

Food Cold Chain Sustainability and Resiliency: Bibliometric Analysis and Emerging Trends

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Abstract. The cold chain has a crucial sector that needs to maintain its sustainability and operational resilience. Along with the times, implementing sustainable and resilient cold chains is growing because it will bring positive effects. Some bibliometric analyses still focus on green, digital, and sustainable supply chains, and there is no detailed discussion of sustainable and resilient cold chains. This analysis aims to provide a bibliometric analysis of the sustainable and resilient cold chains so that the latest developments, trends, and research gaps that need to be resolved can be known. This research uses the bibliometric analysis method using Biblioshiny and Vosviewer using 128 scientific articles. The results show that this topic has an annual growth of 12.26%, and there are 3 interesting research clusters, namely 1) cold chain for food safety through RFID and IOT, 2) cold chain route optimization to improve sustainability through intelligent algorithms, and 3) cold chain model optimization to improve resilience. Based on the major themes obtained, there are various future research opportunities, including adopting smart technology, creating an inclusive cold chain, multiobjective cold chain evaluation, predictive models, decision support systems, early fraud prediction, and evaluating shelf-life commodities.

1 Introduction

Agriculture, fisheries, and livestock commodities are the sectors that act as a source of food for all people in the world, and by 2050, it is predicted that the world's population will reach 9.7 billion people [1]. Based on this, the productivity and sustainability of agro-industrial commodities must be continuously improved. Regarding their characteristics, agro-industrial commodities have two main characteristics, namely, perishable and non-perishable [2]. Fruit, vegetables, fish, and meat are four crucial commodities with perishable properties, while nuts and cereals have good resilience so that they are not easily damaged [3–6]. The perishable characteristics of fruits, vegetables, fish, and meat make the supply chain complex because it must be able to ensure the quality and safety of commodities to be maintained so as not to cause a decrease in the quality of commodities or even cause food waste.

Complex food cold supply chains in perishable agro-industrial commodities cause negative multiplier effects, especially food loss and food waste, if not handled properly. According to the Food and Agriculture Organization, of the total agro-industrial commodities produced, 14% become food loss, and 17% become food waste, with a total loss of 936 billion dollars annually [7]. In more detail, the largest contributor to food loss and food waste was found to come from errors or incompetence in the process of cooling commodities during shipping by producing 526 million metric tonnes of waste, or 12% of the total [8]. This is in line with Heiman and Miller's research, which

states that shipping conditions in the form of appropriate and controlled temperatures will ensure the quality and safety of commodities will always be maintained to reduce food waste produced and at the same time reduce greenhouse gas emissions [9]. Specifically, developing countries such as Indonesia have many failures in food cold supply chain control [10]. Based on these problems, there is a need for visionary solutions in the food cold supply chain to keep commodities with good nutritional value, appropriate quality, and guaranteed safety.

Based on previous research, several solutions have been investigated, ranging from using radio frequency identification and wireless sensor networks for food cold supply chain transparency and improving the traceability of the quality of distributed commodities [11–14]. Research to improve the efficiency of food cold supply chain routes using various genetic algorithms, ant colony optimisation, and particle swarm optimisation is also an interesting solution because it can minimise the costs and reduce the transportation emissions generated [15–17]. Blockchain is also often used as a solution in food cold supply chains because it offers transparency in communication and distribution processes through centralised data. On the other hand, blockchain also has excellent data reliability and data security [18–20]. Research on near-infrared spectroscopy has also been conducted by several researchers to detect early damage to distributed commodities, especially perishable commodities such as apples to salak pondoh [21–23]. This shows that research in the field of food cold supply chain has a very

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interesting development to be discussed in depth and explored further.

This research will provide new findings and is different from previous research; previous research discussed green supply chain management, sustainable supply chain management, and digital supply chain. There is still no research that specifically and in-depth explains the concepts, themes, and subthemes related to sustainable food cold supply chains and resilience through bibliometric analysis. It is hoped that this research can provide benefits to cold chain agro-industry players to broaden their horizons and find out the latest advances in a strong and sustainable food cold supply chain. In addition, it is also hoped that this research can be useful for academics to find out the latest opportunities and trends in research in this field. This study aims to analyse and explore in depth the research publications related to sustainable and resilient food cold supply chains.

2 Methods

Bibliometric analysis is one of the popular methods used to analyse research trends in a field so that blind spots or research that is of less concern can be identified. In addition, bibliometric analysis can also provide information about hot spots or topics that get a lot of attention in research [24]. On the other hand, bibliometric analysis also shows some other important attributes, such as research productivity and research impact. In bibliometric analysis, several software is often used, including Vosviewer, and Biblioshiny through R Studio. In its application, several stages must be passed, including initiating a literature study, data acquisition and preprocessing, conducting bibliometric analysis, keyword analysis, and content analysis and clustering.

Researchers searched for papers relevant to sustainable food cold supply chains and resilience in the literature study stage through international scientific databases, including Web of Science and Scopus. These two international scientific databases were chosen because they have good credibility and are the centres of research publications used by the academic community. To get the appropriate research, criteria and keywords are used in accordance with the criteria. The criteria used are research published from 2009-2024, using English, and by using several keywords, including “cold chain”, “food”, “logistics”, “supply chain”, and “management”. The results of data collection obtained a total of 236 articles with the above keywords. The articles that have been obtained are then sorted, extracted, and pre-processed to eliminate irrelevant articles that do not match the topic and duplicate using Biblioshiny in R Studio so that 128 research articles are obtained.

