Food cold chain management: what we know and what we deserve

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Abstract

Purpose – The purpose of this paper is to present a quantitatively supported explanation of the intellectual development, the schools of thought and the sub-areas of the food cold chain (FCC) research to derive meaningful avenues for future research.

Design/methodology/approach – This study builds on bibliometric analysis and network analysis to systematically evaluate a sample of 1,189 FCC articles published over the past 25 years. The descriptive statistics and science mapping approaches using co-citation analysis were performed with VOSviewer software.

Findings – The findings reveal a state-of-the-art overview of the top contributing and influential countries, authors, institutions and articles in the area of FCC research. A co-citation analysis, coupled with content analysis of most co-cited articles, uncovered four underlying research streams including: application of RFID technologies; production and operation planning models; postharvest waste, causes of postharvest wastage and perishable inventory ordering polices and models; and critical issues in FCC. Current research streams, clusters and their sub-themes provided meaningful discussions and insights into key areas for future research in FCC.

Originality/value – This study might reshape practitioners', researchers' and policy-makers' views on the multifaceted areas and themes in the FCC research field, to harness FCC's benefits at both strategic and tactical level. Finally, the research findings offer a roadmap for additional research to yield more practical and modeling insights that are much needed to enrich the field.

Keywords Bibliometric analysis, Food cold chain, Network analysis, Supply chain, Sustainability, Sustainable equality

Paper type Research paper

1. Introduction

Nowadays, cold chain (CC) management plays a significant part in modern global perishable industries. Although multiple definitions have been offered in the literature, it can be described as "the process of planning, implementing and controlling the flow and storage of perishable goods, related services and information to enhance customer value to ensure low costs" (Singh *et al.*, 2018, p. 532). Perishable products require a precise temperature-controlled atmosphere along the entire supply chain (SC), from production to consumer touchpoints. This requirement, commonly denoted as "CC", refers to a post-production SC for perishable and temperature-sensitive goods, and is specifically designed to keep these products in a conditioned environment (i.e., within optimal temperature and humidity range) to guarantee product safety, preserve value and maximize commercial potential (Salin and Nayga, 2003; Joshi *et al.*, 2009; Rodrigue, 2014). The perishability of goods is a key point of this definition. In other words, refrigerated transportation and storage are two fundamental aspects to prevent deterioration of the product quality (James and James, 2010). Transport and storage of non-perishable goods requiring controlled and low-temperature conditions (e.g. art objects) are usually not

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considered a CC (Heap, 2006). Therefore, CC management can be seen as a specific implementation of SC management for perishable goods (Bogataj *et al.*, 2005) adding characteristic features and activities to existing SCs (Kuo and Chen, 2010).

The CC includes a variety of perishable products, namely fresh agricultural products, frozen food, seafood, chemicals and pharmaceutical drugs and photographic film (Allied Market Research, 2019). Regarding end-use, the CC market is classified into five main categories, namely, fruits and vegetables, bakery and confectionary, dairy and frozen desserts, fish and seafood, drug and pharmaceuticals (Liu *et al.*, 2020). This classification integrates two main CC fields, namely, food cold chain (FCC) and pharmaceutical cold chain (PCC) (Herjolfsson, 2019). Although both fields have very diverse packaging requirements (Brenner, 2015), product quality, packaging integrity and punctuality has been worse in FCC as compared to PCC due to better transportation schedules and automatization for pharmaceutical products. In addition, food demand is subject to frequent modifications due to changing customers' tastes, preferences and lifestyles (Aramyan *et al.*, 2007), which is not the case for pharmaceutical products. Similarly, both the FCC and pharmaceutical CC have different regulatory requirements for handling, sorting, and distributing the related products (Ruiz-Garcia and Lunadei, 2010). In fact, pharmaceutical SC disruptions are limited to deviations from production plants, whereas food SC disruptions refer to lower performance overall (Brenner, 2015).

Within the overarching research area of CC management, the FCC is a rapidly growing research field (Bremer, 2018; Göransson *et al.*, 2018) because it prevents food waste, which has numerous detrimental effects. In fact, food waste has not merely economic implications but also social and environmental ones. The world population is anticipated to reach 8.5 billion by the end of 2030 and 9.5 billion by 2050 (UN DESA, 2015). Currently, even with a world population of 7.7 billion (Patierno *et al.*, 2019), some individuals remain deprived of food. Consequently, above 820 million people sleep with an empty stomach every night worldwide (FAO, 2019a). Hence, meeting future food demand seems impossible and pressures food SC (Shashi *et al.*, 2018). Surprisingly, 30% of the total food produced is either lost or wasted globally every year. This is equivalent to 1.3 billion tonnes of food (FAO, 2017a; Özbük and Coşkun, 2019), US$1tn in economic costs, approximately US $700bn in environmental costs, and approximately US$ 900bn in social costs (FAO, 2017a). Besides, this enormous food wastage is a significant contributor to global greenhouse gas emissions and diminishes the productive output of food systems (FAO, 2017b). The carbon footprint of food wastage is about 3.3 billion tonnes of CO_2 (FAO, 2019b). By controlling this amount of food wastage, it would be possible to feed almost four times the number of hungry people with the food wasted worldwide every year (We Eat Responsibly, 2019). In fact, the deterioration of perishable food products can easily cause adverse effects on consumers' health, as well as product price and availability. The raw and ready-to-eat products cause the majority of foodborne illness and uncooked products are the source of cross-contamination (Reed, 2005). Hence, reducing global food waste at production, SC, retail and consumer levels is reflected as one of the goals of the 2030 sustainable development agenda to end hunger and negative impact of food wastage (FAO, 2017a, 2017b; FAO, 2019a).

