activities can lead to the development of climate-smart farming systems. Innovation fosters sustainability, leverages emerging technologies to minimize carbon emissions, and enhances nutrition, including a consideration of the role of new sources of protein from insects and plants [12]. Moreover, in light of the direct effects of the pandemic, it is noted that the food industry urgently needs innovative and technological solutions, particularly concerning food safety, food security, and food system sustainability [10]. Internet and communication technologies, implementing blockchain technology in the FSC, applying Industry 4.0 in the food system, and research-based food production and consumption alternatives such as plant-based and lab-grown food products are examples of potential innovations [10]. Related to this cluster's topic, future studies' key contribution will be examining the governance issues arising from implementing innovative technologies in the FSC during potential shocks and disruptions [159]. Additional studies are also required to understand governments' role in shaping innovation in food supply stability during pandemics [18]. There is still a lack of studies on the governance mechanisms necessary to enhance information visibility and flexibility in FSCs during the COVID-19 pandemic. A research question worth addressing is how public policies can benefit from innovation and coordination between governance systems to empower FSC stakeholders and overcome the dysfunctions within the FSC during the pandemic.

6. Discussion

The global FSCs are very complex, and the current COVID-19 pandemic has shown how vulnerable they are by disrupting the vital flow of food products from farmers and producers to final consumers. The social and economic effects of the pandemic can be seen all across the world. FSCs have been impacted hard by hazards ranging from humanitarian concerns to an unstable business climate. There has been a particularly serious threat to the food supply throughout the COVID-19 pandemic. The four tenets of food security, namely, accessibility, availability, stability, and utilization [19], have been severely influenced by the pandemic [170,171]. The executive director of the World Food Programme has warned that this global health crisis has the potential to become a famine if nothing is done to stop it. Likewise, disruptions in FSC activities (e.g., production, processing, shipping, distribution, marketing, etc.) have a negative impact on food security and affordability. As a result,

to prepare for the future post-COVID-19, the food industry can learn several valuable lessons from the current pandemic. The goal of this paper was to employ bibliometric methods and scientific mapping to investigate the impacts of COVID-19 on the FSC. To this end, 287 papers have been published on the topic of COVID-19's effect on the FSC, suggesting a rise in the number of articles in this area since 2020. Kazancoglu Y. with five publications, Mangla S.K. with four publications, and others have all contributed significantly to the knowledge of this topic by shedding light on various aspects of the FSC's dynamics through time. These scholars have established themselves in prominent academic journals devoted to examining the impact of the COVID-19 on the FSC, such as *Sustainability* and the *International Journal of Logistics Management*. As a result, the editorial boards of journals may want to reach out to the most productive and active scholars to increase awareness of their publications and spark new ideas for research on the FSC and the COVID-19 pandemic. Being cognizant of the most prominent and productive authors within the scientific community can serve as a source of inspiration for new ideas, motivation for teamwork and research collaboration, and impetus for further studies.

The most influential works on COVID-19 and the FSC are those authored by [92–94], each of which has received a total of 243, 189, 127 citations, respectively. These influential publications identified in this study can serve as a suitable jumping-off point for scholars, new scholars, and doctoral students who want to learn more about the conceptual underpinnings of FSC research and its evolution with the unfolding of the pandemic.

In addition, WorldFish, with eight publications, followed by the International Food Policy Research Institute and China Agricultural University, with six publications each, have attempted to advance the field by promoting research on the topic. As these institutions have made substantial contributions to FSC research, it would be beneficial for future studies to investigate the factors that contribute to these institutions' comparatively high levels of scholarly output. In the future, researchers may apply quantitative and qualitative approaches to dig further into the connections between the growing number of FSC-related studies and factors including government policy to counter COVID-19, the economic situation, social issues, and human capital.