Based on the results of the curation that has been done, 128 studies are obtained that will be used in bibliometric analysis. The 128 articles were evaluated according to the established criteria, which pertained to enhancements in the cold chain through implementing sustainability and resilience principles within the supply

chain. If the data obtained has been cleaned, then bibliometric analysis is carried out through Biblioshiny in R Studio. The bibliometric analysis was conducted with the aim of exploring the development of sustainable and resilient food cold supply chain research. Bibliometric analysis will present the distribution of research areas, research institutions, and research productivity [25]. This is very useful because it provides new knowledge for researchers to understand the latest trends and provides insights for industry practitioners to implement and developed.

In bibliometric analysis, there are three things that will be analysed in depth: keywords, clusters, and content. Keyword analysis will provide an overview of the relationship between one keyword and another. In addition, keyword analysis is also useful to provide information about the most frequently discussed themes on the topic of food cold supply chain. Meanwhile, cluster and content analysis is carried out to visualize and group the dominant keywords or themes in the form of a heat map so that it is easier to understand.

3 Results and Discussion

3.1 Performance

Performance analysis is the first thing that needs to be done to know the outline of research development in the field. Based on the results of the analysis carried out, several things are used to measure the performance of topics such as total research produced, total citations, average citations per year, total researchers, and the development trend of the number of studies conducted from year to year [26].

In the period 2009-2024, there were 128 publications or an average of 8.53 publications per year from 95 journal sources. The total citations obtained on this topic were 2755, with an average citation per publication of 21.52 and an average citation per year of 183.67. Research on this topic in total was conducted by 351 researchers with details of 7 publications produced by individuals and 121 publications prepared by groups. Based on the data above, the collaboration index is 2.742, and the collaboration coefficient is 0.635. The first publication in this topic area was identified in 2009; in 2012, it became the lowest year of research publications in this area, while 2022 became the highest year of research publications in this field. Based on the above, the annual growth of this research is 12.26%. This shows that the research trend in this topic is experiencing a steady increase, but further research is needed to fill the existing gaps. The details of the summary and visualization of research trends in this field are shown in Table 1 and Figure 1.

Table 1. Descriptive analysis of research documents

Component	Description	Result
Publication	Total number of research publications in related fields	128
Publication Period	Active period of research publications in related fields	2009-2024
Productivity	Publication/period	8.53
Source	Total number of journal sources in related fields	95
Total Citation	Total number of citations in related fields	2755
Average Citations per Document	Total citation/publication	21.52
Average Citations per Year	Total citation/period	183.67
Total Author	Total research authors contributing to the field	351
Single Author Publication	Individual research publications	7
Group Author Publication	Group research publications	121
Collaboration Index	Total author/publication	2.742
Collaboration Coefficiency	(1- (publication /total author)	0.635

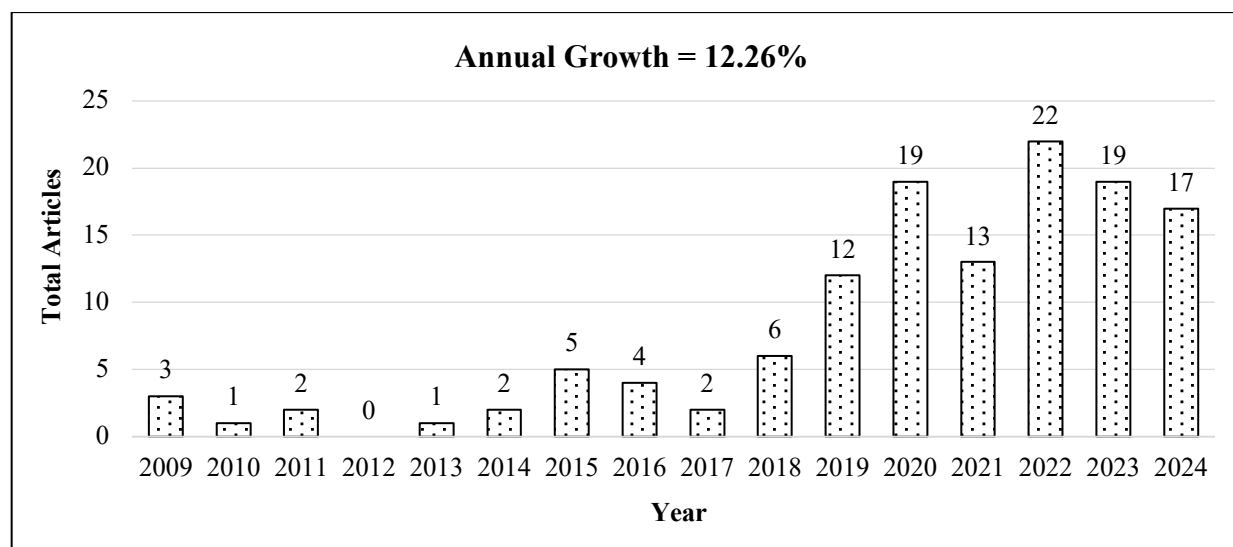


Fig. 1. Year on year publication trends

3.2 Science Mapping

In the mapping section, several identifications are made, including citations of published scientific articles, researchers, journals, countries, and keywords to determine the influence and impact. Citation is used to indicate the quality of research written, and keywords show the relationship between one research and another [27]. In the citation indicator, two things will be analysed, namely global citations and local citations. Global citations mean all citations obtained from all research spread across the internet, while local citations are citations obtained from 128 articles involved in this study. This will be able to display the best articles by showing their influence.