Based on the pivotal role of the FCC in the food sector, theories and practices have evolved to improve the body of knowledge on this topic (Minner and Transchel, 2010; Aung and Chang, 2014a; Qi *et al.*, 2014; Chaudhuri *et al.*, 2018). Consequently, research on FCC has been growing rapidly by incorporating the attributes of a well-defined scientific domain. Two leading journals even published special issues on FCC in 2018 (Carson and East, 2018; Tsai and Pawar, 2018). Moreover, there are many international FCC collaborations and research groups worldwide fostering the growth rate of this rapidly growing research field.

Given the rise in empirical studies on FCC (Joshi *et al.*, 2010, 2012; Zanoni and Zavanella, 2012; Ucar and Ozcelik, 2013; Shabani *et al.*, 2015; Ali *et al.*, 2018; Gligor *et al.*, 2018), some scholars reviewed the FCC literature from different perspectives (James *et al.*, 2006; Raab *et al.*, 2011; Defraeye *et al.*, 2015; Shashi *et al.*, 2016; Mercier *et al.*, 2017; Shashi *et al.*, 2018; Chaudhuri *et al.*, 2018). These works have provided insights into the field through structured review and classification into future research avenues. James *et al.* (2006) presented an overview of the food transportation system. Raab *et al.* (2011) identified and compared the already existing and novel temperature monitoring solutions in the meat SC. Defraeye *et al.* (2015) summarized recent articles on fresh food package solutions to improve CC performance. Mercier *et al.* (2017) reviewed the current status of commercial CC. Chaudhuri *et al.* (2018) identified the multiple types of data that can be collected and analyzed by CC practitioners. Shashi *et al.* (2018) classified FCC literature into four main parts (i.e. factors affecting negatively FCC, popular methods used for FCC performance evaluation, performance measurement indicators and FCC sustainability concerns) and highlighted the associated research gaps.

The literature lacks, therefore, a study that summarizes holistically FCC research advancements and trends for the benefit of multiple stakeholders. Although extant research has provided deep insights into FCC by mobilizing a great variety of disciplines, theoretical frameworks, methodologies, perspectives and research paradigms, this process has led to a gradual fragmentation of FCC scholarship into several sub-areas, as presented above. The lack of a comprehensive overview of the FCC domain has therefore appeared. This is problematic as it prevents researchers, practitioners and policy-makers alike from navigating through the complex domain of FCC and find relevant knowledge to solve key issues, find meaningful answer to theoretical or applied problems or simply understand the evolution of the field. These issues may relate to the absence of past reviews using complementary analyses such as bibliometric and/or network analyses. These types of analyses are very worthwhile in a research field because they identify both established and emerging areas of research (Fahimnia *et al.*, 2015). In addition, they provide both scholars and practitioners alike with a bird's eye on the state of a research field in terms of authors, countries but also topics and areas of research (Mishra *et al.*, 2018). They also suggest emerging clusters while fostering researchers to collaborate and further expand the current knowledge in the research field (Chen *et al.*, 2010).

Scholars widely acknowledged the imperative role of classifying the research published on an exponentially-growing research field to facilitate researchers and practitioners in

attaining a deeper understanding of the field (Merigó *et al.*, 2016; Blanco-Mesa *et al.*, 2017; Nunen *et al.*, 2018). The application of both bibliometric analysis and network analysis may enable to achieve this aim. Previously, researchers also attempted to conduct bibliometric analysis and network analysis in the SC management domain. In this regard, researchers identify and illustrate major research themes associated with information sharing in SCs (Colicchia *et al.*, 2019), green SC (Fahimnia *et al.*, 2015), low carbon SC management (Shaharudin *et al.*, 2019), reverse logistics research (Wang *et al.* (2017), SC disruption (Xu *et al.*, 2020) and corporate social responsibility for SC management (Feng *et al.*, 2017).

Therefore, to provide a structured and encompassing overview of the FCC research field, this paper provides:

- A review of the literature of FCC dating back to 1995.
- A robust insight into the research field by using bibliometric and network analyses applied to a total of 1,189 publications, to identify key contributing authors, countries, institutions and journals in the field.
- A comparison of the most influential contributions according to the citations.
- Research clusters on articles and authors within the FCC research field.

Therefore, this paper tends to bridge the aforementioned research gap concerning the lack of a comprehensive overview of FCC using a robust analytical approach, by offering the broad qualitative and quantitative insights of FCC research through bibliometric and network analysis methods. Therefore, this review is expected to make considerable contributions to the extant literature for the following reasons:

- It offers a wide overview of the FCC literature.
- It provides significant information for future researchers summarizing the most significant contributions, the most cited outlets (as represented by journals), the centers of excellence (as represented by institutions) and the most prolific and cited authors in this field.
- It identifies the research scopes, research methodologies and empirical issues adopted by this stream of research.

In addition, this study identifies new research streams and perspectives for further investigation that warrant special attention and offers valuable insights for future research.

The remainder of the paper is structured as follows: after this introduction, Section 2 introduces bibliometric and network analysis methods, material collection and selection. Sections 3 and 4 present and discuss the performance assessment and the science mapping results, respectively. Finally, the conclusions and implications present the contributions to theory, managerial practice, and limitations of the study in Section 5.