The nations that have contributed the most to the body of literature in this area are the United States, India, the United Kingdom, and China, with 66, 42, 41, and 37 publications, respectively. The leading position of these countries can be explained by several reasons. For example, US food insecurity has risen drastically due to the COVID-19 pandemic [43]. Wolfson and Leung [172] showed that 44% of the surveyed US participants (n = 1478) had trouble obtaining food products. Moreover, a great interest in the resilience of good systems has been sparked by COVID-19 in the United States, including efforts to comprehend how players across the FSC reacted to this systemic disruption, with an eye toward improving the food system's resilience in the face of such threats in the future [173]. Despite being the major producer of numerous food products and commodities and also maintaining a well-structured legislative and institutional system for food distribution, India has faced several challenges, such as food insecurity, hunger, and food losses, during the pandemic [174]. Firms operating in the perishable FSC in India have been under a lot of pressure because of the potential threats to their activities posed by the pandemic, including the unpredictability in demand and supply, insufficient logistics, questionable information credibility, the suspension of economic operations, and the closing of markets [105]. Overall, most of the productive nations enjoy high scholarly influence; thus, global research cooperation should be promoted, particularly for scholars in developing countries. In line with the contention of Narin et al. [175], we posit that excellent research is inherently global. Therefore, researcher mobility may be encouraged to broaden participation in international research cooperation networks, enhance research quality, and strengthen international research partnerships.

The construction of the reference co-citation network results in the formation of four clusters. The focus of the first cluster is on the general impact of the COVID-19 pandemic on FSC systems and agriculture. The literature can be further extended to consider the impact of climate-related crises [137] and the Russia-Ukraine conflict on global FSCs during

the pandemic [176]. The second cluster explored the mitigation strategies and measures required to improve FSC resilience. These include proactive business continuing planning, collaborative management, and financial sustainability [105]. The literature in the second cluster can be broadened by exploring the role of new technologies such as blockchain technology, artificial intelligence, big data analytics, the internet of things, and additive manufacturing in reducing FSC disruption and increasing the sustainability of the food sector [139].

Other research includes the examination of the resilience elements in different FSC operations and possible strategies to enhance organizational flexibility, create redundancy, improve supply chain agility, and strengthen inter-firm collaborations [142]. The third cluster revolves around the risks of the COVID-19 pandemic to worldwide food security. From the perspective of this literature, future studies need to develop food security response policy frameworks to offer solutions for efficiently managing COVID-19 and any such public health situations in the future [138]. The final cluster is essentially related to the influence of the pandemic on seafood systems. According to the literature stream in this cluster, it would be worthwhile to explore the types of necessary responses to absorb COVID-19 disruptions and restore the normal functioning of seafood systems [111]. Research can also provide a set of tools for future practitioners in the fishing industry to develop various monitoring approaches for fisheries' supply chains with the help of emerging technologies. This is crucial to respond to fluctuations in product supply and demand and increase the efficiency of special storage of live or perishable seafood products [21].

The analysis of journal co-citations enables us to tease out three distant clusters with a focus on logistics and supply chain management, food sciences and agriculture, and sustainability. As a result, it is recommended that future researchers publish in journals from their own field and from other disciplines (e.g., marketing, psychology, etc.) to contextualize their findings and advance the multidisciplinary nature of FSC research in the COVID-19 era. Furthermore, the analysis of journal co-citation networks and country co-authorship suggests the need for stronger research collaboration across institutions and countries to enhance research output, quality, and influence. The analysis of the countries' bibliographic coupling network also reveals six clusters capturing the research similarities between countries.

To complement the results of the reference co-citation analysis, we analyzed the results of the article co-citation network. According to this approach, five research clusters were identified with at least one co-citation. The majority of these clusters consisted of the works of Kazancoglu Y. The first cluster concerns the impacts of COVID-19 on the FSC and urban agriculture. The pandemic has prompted discussions about transitioning from relying on long food supply channels to relying on shorter, more local supply channels, such as urban agriculture [151]. The importance of urban agriculture is attributed to several factors, including its role in addressing food security issues and the efficiency of urban agriculture systems in terms of yield per unit area, nutritional value, and short growing seasons [54]. As a result, the growing relevance of cutting-edge agriculture technology in today's urban agriculture has to be emphasized, and educational institutions should play a vital role in preparing the next generation of farmers. Awareness of the significance of this approach, especially for urban food security during pandemics, must be created and maintained via the combined efforts of researchers, government agencies, and academic institutions. Future research should be also devoted to understanding how the long-term collaboration between the private sector, the education sector, and government agencies can promote advanced technologies in urban agriculture and ensure the participation of the urban community in these types of activities.