Based on global citations, research conducted by Pournader et al with the title “Blockchain Applications in Supply Chains, Transport, and Logistics: A Systematic Review of the Literature” became the literature with the highest global citation with 546 global citations [28]. Followed by the research of Jedermann et

al. entitled “Spatial Temperature Profiling by Semi-passive RFID Loggers for Perishable Food Transportation” with 215 global citations [29] and research by Wang et al. with the title “Optimization of Location–Routing Problem for Cold Chain Logistics Considering Carbon Footprint” ranked third with 130 global citations [30].

Based on local citations, Wang et al. research entitled “Optimization of Location-Routing Problem for Cold Chain Logistics Considering Carbon Footprint” is the highest with 12 local citations [30]. Followed by research by Wang et al. with the title “Optimization of Vehicle Routing Problem with Time Windows for Cold Chain Logistics Based on Carbon Tax” with a 10 local citation [31] and the third highest local citation was achieved by the research of Zhao et al. with the title “Cold Chain Logistics Path Optimisation via Improved Multi-Objective Ant Colony Algorithm” with 8 local citations [32]. The complete 20 best articles in terms of total global and local citations on the topic of sustainable food cold chain and resilience are presented in Table 2.

Table 2. Top 20 scientific articles based on global citations and local citations

Ranking	Articles	TGC	Articles	TLC
1	Pournader, 2020, Int J Prod Res	546	Wang, 2018, Int J Env Res Pub Health	12
2	Jedermann, 2009, Comp Electr Agr	215	Wang, 2017, Sustainability	10
3	Wang, 2018, Int J Env Res Pub Health	130	Qin, 2019, Int J Env Res Pub Health	8

4	Zhang, 2019, J Clean Prod	111	Zhao, 2020, IEEE	8
5	Liu, 2020, Resour Conserv Recycl	106	Leng, 2019, Sustainability	6
6	Qin, 2019, Int J Env Res Pub Health	105	Xiao, 2012, Comp Oper Res	6
7	Shen, 2018, Int J Env Res Pub Health	73	Dukkanci, 2019, Comp Oper Res	5
8	Leng, 2020, J Clean Prod	70	Leng, 2020, Plos One	5
9	Zhao, 2020, IEEE	61	Leng, 2020, J Clean Prod	5
10	Tirkolaee, 2020, Comput Intell	59	Wang, 2018, Energies	5
11	Chen, 2019, Sustainability	57	Chen, 2019, Sustainability	4
12	Wang, 2021, Trends Food Sci Tech	58	Demir, 2011, Transport Res	4
13	Yang, 2021, Elect Commer Res App	55	Govindan, 2014, Int J Prod Econom	4
14	Zhou, 2020, IEEE	54	Leng, 2019, Int J Env Res Pub Health	4
15	Mara, 2021, Int Trans Oper Res	52	Liu, 2020, Resour Conserv Recycl	4
16	Yang, 2021, Elect Commer Res Appl	52	Meneghetti, 2015, Int J Prod Res	4
17	Perdana, 2020, Heliyon	51	Mercier, 2017, Comp Rev Food Sci Saf	4
18	Arduino, 2015, Marit Policy Manage	38	Shen, 2019, Int J Env Res Pub Health	4
19	Shen, 2019, Int J Env Res Pub Health	36	Toro, 2017, Comp Indust Eng	4
20	Leng, 2020, Comp Oper Res	35	Zhang, 2019, J Clean Prod	4

Note: TGC = total global citation = number of citations received in the database, TLC = total local citation = number of citations received within 128 articles (dataset used in this study).

This research analyses the sources selected by researchers to determine the potential of a publication site. In total, there are 95 sources analysed, and four main indicators will be used to measure the impact of a source, including the H-index, G-index, total citations, and total publications of a source. The H-index is a metric used to measure the impact of a scientific article or journal by measuring the number of publications by the number of citations. Meanwhile, the G-index is a perfect parameter or indicator that is considered the most accurate because it can measure the number of publications and the distribution of citations of a scientific article or publication source [33].

Based on the source of publication of scientific articles on the topic of sustainable food cold chain and resilience, when viewed from the H-index, Sustainability is the highest journal with 7 H-index, followed by the International Journal of Environmental

Research and Public Health with 6 H-index, and Journal of Cleaner Production with 3 H-index. Regarding G-index, the Sustainability journal is the highest with 13 G-index, followed by the International Journal of Environmental Research and Public Health with 7 G-index, and IEEE with 4 G-index. On the other hand, in terms of total citations, the International Journal of Production Research is the highest journal with 546 citations, followed by the International Journal of Environmental Research and Public Health with 384 citations, and Computers and Electronics in Agriculture with 215 citations. Meanwhile, regarding total published papers, the Sustainability journal is the highest with 15 publications, followed by the International Journal of Environmental Research and Public Health with 7 publications, and IEEE with 4 publications. The complete 10 best publication sources on this topic based on G-index are presented in Table 3.

Table 3. Top 10 publication sources based on several indicators

Ranking	Sources	H-Index	G-Index	Citation	Articles
1	Sustainability	7	13	173	15
2	International Journal of Environmental Research and Public Health	6	7	384	7
3	IEEE	2	4	115	4
4	Journal of Cleaner Production	3	3	194	3
5	Industrial Management and Data Systems	2	3	61	3
6	Mathematics	1	3	15	3
7	Heliyon	2	2	62	2
8	Expert Systems with Applications	2	2	35	2
9	Plos One	1	2	18	2
10	Research Anthology on Food Waste Reduction and Alternative Diets	1	2	6	2

Note: H-index = number articles cited at least h times, G-index = number articles cited at least g² time

The analysis results regarding the distribution of countries contributing to the topic of sustainable food cold chain and resilience: in total, there are 31 countries spread across the continents of Asia, Europe, America, and some in Africa. The Asian continent is the dominating region regarding this topic; this is because Asia is a vital region for its contribution to the food system in the world. This is further supported by the development of food cold chain technology in its distribution, which is improving [34].