2. Methods, material collection and selection

2.1 Methods

Bibliometric analysis is a powerful and effective technique used in many disciplines to systematically capture the growth trends, characteristics and advancements in academic literature related to a specific field or topic (Ertz and Leblanc-Proulx, 2018). It offers a structured macroscopic overview of foundational and impactful literature in terms of prolific authors, impactful publications, as well as leading journals, institutions and countries (Merigó *et al.*, 2016; Gaviria-Marin *et al.*, 2019). In this paper, a bibliometric analysis combines research performance assessment and science mapping approaches (Noyons *et al.*, 1999; Cobo *et al.*, 2011).

Research performance assessment means "counting citations of specific papers, for instance, paper pb1 is cited three times (by pa1, pa2, and pa3)" (van Raan, 2014, p. 18). Therefore, citation analysis for research performance includes a wide range of techniques to analyze bibliometric data including keyword frequency analysis, citation analysis, and counting articles by countries, universities, authors and journals (Thelwall, 2008). Research performance assessment will measure, quantitatively and qualitatively (Alcaide-Muñozet al., 2017), the contribution of FCC, as well as the influence of the particular research themes in the FCC research field, with the aim to grasp the dynamics over multiple years of the evolution of FCC research and identifying the sub-fields that are most productive, prominent and impactful.

As a second procedure of bibliometric analysis, science mapping determines how different authors are related to each other (Small, 1999). This methodology shows specifically the structural and dynamic aspects of the scientific domain under investigation (Börner *et al.*, 2003; Cobo *et al.*, 2012). Science mapping uncovers specific patterns hidden in the mass of published knowledge and assists the researcher in interpreting these patterns (van Raan, 2014). Science mapping will thus provide a novel perspective on FCC by revealing the scientific frontiers and dynamic structures of the research field with visualization methods.

2.2 Material collection and selection

In this study, we used Thomson Reuters' Web of Science (WoS) database as a scientific search engine to retrieve bibliometric data on FCC. More specifically, this study uses the WoS Core Collection. The choice of WoS over other databases is motivated by several reasons. First, WoS is considered as one of the leading databases worldwide, because it includes a broad range of publications from different disciplines and research areas, with more than 15,000 high-quality journals and 50,000,000 articles, divided into 251 research categories, and 150 thematic research areas (Gaviria-Marin *et al.*, 2019). Second, although other databases (e.g. Scopus) are more comprehensive, WoS is more selective as it includes only journals indexed by the International Scientific Indexing (ISI) (Yong-Hak, 2013). Therefore, the journals indexed in WoS have their impact scores in the Journal Citation Report (JCR), also run by Thomson Reuters, creating synergies between both tools. It is worth mentioning that while WoS is selective with regards to the quality of outlets, the selection does not regard specific topic areas so that even emerging topics are included. Bibliometric researchers consider WoS to be a relevant database because it provides a set of metadata that is essential for this type of analysis a relevant database for conducting interdisciplinary literature review (Fetscherin and Usunier, 2012, p. 735). In fact, it provides a set of metadata that is essential for this type of analysis, including abstracts, references, number of citations, research collaborations, lists of authors, institutions, countries and the journal impact factor (Carvalho *et al.*, 2013; Gaviria-Marin *et al.*, 2019). WoS has complete and consistently formatted citation information for its

entries (Trujillo and Long, 2018). Also, it provides a unique feature of citation counts, which allows the relative importance of articles out of a large pool to be qualified through the use of an objective measure of influence. The systematic quantitative literature reviews and bibliometric studies in the social sciences field – and somehow also those related to research streams on food SC – typically use one database: either WoS (Handayati *et al.*, 2015; Jose and Shanmugam, 2019; Óskarsdóttir and Oddsson, 2019; Özbük and Coşkun, 2019) or Scopus (Wahyuni *et al.*, 2019) because data homogenization issues emerge when multiple different databases are deployed (Mariani and Borghi, 2019). Dwivedi *et al.* (2011, p. 45) also argued that "restricting the search activities to a single publication database removed many of the potential problems of duplication inherent in the use of multiple data sources." Besides, even authors of literature review and bibliometric studies on research areas that have emerged in the past decade (e.g. blockchain, internet of things, big data analytics) and thus with limited influence, considered WoS and recommended the use of WoS database (Choi *et al.*, 2020; Kamble *et al.*, 2020; Nakhodchi *et al.*, 2020; Prieto-Sandoval *et al.*, 2018). Finally, we perform co-citation analysis using the references cited within sample articles retrieved from WoS. This facilitates the identification of additional relevant literature and scholar communities that may be overlooked in standard approaches to literature search (Trujillo and Long, 2018). Accordingly, in our context, co-citation analysis facilitated the identification of additional relevant literature, not included in WoS database but in other databases (e.g. Scopus, Google Scholar and EBSCO). This enabled us to draw the overall main research topic and trends in the current FCC literature, as well as future research suggestions. Collectively, these reasons suggest that WoS provides more reliable and standardized records than other databases (Falagas *et al.*, 2008). In summary, since WoS represents "the most influential and highest quality journals from a broad variety of disciplines (Tian *et al.*, 2018, p. 150) and constitutes the most suitable database for bibliometric analysis (Gaviria-Marin *et al.*, 2019)," we focused on the WoS database.