The second cluster is related to the implications of the pandemic on household income and food security. According to Béné [135], the economic repercussions of the lockdown and movement restrictions are as much important as COVID-19 fatalities, in terms of the security and negative effects of the pandemic. Measures intended to restrict the transmission of the virus have affected household income and FSC activities, including production, trans-

portation, and logistics, thereby resulting in recurrent food price hikes and food insecurity. Related to this cluster theme, future studies can evaluate the impact of pandemics in terms of the trade-off between the health advantages of preventing the transmission of viruses and the severe economic consequences for vulnerable communities and food-insecure families [136]. There is also a need to understand how a limited household income can impact food choices and demand during pandemics [58]. The third cluster sheds light on the FSC disruptions caused by the pandemic in developing nations. Even though the spread of COVID-19 has affected most countries, the pandemic's effects on FSCs in developing and impoverished nations threaten to exacerbate food security and the plight of the poor, who mostly rely on agriculture.

According to Jribi et al. [177], the pandemic has had major effects on developing countries' ability to reach sustainable development goals, especially regarding ending hunger (SDG2) and ensuring sustainable consumption and production patterns (E12). Consequently, future researchers should address the lack of studies examining the impact of the pandemic on small and medium food enterprises in developing countries [178]. Furthermore, measures and strategies to increase developing countries' preparedness for similar catastrophes deserve further attention considering resource scarcity, inflation rates, and economic difficulties [4]. Finally, the articles in the fourth and fifth clusters discuss the risk mitigation strategies to boost FSC resilience and the impact of the pandemic on seafood systems. These themes overlap with the findings of the reference co-citation analysis; thus, the same future research directions apply to these clusters.

Keyword analysis of the selected publications yielded six distinct clusters. The articles in the first cluster, labeled "The impact of COVID-19 on the FSC and agriculture", discuss the disruptions caused by the pandemic in the FSC in terms of food supply, labor shortage, and limited sourcing of raw materials. The second cluster, labeled "FSC resilience", contains articles that discuss the need to increase resilience to combat the adverse implications of the pandemic in the food industry. Organizations are incentivized to improve their supply chain resilience to prepare for potential unforeseen events associated with the pandemic and to recover from disruptions while keeping operations running as usual. The third cluster, "Food waste and insecurity", highlights the increase in food waste and insecurity during the COVID-19 pandemic due to changes in consumer behavior and lifestyle habits. The fourth cluster, which is labeled "Fisheries and aquaculture", deals with the impact of the pandemic on fisheries and aquaculture activities. Farmers are the participants who are most exposed to the disruptions of the pandemic, since they are responsible for a substantial financial investment that is subject to a wide range of potential hazards, lower production, higher mortality of fishers, and market fluctuations. The fifth cluster relates to the potential of blockchain for developing sustainable and traceable FSCs during the COVID-19 pandemic. Finally, the sixth cluster contains articles that discuss governance and innovation as a means to withstand the different sets of constraints that the pandemic has placed on FSCs. In addition to the in-depth analysis of these clusters, several knowledge gaps and future research opportunities were highlighted.

In a nutshell, FSC research has drawn a great deal of interest from various parties, including academics, universities, and research centers. As far as the authors are aware, this is the first study to attempt to map out the intellectual structure of the FSC research during the COVID-19 pandemic and the outcomes accomplished so far. Researchers in various academic fields can benefit from a deeper knowledge of the numerous perspectives that have shaped the intersection of FSC research and COVID-19. Researchers can also seek guidance from this study to learn about the current knowledge gaps and potential research directions. Our research may help them to initiate fruitful research collaboration and identify the most suitable journals for their topics. The bibliometric approach can benefit academics and students at the PhD level, who may use the present findings to learn more about the FSC literature and investigate FSC-related issues in more depth.