China is the most productive country by producing 247 scientific articles, then the second highest rank is

Germany by producing 22 scientific articles, and in the third rank with the highest production of scientific articles obtained by South Korea with 21 scientific articles that have been published. Meanwhile, regarding impact through citations, China is still the country with the highest citations with a total of 1247 citations, in second place is Australia with 551 citations, and in third place is Spain with 215 citations. These results show that China currently dominates the development of food cold supply chains, especially in the food sector, as evidenced by the research that has been produced. The research shows that China considers the agricultural

food cold supply chain to be a crucial area to focus on as it has a direct impact on gross domestic product and household consumption levels [35,36]. A visual graph

of the 10 most productive and impactful countries is presented in Figure 2.

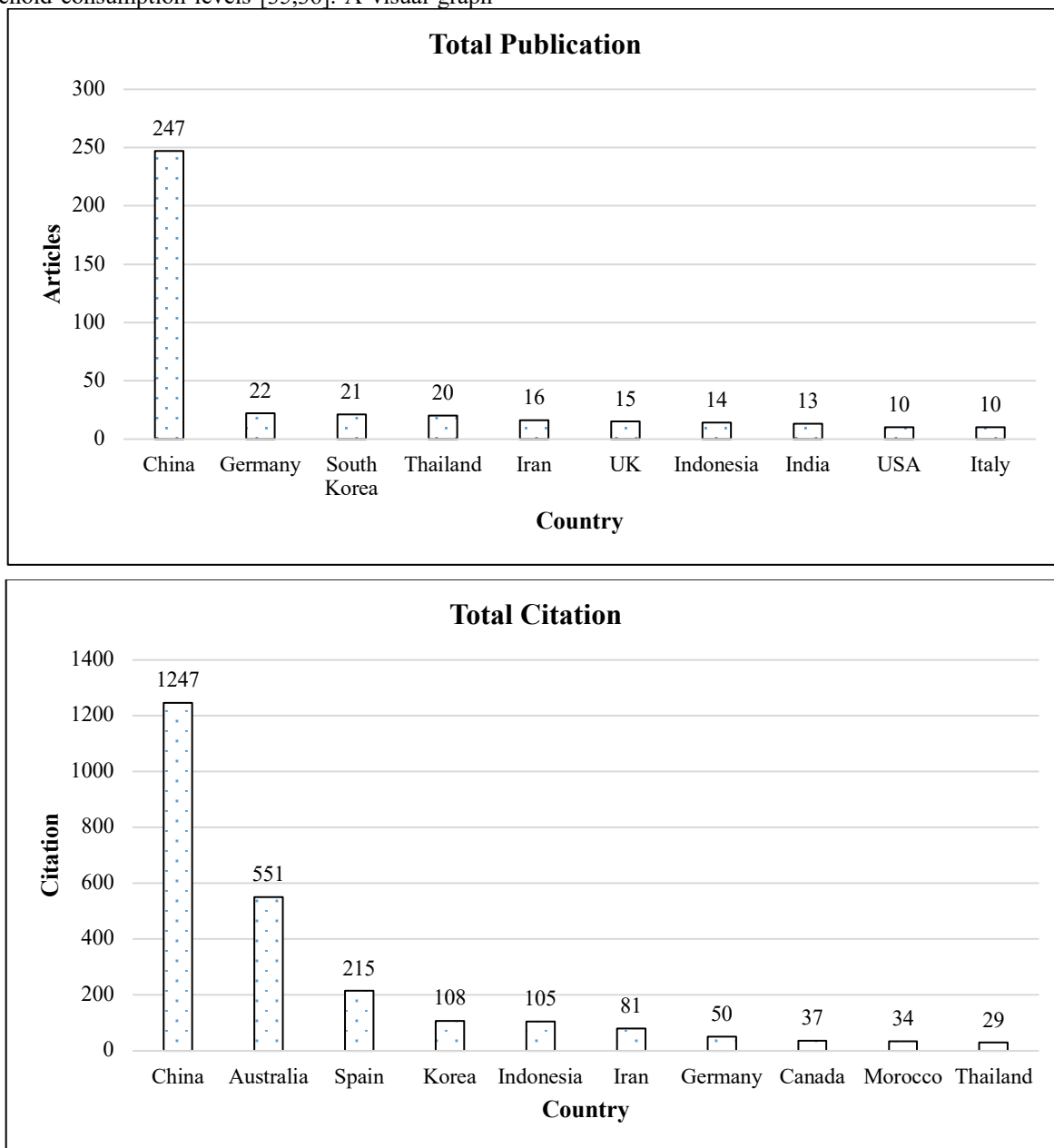


Fig. 2. Distribution of the 10 most productive and impactful countries

The last important thing that needs to be analysed is word analysis through word mining methods from available scientific articles. Word analysis identifies several important factors in a scientific article such as title, keywords, and research abstract. This word analysis allows the detection of words simultaneously so that it can have several benefits, including seeing the relationship between one word and another [37]. In addition, the word analysis was also able to point out gaps and directions for future research [38]. In its application, word analysis will also divide the words into several clusters depending on how often the word is used and how close the relationship between words in scientific articles using Vosviewer software so that a theme will be formed.

Before conducting a word analysis of the available scientific article data, irrelevant words were removed to

provide more accurate results, and then clustering was performed to facilitate clustering. The results show that 37% of the words are in cluster 1, 32% of the words are in cluster 2, and 31% of the words are in cluster 3. Figure 3 shows that 10 most frequently occurring words represent research in this field. Of the 127 articles analysed, the 10 words include “cold chain logistics” with 251 times, “carbon” with 243 times, “carbon emission” with 163 times, “algorithm” with 146 times, “optimization” with 129 times, “logistics” with 126 times, “cost” with 120 times, “vehicle routing” with 113 times, “sustainable development” with 101 times, and “multiobjective optimization” with 89 times.