A search string of keywords was initially used to search publications between 1985 (first year available in WoS) and 2019. However, through the paper retrieval in WoS, no paper seemed to have been published before 1995 using those keywords. Therefore, we chose 1995 as the starting date instead of 1985, while 2019 as the closing year remained unchanged. This structure accommodates a broad range of search terms to select publications (Tian *et al.*, 2018). The terms ("cold" OR "perishable" OR "fresh" OR "temperature" OR "refrigerated" OR "frozen") AND ("logistics" OR "supply chain*") AND ("food*" OR "fish*" OR "meat*" OR "milk*" OR "seafood*" OR "dair*" OR "fruit*" OR "vegetable*" OR "ice cream*" OR "cheese*" OR "butter*" OR "fresh pasta*" OR "egg*" OR "yogurt*") were used as keywords to retrieve publications that included the terms in the title, abstract or keywords. In addition, both singular and plural relevant terms are combined using asterisk (*) to avoid relevant missing articles.

The process resulted in the removal of those publications that were found to be irrelevant. More specifically, irrelevant publications refer to those articles without any substantial contribution to FCC. An initial sample of 1,779 publications was thus identified and selected. Second, we considered only articles written in English, due to the predominance of that language in scholarly research (Tian *et al.*, 2018). Finally, we chose to consider only journal articles and reviews to foster the reliability of the data, since journal articles undergo a formal double-blind peer-review process. In this regard, conference proceedings, editorial notes, book chapters, book reviews, extended abstracts, technical reports, newspaper articles, consultant reports and reprints were not considered. According to Pittaway *et al.* (2004), Ertz and Leblanc-Proulx (2018) and Shashi *et al.* (2020), the selection of the papers was led by two exclusion criteria and one inclusion criterion. The application of the three criteria was progressive. The *first exclusion criterion* concerns the focus of the abstract and it narrowed the hits to those whose abstract is focused on FCC. The abstracts were read in parallel by two researchers, plus a third one in case of uncertainty. The *second exclusion criterion* concerns the focus of the entire paper. Starting from the selected abstracts, the entire papers were reviewed by the three researchers to ensure the relevancy and applicability to the study. The non-relevant papers discovered in WoS which were not directly linked to the FCC were retracted from our set. Finally, the *inclusion criterion* regards the integration of contributions that were not found through the research string and/or comprised in the selected academic database but were cited in the literature on FCC. Therefore, the inclusion criterion is a validation criterion for the choice of search string and academic database. The "Full Record and Cited References" of the final sample comprising 1,189 relevant articles was downloaded using the "save for other file formats" export function with "Tab delimited (window)" and analyzed through VOSviewer.

3. Performance assessment

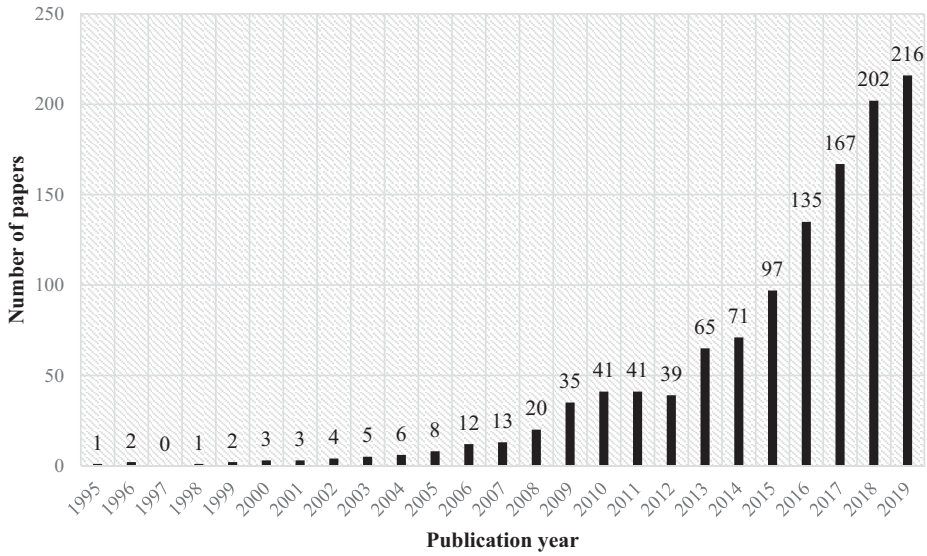
The total number of publications per year from 1995 to 2019 is shown in Figure 1. The results reveal that the first paper included in our sample dates back to 1995. However, the number of papers published started to grow from 1998 onwards. The findings also reveal that the value of the total number of articles published on FCC increased stably from 1995 to 2008 (i.e. 80 articles were published during this 14-year period). In 2009, the number of papers grew by 75% and, for the following three years – up to 2012 – remained fairly stable. However, only from 2013 there is a significant growth of papers published on FCC topic.

Overall, the FCC literature experienced a significant year-by-year growth, with 1,109 published articles between 2009 and 2019. The results may suggest that globally, hunger and food issues have become rising multi-disciplinary and multi-dimensional topics of interest and this is particularly reflected in the FCC literature.