7. Conclusions, Implications, and Limitations

The major goal of this article is to provide a synopsis of recent works on FSC research in the COVID-19 context and contribute to the body of knowledge by identifying several gaps and directions for future studies. With the help of bibliometric techniques and a qualitative evaluation of the selected publications, we have determined the most prominent areas of study and uncovered new and exciting directions for future research. In total, 287 publications from peer-reviewed journals were reviewed for this study using performance analysis and science mapping. Based on the initial statistics and the performance analysis—the publications' trend, the most productive journals, authors' productivity and influence, the most productive institutions and countries, the most frequent keywords, and the most influential publications are just a few of the indicators that can be utilized to characterize the current state of the FSC literature in the COVID-19 era. Furthermore, the science mapping analysis reveals several insights regarding reference co-citations, journal co-citations, institution co-citations, countries' co-authorships, countries' bibliographic coupling, article co-citations, and keyword co-occurrence.

Researchers looking into the effects of the COVID-19 pandemic on the FSC may find the review findings useful. However, a lack of studies that provide a comprehensive analysis of COVID-19 in the context of the FSC stands in contrast to the plethora of literature on the subject of the pandemic itself. Consequently, we set out to research the nexus of the COVID-19 pandemic and the FSC to address this knowledge gap.

This study helps scholars, practitioners, and decision-makers comprehend the impact of COVID-19 on the performance of the FSC and draws their attention to the scholarly production, trends, and prospects for developing more sustainable and resilient FSCs to combat the current pandemic. Our findings will aid scholars who are interested in gaining a complete picture of the state of FSC research in the COVID-19 era and the areas that still need inquiry. According to the keyword co-occurrence network results, existing research mostly focuses on the impact of the pandemic on FSC, resilience, and food waste and insecurity. Therefore, researchers should explore practical solutions to ensure FSC resilience, reduce food waste, and increase food security and availability. Furthermore, researchers can improve collaboration with scholars and learn from the most prolific scholars if they can identify the most productive contributors in the research area of COVID-19 and the FSC. In addition, the foundational works identified in this review can provide entry points for scholars interested in exploring under-researched facets of FSC research in the pandemic era.

Moreover, clustering the relevant literature based on the keyword co-occurrence approach reveals the fundamental topics of FSC research and highlights important gaps in our understanding. Blockchain technology, governance, and innovation are also topical areas of FSC research, which compose the fifth and sixth clusters. The role of emerging technologies is evident in minimizing food waste and accelerating the transition toward more sustainable and circular FSCs. As a result, understanding the organizational objectives, operations, and corporate environment can assist practitioners in determining the appropriate business context in which technology-enabled FSCs can be implemented to fight the COVID-19 pandemic. To summarize, the present study adopts a unique approach to synthesizing FSC research in the COVID-19 era, drawing on bibliometric techniques to produce a quantifiable and objective evaluation of the current status of the FSC literature. Despite the growing interest in the impact of COVID-19 on the food industry, to the best of our knowledge, no dedicated and thorough review of FSC research has been published during the ongoing pandemic. Our investigation of the state of the research on this topic and the knowledge gaps can encourage the launch of new investigations and boost international academic output on FSC research in the COVID-19 era.

Despite its significant contribution, a number of caveats exist in this study. One major limitation was that we only used journal articles in the Scopus database. Future studies can include other types of publications (e.g., conference papers, books, chapters, etc.) and alternative scientific databases (e.g., the Web of Science) to confirm and eventually

expand our review findings by unpacking new insights, research perspectives, and trends. Furthermore, our literature analysis is limited to visualizing and tracing FSC research during the COVID-19 era. The results of this review should be supplemented by a detailed systematic or bibliometric literature review that compares the impacts of the pandemic on the food industry and other economic sectors (e.g., the automotive sector). Finally, clustering the literature based on bibliographic coupling can be considered in future studies, because this approach is static and retrospective. Unlike co-citation analysis, which is a dynamic and forward-looking approach [27], bibliographic coupling may provide different clustering outcomes.

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