Based on word analysis, cold chain logistics is the centre of attention by many researchers in the current era. This is followed by environmental issues, especially in reducing carbon emissions that occur

during the distribution process. In solving them, researchers utilise various algorithms that can optimise various objectives such as distribution route optimization, carbon emission reduction, cost savings,

and operational efficiency of the agroindustry to support sustainable and resilient food cold supply chain. The details of the distribution of word analyses that occur are presented in Figure 3.

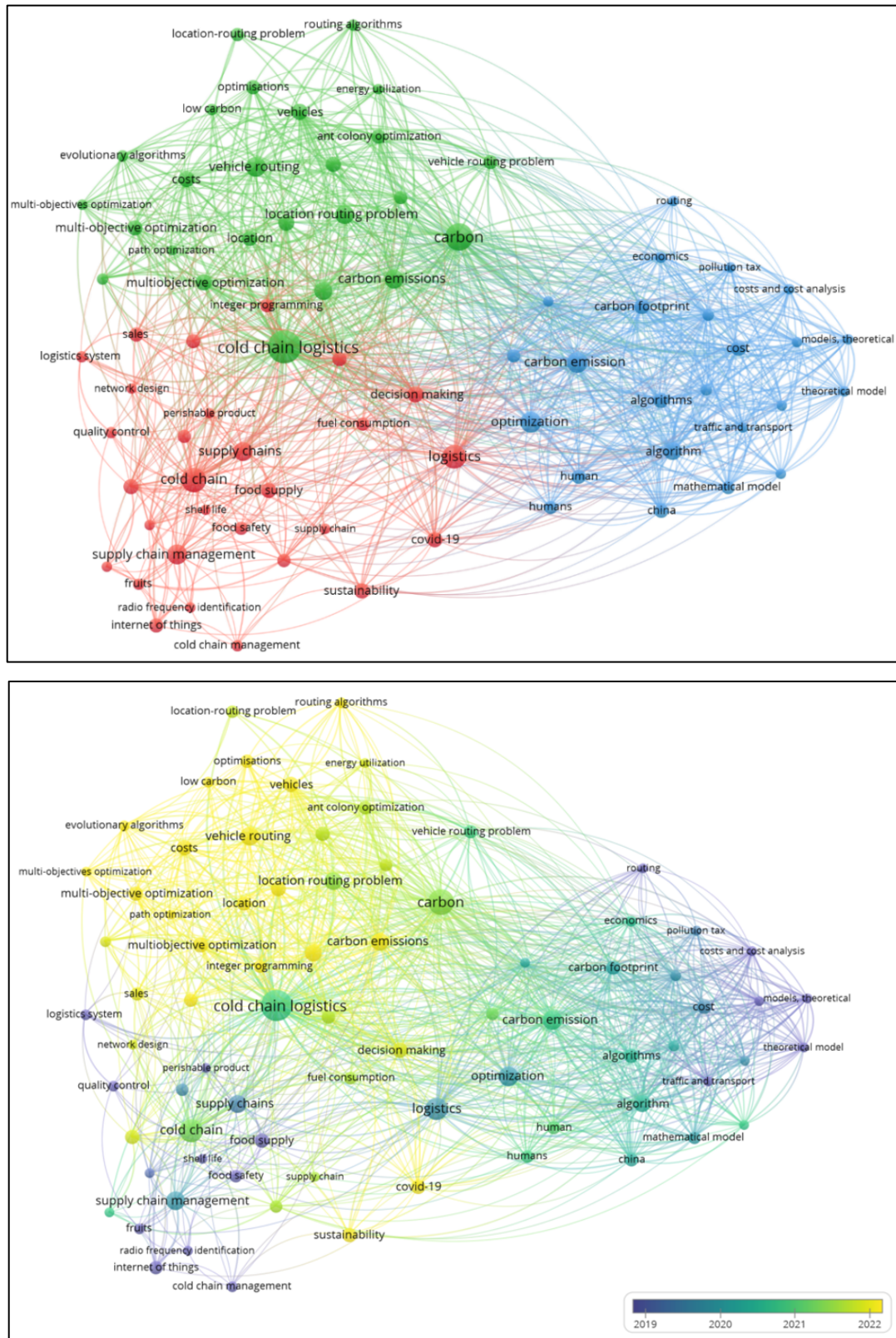


Fig. 3. Research keyword analysis results and development

Based on the results above, the research that has been done is divided into three major themes. Cluster 1 in red shows the topic of food cold supply chain for food

safety through RFID and IOT, while cluster 2 in green shows the topic of food cold supply chain route optimisation to improve sustainability through

intelligent algorithms, and cluster 3 in blue shows the theme of food cold supply chain model optimisation to improve resilience. The three themes above reflect the topic presented: sustainable food cold chain and resilience. Meanwhile, the keyword relationship graph further shows the development of research on the topic of sustainable food cold chain and resilience.

The results of the word analysis above successfully show the major themes that are currently interesting to discuss. In addition, the results of the word analysis also provide a visualisation explanation of the research gaps that need to be filled. Currently, most of the research is directed towards optimizing and tracing food cold supply chain routes for agricultural products to create operational efficiencies, especially in cost savings, emission reduction, resilience enhancement, and sustainability (social, economic, environmental, technological, and legal).