3.1 Country/region, author and institution influences

A particular emphasis on the influence of countries, regions, authors and institutions may grant insights into the development of schools of thought, research hubs and sub-groups of research. Interest at the national or regional level may notably arise among countries or regions that are particularly influenced or dependent on FCC. The influence of authors

Figure 1 Research progress between 1995 and 2019

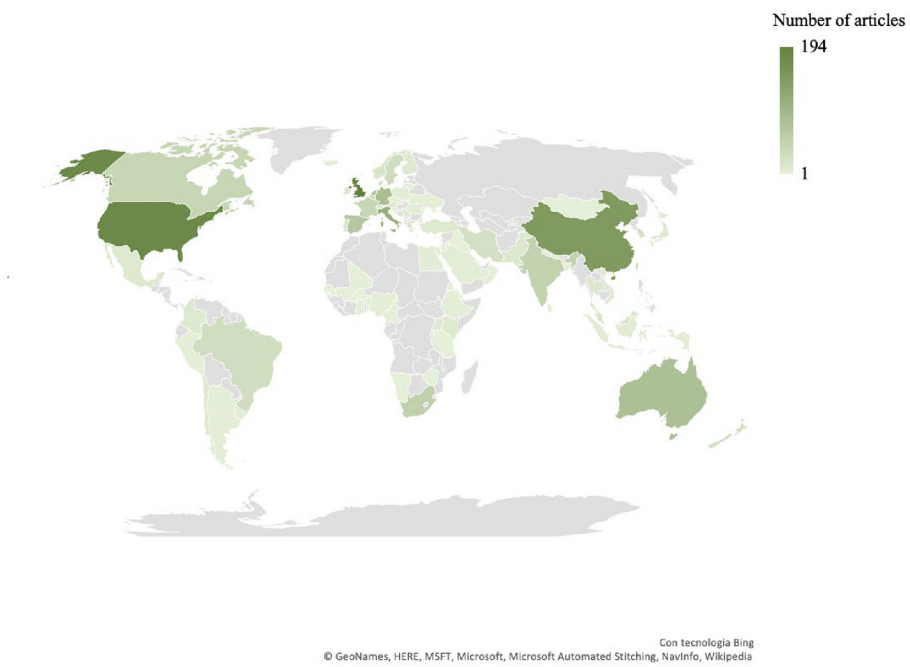


helps defining relationships between disciplines and research interests. FCC is an inter-disciplinary topic and it is interesting to identify those disciplines that have mostly contributed to its recent development. An examination of institutions will provide insights into their influence and collaboration patterns.

3.1.1 Performance of countries and regions

A total number of 85 countries are featured in the 1,189 publications and 22.3% of these countries published only one article. As shown in Figure 2, the USA lead the research on FCC, while China follows closely. The CC infrastructure in the USA is mature and CC transportation facilities availability is approximately 90% for perishable products (Pan *et al.*, 2017). Furthermore, the industry is benefiting from growing online grocery sale which promotes CC developments in the USA (Diego, 2018). In Asia, both China and India are the most productive countries. The extensive population growth in these two countries leads to consider FCC as a critical topic to meet the current food demand and save food for the future. Notably, India is the second most productive country in Asia. However, this is not necessarily well-reflected in terms of number of publications. In contrast, China has approximately 3.5 times

Figure 2 Publication world map



more publications than India. This may be explained by the fact that Indian CC industry is still emerging and the CC potential remains untapped (Bharti and Mittal, 2018). The growth in refrigerated infrastructure and distribution systems within the past few years is promising in this regard, but a fully refrigerated SC is still in its infancy (Dharni and Sharma, 2015; Mercier *et al.*, 2017). Besides, China's CC has been poised for unprecedented growth and benefited from growing penetration of connected devices. Also, the Chinese market has shown potential for growth due to the increasing demand for perishable food items via online channels. Many global CC players are building alliances and collaborative partnerships with China's local service providers (Market Research Report, 2018).

Interestingly, the contribution of African scholarship (except South Africa) is very limited. This is surprising given that there are issues of acute food shortage in several African countries (Trading Economics, 2019). Lack of sufficient and efficient CC infrastructure creates major instances of food wastage in African countries. Meanwhile, fostering FCC research through collaboration between research institutions, academia and other key stakeholders, developing the knowledge networks among researchers and establishing linkages to professional associations, industry bodies and government ministries, are prime necessities of the present time in the region (FAO, 2015). Accordingly, FCC could prevent price inflation by improving storage conditions, hence stabilizing perishable goods and smoothing demand over longer time spans (Bogataj *et al.*, 2005). Besides, according to the Food and Agriculture Organization (FAO) of the United Nations, in Africa, there remains a dearth of research investments and efforts to spawn the unprecedented benefits of FCC sectors in terms of minimizing food waste (FAO, 2016). Meanwhile, it should be stressed that this low number of publications does not account for the share of studies made by non-African academics in Africa. Thus, this aspect could be justified by the fact that African FCC challenges are being partially addressed by non-African researchers (Maertens *et al.*, 2012; Bekele *et al.*, 2017; Sheahan and Barrett, 2017; Heard and Miller, 2018).

With regard to the number of articles published, the first ten countries including the USA, China, the UK, Italy, Germany, Australia, The Netherlands, Spain, South Africa and India, account collectively for 87.46% of the published articles (Appendix 1, part 1). As shown in Figure 2, both the USA and China lead FCC research, with 194 and 178 articles, respectively. Yet, Europe dominates the publication in FCC, as five out of the ten top publishing countries are European.

Part 2 of Appendix 1 shows that the most productive countries are not necessarily the most impactful ones (in terms of the number of citations received). Although the premier publishing nation, the USA ranks second in the number of citations received after the UK. With the slight exception of Canada for North America and South Africa for Africa, all European countries have an equal or better ranking in the number of citations than in the number of publications. Although less productive, European FCC research, appears more influential than FCC research from other regions of the world. The negative gap between the number of articles published and the number of citations received appears larger for Asian countries with the notable exception of Iran. Countries representing other regions of the world (i.e. Australia for Oceania, Brazil for Latin America and South Africa for Africa) follow similar patterns. Likewise, for North America, as represented by the USA.