3.3 Collaboration

In this study, collaboration analysis was also carried out to find the cooperation relationship between researchers in the field of sustainable food cold chain and resilience worldwide. Some of the things that will be analysed in this section include collaboration between researchers and collaboration between countries in the world [24]. The results show that 94.53% of the research in this field

is done collaboratively, while 5.47% is done individually.

The results of the analysis of researcher collaboration divide into 3 clusters. In detail, cluster 1 with red consists of 13 researchers, cluster 2 with green consists of 13 researchers, and cluster 3 with blue consists of 11 researchers. Clustering is done based on the similarity of research themes and the relationships between one researcher and another. The larger node formed illustrates that the researcher has a large contribution as well as collaboration with other researchers. In cluster 1, Shi Y became the most productive researcher with 7 publications and 10 collaborations. In cluster 2, Liu C became the most dominant researcher with 3 publications and 3 collaborations. While in cluster 3, Zhang J became the most dominant researcher conducting collaborations as well as being the most productive researcher producing research in this field with 11 publications and 11 collaborations.

Most researchers dominating collaborations hold Chinese citizenship. Therefore, a collaboration analysis based on country of origin will be conducted to examine the relationships that occur between one country and another country in the world to carry out sustainable and resilient cold chain supply chain research. In detail, the mapping of researcher collaboration based on contribution is presented in Figure 4.

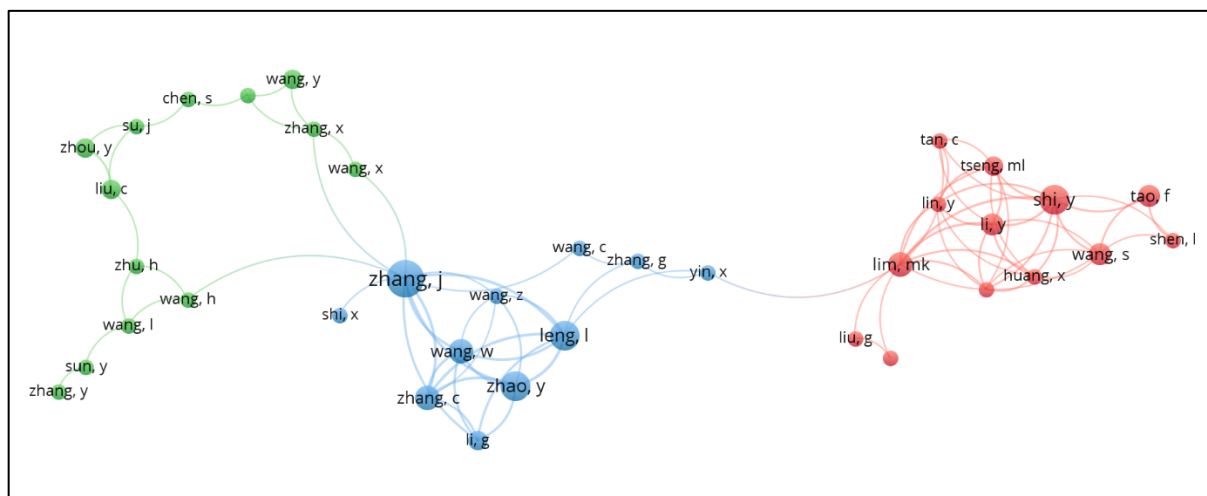


Fig. 4. Results of researcher collaboration analysis based on contribution

Collaboration analysis will also be carried out on research countries to determine the research relationship between countries in the field of sustainable and resilient food cold chains. Of course, the food cold chain is also a topic that needs to be a concern in various countries, especially agrarian countries like China, Thailand, and Indonesia. The presentation of the analysis results is displayed in the form of clustering. It divides the research countries into 3 clusters with details of cluster 1 in red consisting of 9 countries, cluster 2 in green consisting of 8 countries, and cluster 3 in blue consisting of 5 countries.

In cluster 1, China became the most dominant country overall because it managed to produce 75 publications by collaborating with 15 other countries worldwide. In cluster 2, Poland became the most

collaborative and most active European country with 4 publications and 7 country collaborations. While in cluster 3, Germany became a country that became a food cold chain as something important because it managed to publish 10 publications and collaborate with 5 countries.

These results indicate that a sustainable and resilient food cold chain has geographically spread across various countries worldwide, and some countries have even engaged in collaboration. This collaboration between countries is seen as a positive signal and demonstrates that the food cold chain has become one of the most important aspects in the current era, as it will facilitate the exchange of knowledge based on the cases faced. [39]. The mapping of collaboration among countries is presented in Figure 5.

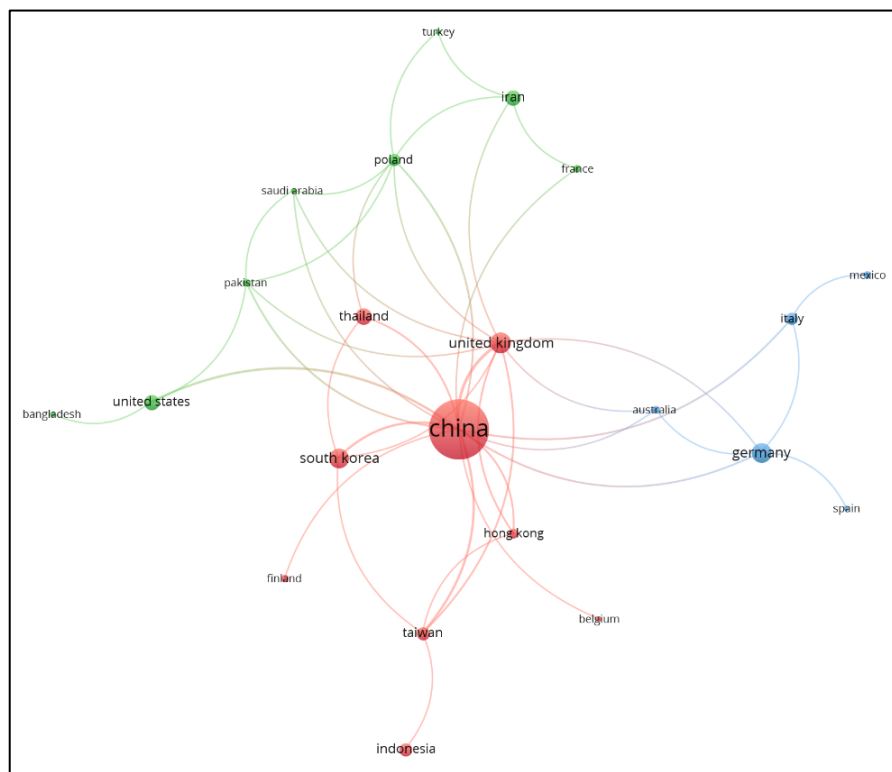


Fig. 5. Results of the analysis of collaboration among countries based on contributions.

3.4 Trend Analysis & Future Research

This study plays a crucial role in analysing the growth of research in the field of sustainable cold chain logistics and resilience based on the growth of keywords used in the selected top scientific articles. In general, it can be observed that the food cold supply chain is increasingly gaining attention. This is evidenced by the growing number of studies focusing on enhancing sustainability and improving resilience within the food cold supply chain.

China has become a pioneer and a country that is highly focused on sustainable food cold supply chains because it believes that a well-managed food cold supply chain can provide a positive multiplier effect across various sectors. Conversely, if the food cold supply chain is not managed properly, it can lead to many negative effects, such as a decline in the quality of distributed commodities, a decrease in the safety of consumable goods, and a significant increase in food waste [40–42]. Researchers from various countries make sustainability and resilience the foundation of their issues.

Several studies utilize technologies such as blockchain and RFID to trace perishable commodities [28,43,44]. There is also research related to multi-objective commodity scheduling systems using intelligent algorithms such as Dijkstra and Non-Dominated Sorting Genetic Algorithm, allowing for timely delivery in accordance with the characteristics of the commodities [45]. One of the most encountered studies in this field relates to route optimization. Optimizing routes for perishable commodities is considered capable of having an impact on the

environment because it can reduce emissions. From an economic perspective, good route optimization can help lower distribution costs, making it more economical. Researchers use various algorithms and modelling in its application, such as hybrid genetic algorithms combined with heuristic rules [30], ribonucleic acid combined with ant colony optimization [46], simulated annealing algorithm [47], cycle evolutionary genetic algorithm [48], particle swarm optimization [49], and dan multi-objective evolutionary algorithms [50].

Another interesting research topic to discuss in the field of food cold supply chains is research related to the use of gas sensors to measure parameters such as CO, NO₂, SO₂, methane, ethane, propane, or volatile components. In its application, this is also combined with mathematical modelling for enhanced transparency and product quality monitoring. This is certainly very good considering that food cold supply chain products are very sensitive, so it will benefit decision-making [51]. There are various methods and sensors used, starting from the quartz crystal microbalance, which is utilized to measure the freshness of apple commodities using aroma parameters [52]. There are also studies that use gas chromatography, liquid chromatography, and sensor arrays to analyse the shelf life of vegetable and fruit commodities by identifying the levels of ethylene contained in perishable goods. Also, chromatography and sensor arrays are useful for detecting pesticide residue levels in a commodity [53,54].

Based on the trend analysis results, it can be observed that topics related to route optimization, travel time, carbon emission reduction, and cost efficiency have been experiencing improvement and growth recently. Meanwhile, topics related to the shelf life of commodities, evaluation of food cold supply chain

performance, predictive models, decision support systems, and intelligent distribution have yet to be explored in depth, presenting opportunities for further

development. In more detail, the research trends in the field of sustainable and resilient food cold supply chains are presented in Figure 6.