It is worth mentioning that average values of citations tend to be inflated by a small number of heavily cited papers, which may thus constitute outliers that increase average values. To control this aspect, we present the median value of citations. The results tend to confirm the presence of outliers, as average values tend to be two to three times higher than median values. Besides, the results are consistent with the abovementioned findings suggesting that Europe is more influential than other regions (Appendix 1, Part 2). More specifically, both Finland and Norway are topping the list with 22 median citations each, followed by Greece, Sweden, The Netherlands, Belgium, Denmark, Spain and the UK, respectively.

3.1.2 Performance of authors

The results show that a total of 3,882 authors contributed to the 1,189 sample articles, that is, an average of 3 authors per paper. However, 87.86% of authors have published just one article, suggesting that FCC has essentially been an area of research diversification instead of research specialization (Ertz and Leblanc-Proulx, 2018). Appendix 2 summarizes the 10 most prolific FCC researchers based on the number of articles published as a first author. Notably, in case of equal publications, citations are considered for ranking. The most productive scholars belong to the most productive and influential countries, namely, European countries, and to a lesser extent, Australia. Xiao Xinqing, from China, is the most prolific author with 8 articles published followed by Stephen Wiedemann with 6 (from Australia), and Badía-Melis Ricardo (from Spain) and Kirezieva Klementina (from The Netherlands), with five articles published for each.

With regard to the average number of citations received per article among the 10 most prolific researchers, Sivakumar Dharini from South Africa, appears to be the researcher with the highest number of average citations received per article (56.75), followed by Badía-Melis Ricardo (32.00) and Kirezieva Klementina (25.80). None of the most prolific authors belongs to North American and Latin American institutions, and only one belongs to Asian institutions.

3.1.3 Performance of institutions

A total of 1,475 academic institutions have published on FCC from 1995 to 2019, while roughly three quarters (73.35%) contributed a single article, suggesting that FCC has become an area of expertise in a few key institutions. Appendix 3 reports the top 25 performing research organizations based on both the number of articles published (Part 1) and citations received (Part 2). Based on the number of articles published (Part 1 of Appendix 3), Wageningen University (44 articles), China Agricultural University (37), Ghent University (19 articles), University of Pretoria (18) and Cranfield University (16) are the top 5 most productive institutions. These institutions also belong to the most productive and impactful countries.

The analysis of the number of citations (Part 2 in Appendix 3) shows that the Wageningen University & Research Center, the Cranfield University, the Katholieke Universiteit Leuven (KU Leuven), the Ghent University, and the Technical University of Denmark are the top 5 most influential

institutions. The total number of citations from these publications range from 481 to 1013. Nevertheless, another interesting finding emerged from this analysis.

Among the top 25 in terms of the number of citations, only 7 institutions are extra-European, including 2 institutions from Africa, 2 from Australia, 1 from China, 1 from the USA and 1 from Vietnam. This contrasts with the top 25 most productive institutions, where 11 institutions are extra-European. The results suggest clearly that European scholarship prevails as the most productive and impactful in the FCC research field. When considering the average citations per article, both the British and Spanish institutions, in particular, display the highest scores. Overall, while the average citations per article range between 22.15 and 126.50 in Europe, the variance is lower for institutions outside of Europe with a range of 9.05 to 79.66.

Median citation analysis further confirms that European institutions have published influential FCC research. In this line, University of Birmingham (UK) and Tekniker (Spain) display the highest median values (that are also similar to their respective average values). Other top institutions include the University of York (UK), the Scientific Veterinary Institute Novi Sad (Serbia) and Aalborg University (Denmark). However, the National Institute of Veterinary Research (Vietnam) appeared as an exception as it constitutes a non-European influential institution.

Further refinements taking the QS World University Ranking 2019 [1] suggested that among the top 25 organizations in number of articles, only twenty were listed in the QS World University Ranking 2019 [2]. More surprisingly among them, only two (i.e. Cornell University and KU Leuven) are listed in the World's Top 100 Universities ranking of 2019 [3]. These findings reflect that a large part of the FCC research was not conducted by the top research institutions.

3.2 Journals analysis

We examined the main journals that have published papers on the topic of FCC. Since journals are representative of specific disciplines or multiple disciplines from an interdisciplinary perspective, this examination provides insights into the disciplines that appear to be the most interested in this topic.

The 1,189 articles were published in 458 unique journals. Appendix 4 summarizes the top 25 contributing outlets in terms of number of papers published on the FCC topic. More than two out of five articles (35.75%) (425 articles) were published in one of the top 25 journals. The remaining 764 journals published 64.25% of the papers. While top-tier journals concentrate major research on FCC, about 35.8% of journals have published more than one article on the topic of relevance, indicating that the FCC literature is relatively scattered across various journals.

The distribution of articles across journals shows great diversity in disciplines and journals.

Food Control emerged as the most popular journal with 42 published articles, followed by *Journal of Cleaner Production* (34 articles), *British Food Journal* (33 articles) and *International Journal of Production Economics* (28 articles). These international journals are very diverse in nature and scope. *Food Control* is concerned about food process control and food safety. Specific topics such as quality assurance, risk assessment, hazard analysis, food packaging, processing and manufacturing fit well with the scope of FCC. The *Journal of Cleaner Production* is a trans-disciplinary publication outlet. This journal is directly linked to environmental and environmental sustainability issues such as sustainable products and services, corporate social responsibility, sustainable consumption/development or corporate sustainability. *British Food Journal* is a long-standing journal that fosters a broad and unique interdisciplinary coverage of food-related topics of research. The journal provides an essential communication link between all the sectors of the food industry while informing on topical issues and emerging trends. This journal covers a breadth of topics including food SC and logistics, food quality/safety and food sustainability and economics (e.g. food and water security). The journal has also a large share of publications on marketing, distribution, retailing and consumer behavior. *International Journal of Production Economics* is also interdisciplinary and publishes research on the interface between management and engineering. Topics of particular interest include the whole cycles of activities such as product life cycle analysis, from product research and development to product disposal. The journal also addresses the material flow cycle including supply, production and distribution, in which the FCC research field fits well.