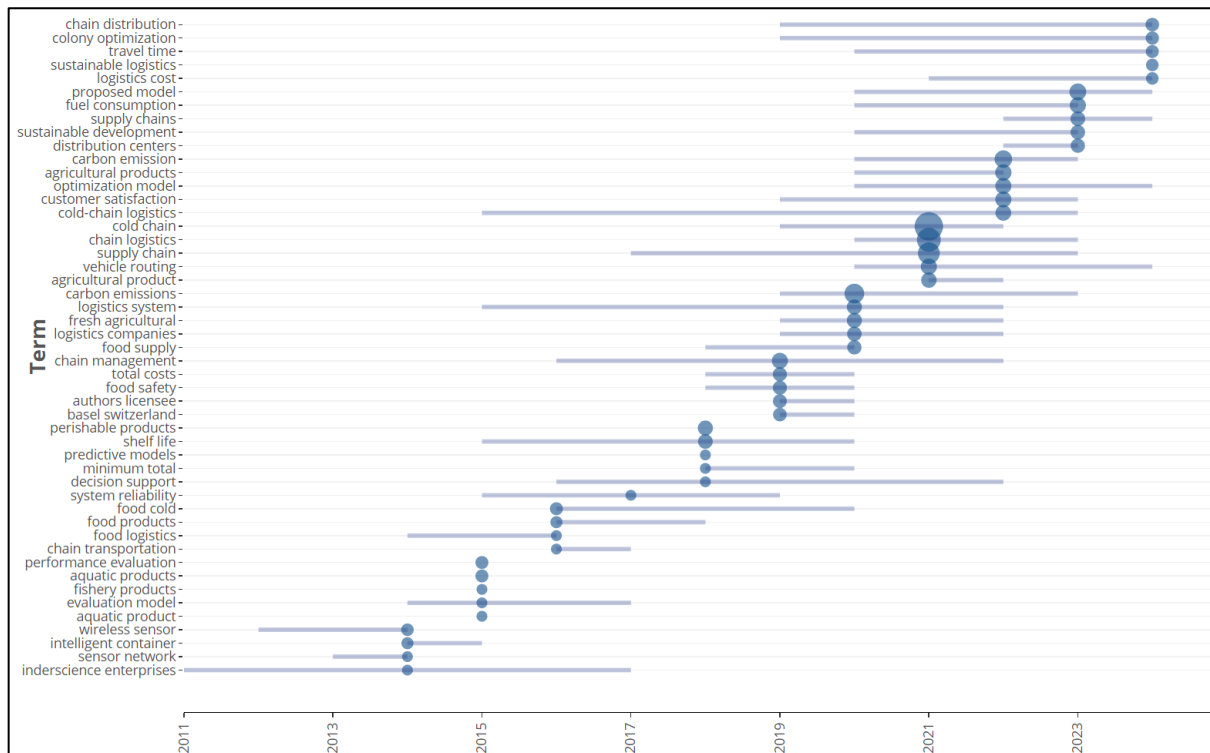


Fig. 6. Research topic trends from 2009 to 2024

Research in the field of sustainable and resilient food cold supply chains needs to be consistently developed to enhance operational efficiency, realize sustainability principles, be adaptive, and reduce undesirable outcomes such as the emergence of agricultural product waste. Several aspects that present opportunities for research development in the field of sustainable and resilient food cold supply chains include the adoption of smart technology, the creation of inclusive food cold supply chains for all industries, multi-objective performance evaluation of food cold supply chains, the development of predictive models in the form of food cold supply chain simulations, research on early damage estimation and shelf life evaluation, and the creation of decision support systems for food cold supply chain stakeholders.

Adopting smart technologies such as blockchain, RFID, digital twin, machine learning, and artificial intelligence has become an intriguing subject for further research. These technologies have a very positive impact as they can provide benefits from upstream to downstream. Blockchain and RFID can enhance traceability and transparency, minimize fraud, and improve efficiency [55]. Although in the implementation of blockchain, costs become a challenge [56]. However, there is hope for alternatives through further research to address the issue. On the other hand, machine learning, digital twins, and artificial intelligence can also support decision-making, optimize processes in food cold supply chain commodities processes, and simulate food cold supply chain processes to anticipate unexpected events [57,58]. The

analysis of technological readiness, the combination of intelligent algorithms, and the testing of technology accuracy can be carried out next.

The second interesting aspect to research further is the development of an inclusive food cold supply chain that can be applied by many agricultural industries. Large industries can only enjoy the majority of food cold supply chain implementations because their implementation requires complex infrastructure and high costs [59]. There is a need for a food cold supply chain simulation, the design of an inclusive food cold supply chain, needs analysis, and feasibility analysis.

The third aspect that needs further examination is evaluating the food cold supply chain, which can be developed by studying several objectives or aspects such as economic, social, environmental, technological, and legal factors in agricultural and fishery commodities. Most existing food cold supply chain research only provides an overview of each aspect but has not offered a comprehensive evaluation. The fourth aspect that can be researched is the evaluation of the food cold supply chain based on the types of commodities, as each perishable agricultural commodity has its own characteristics, necessitating further study on this matter.

The fourth aspect is the creation of decision support systems and predictive models in the food cold supply chain. Research in this area is essential as it will help agricultural industry players predict future uncertainties while also making the right decisions. The last aspect that needs thorough investigation is estimating early damage and shelf-life evaluation for specific

commodities. Estimating early damage and evaluating shelf life for specific commodities will assist agricultural industry players in providing the appropriate treatment for these commodities, ensuring that the quality of the distributed products remains well-maintained and consistent.

4 Conclusion

This research successfully provides a comprehensive bibliometric review that includes recent developments, trends over time, and research gaps that need to be addressed on the topic of sustainable and resilient food cold supply chains. The study offers several insights, including: (1) research in the field of sustainable and resilient food cold supply chains has shown consistent growth year after year, (2) Sustainability has the highest number of published documents, while the International Journal of Environmental Research and Public Health has the highest citations, (3) China, Germany, South Korea, Thailand, and Iran are the countries with the most published documents, whereas China, Australia, Spain, South Korea, and Indonesia have the highest citation counts, (4) the keyword “cold chain logistics” is the central keyword, followed by “carbon”, “carbon emission”, “algorithm”, “optimization”, “logistics”, “cost”, “vehicle routing”, “sustainable development”, and “multi-objective optimization”. There are three clusters representing major themes: food cold supply chains for food security through RFID and IoT (cluster 1), optimization of food cold supply chain routes to enhance sustainability through intelligent algorithms (cluster 2), and optimization of food cold supply chain models to improve resilience (cluster 3).

The bibliometric analysis conducted also successfully (5) provided recommendations for future research opportunities, including the adoption of artificial intelligence technology, the creation of an inclusive food cold supply chain for the entire industry, multi-objective performance evaluation of food cold supply chains, the development of predictive models in the form of food cold supply chain simulations, research on early damage estimation and shelf life evaluation, and the creation of decision support systems for food cold supply chain actors. If further investigated, the research gap that has been outlined will certainly serve as a strong foundation for agricultural industry players or policymakers in the future to enhance the implementation or performance of sustainable and resilient food cold supply chains.

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