According to Shashi *et al.* (2018), FCC is a crossroad research domain covering different subjects and involving a variety of journals belonging to different countries and publishers. Therefore, it is worth classifying the journals according to their country and publisher to assist researchers in identifying the top publishing countries and publishers of the field (Zolfani *et al.*, 2015). Furthermore, scholars strongly recommended *h-index* (Mingers and Yang, 2017), *SCImago Journal Rank (SJR)* (Gonzalez-Pereira *et al.*, 2010) and the *impact factor of JCR* (Garfield, 2006) as three key measures to assess the journal performance. Appendix 6 summarizes the publisher, country, coverage, *h*-index, SJR score, impact factor and subject categories of the top 25 journals. Appendix shows that among 25 journals, Elsevier emerged as a dominant publisher in the FCC research, followed by Emerald. Appendix 6 also shows that the top 25 journals include ten thematic disciplines that are the most frequently represented.

Regarding ranking of journals in terms of citations, we included in the analysis journals with at least two publications, and consequently, journals with only one published article albeit with a high number of citations did not appeared in the ranking. In this line, the *International Journal of Production Economics* emerged as the most influential journal (1,089 citations) followed by *Journal of Food Engineering* (858 citations), *Food Control* (827 citations) and *Trends in Food Science & Technology* (588 citations). While the *International Journal of Production Economics* is highly impactful in terms of number of citations (1,089), *OR Spectrum* has the highest average number of citations per article (105.50) followed by *Industrial Marketing Management* (97.00) (see Appendix 5). Turning to median citation analysis, the findings confirmed *OR Spectrum (105.50* median citations*)* and *Industrial Marketing Management* (97.00 median citations) as top influential journals, followed by *Environment and Planning A-Economy and Space* (84.00 median citations) and *International Journal of Life Cycle Assessment* (43.50 median citations).

3.3 Articles' citations analysis

The article's citations are considered as an indicator to evaluate their quality and impact, as well as their contribution to theory building. The impact of frequently cited articles is generally considered higher than the impact of less cited articles (Culnan, 1986; Furrer *et al.*, 2008). Citation analysis thus facilitates the identification of the most impactful articles, journals, organizations and countries (Liu, 1993). A total of 27,544 cited references were featured in the selected articles. Appendix 7 summarizes the top 50 cited articles among the sample.

The article entitled "Food waste within food SCs: quantification and potential for change to 2050" published in 2010 by Parfitt *et al.* emerged as the most cited article with 788 citations since 2010 (until 2019), within the data set. This article also displays the highest average number of citations per year (78.8). Furthermore, "Follow the thing: Papaya," published by Cook in 2004, came out as the second most cited article with 243 citations. Interestingly, these two papers were published in journals that did not emerge in the top 25 contributing journals as per number of articles (Appendix 4) or the top 25 cited journals as average citations per article (Appendix 5). This is due to the fact that these journals have contributed a single article to FCC research. Similarly, there are other journals *Green Chemistry*, *Simulation Practice and Theory* and the *Lancet Infectious Diseases*, and that are not specialized in either SC, food studies or agriculture. In fact, the scope of these journals respectively is ecology, mathematics and computer science, as well as medicine. This demonstrates that FCC is inter-disciplinary from its inception and that the development of FCC theory largely benefitted from a variety of disciplines outside of the sole areas of agronomics and logistics.

3.4 Keywords analysis

Keywords summarize the content of an article, but may also include the methods, objectives, purposes and study areas (Tian *et al.*, 2018). According to Keupp *et al.* (2012) and Feng *et al.* (2017), keywords analysis is a quantitative approach to scientifically discover linkages among sub-fields. The greater the occurrence frequency of the keywords, the higher the attention paid to the topic. A total of 5,930 different keywords were identified within the 1,189 articles. Appendix 8 reports the top 20 most frequently occurred keywords. The most frequently cited keywords are relevant to FCC as they include "quality", "supply chain(s)", "management", "model(s)", "temperature", "food(s)", "system(s)", "food safety" and "cold chain(s)", with 181, 176, 140, 133, 117, 111, 109, 105 and 101 occurrences, respectively. Keywords such as carbon emission(s), shelf-life, sustainability, traceability and storage, further show that the FCC appears as a major contributor to environmental sustainability and social responsibility.

4. Science mapping analysis

The science mapping was conducted using network analysis. In recent years, several software tools with different characteristics were developed to conduct network analysis to map science. In this paper, we use VOSviewer to conduct science mapping analyses and more specifically, to perform co-authorship and co-citation analyses. VOSviewer [4] is a freely accessible program widely used for developing and visualizing network maps using bibliometric data (van Eck and Waltman, 2010). VOSviewer provides "a low-dimensional visualization in which objects are located in such a way that the distance between any pair of objects reflects their similarity as accurately as possible" (van Eck and Waltman, 2007, p. 1).

Overall, the two-dimensional visualization map created by VOSviewer includes *items* and *links*. The items are the unit of analysis of the map and may refer to articles, authors, countries, journals or organizations (Rizzi *et al.*, 2014). The size of each item and the font of its label reflect the frequency of occurrence. The higher the item size and the label form, the higher the frequency of occurrence. Items connect via *links* and, if present, they indicate that a relationship between items does exist. For instance, co-citation links suggest links between articles and co-authorship links suggest links between authors. Each link has also certain *strength*, a positive value that may vary depending on the degree to which the relationship between items is strong. The larger the strength of the link, the stronger the co-authorship/co-occurrence/co-citation will be. In VOSviewer, both the *x*- and the *y*-axes of the network visualization do not entail intrinsic significance and therefore the visualized maps can be freely interpreted (Nunen *et al.*, 2018). However, items located close to each other are strongly related, whereas items located far away from each other are weakly related. The items of the network can be grouped into *clusters*. Items in the same cluster reveal their relatedness and similar characteristics. As for the layout and clustering of the map, the association strength normalization method is used for normalizing the strength of the links between items and for visualizing maps (Van Eck and Waltman, 2009).

In this study, we use co-citation analysis with VOSviewer to perform science mapping. Since scientific documents are created by citing earlier scholarly work, the network of citations provides evidence of the intellectual base of a knowledge domain (Liu *et al.*, 2015). More specifically, co-citation frequency and patterns provide clues of knowledge domains as larger co-citation frequencies between articles indicate stronger relationships and groups of highly co-cited articles represent collective knowledge (Feng *et al.*, 2017; Liu *et al.*, 2015). Co-citation appears when both A and B (considering that A and B may be articles, authors or journals) are together cited by C (where C may be an article, an author, or a journal) (Ertz and Leblanc-Proulx, 2018). High (low) co-citations demonstrate similar (different) research themes and interests (Benckendorff and Zehrer, 2013). Co-citation analysis can either be used with authors and/or publications to identify and study the links between authors, articles, journals and countries (Pilkington and Liston-Heyes, 1999). This paper examines two types of co-citation trends: co-citations of cited references and co-citations of cited authors. According to White and Griffith (1981, p. 163), the authors' co-citation analysis may contribute to a better understanding of the intellectual structure in the sciences and "in other areas to the extent that those areas rely on serial publications." In addition, highlighting the importance of the authors' co-citation analysis, Mishra *et al.* (2018) reported that it shows the structural configuration of associations between authors. Conversely, co-citation analysis of cited references connects specific published documents (McCain, 1990). Therefore, the number of identical citing items defines the strength of co-citation between the two cited papers

(Small, 1973). Accordingly, cited articles create the intellectual structure of a research field (Ding *et al.*, 1999; McCain, 1986; Dzikowski, 2018), its structure, dynamics and evolution (Pilkington and Meredith, 2009; Liu *et al.*, 2015). Koseoglu (2016) advocated that the visualization of the co-citation networks can help researchers to clarify the strength of the ties within the entire network and the positioning of a given citation within the field (Koseoglu, 2016). Therefore, co-citation analysis of authors and articles is implemented to identify groups of topics and authors and investigate how they might be related (Chen, 2006).

We provide a detailed explanation of the co-citation analysis methodology for both cited authors and cited references, in Sections 4.1 and 4.2, respectively.

4.1 Co-citation analysis of cited authors

After processing the cited references' data retrieved from 1,189 articles belonging to the data set, we obtained a pool of 31,423 cited authors. This pool was further trimmed down to authors with at least 35 citations, resulting in 74 authors cited 3,881 times. As for articles, a data clustering placed together sets of authors sharing similar characteristics (Radicchi *et al.*, 2004) (Table 1). Figure 3 reveals the four main clusters identified and that "Ruiz-Garcia I" and "Jedermann R" are the most highly co-cited authors (120 co-citations) followed by "Jedermann R" and "Defraeye T" (108 co-citations); "Henson S" and "Reardon T" (91 co-citations); "Jacxsens I" and "Luning PA" (91 co-citations); and "Jedermann R" and "Badia-Melis R" (80 co-citations).

Each extracted cluster comprises a few leading FCC researchers whose inputs have had a profound role in the growth of FCC research. For example, in Cluster 2, Van der Vorst's work specializes in food SC performance improvement and in simulation modeling for food SC redesign; integrated decision-making on product quality, environmental sustainability and logistics, had a substantial influence on authors working on the durability of FCC such as Zanoni or Govindan, both visually close to van der Vorst. Van der Vorst also furthered the application of statistical tools such as planning models, used by Ahumada – another influential author - or optimization tools used by Rong – who specializes in managing fresh food quality. Both are topically close and leading authors in Cluster 2. Cluster 1's influential authors are Jedermann who specializes in intelligent food logistics and to a lesser extent Ruiz-Garcia whose work is also tangential to technology use in agricultural SC. In contrast, Cluster 3 counts mainly supra-national (e.g. FAO, European Commission and WRAP) or national (e.g. USDA) organizations, as influential contributors. Both FAO and WRAP specialize in food waste. Finally, Cluster 4 counts the seminal author Christopher on agile SC, whose visually central position in the cluster shows how deeply connected his work is to those of other authors in the cluster.

4.2 Co-citation analysis of cited references

To develop a better understanding pertaining to the theoretical roots of the sampled articles, we use a co-citation analysis in which the quoted references constitute the key element of analysis. Within the original sample of 1,189 articles, a total of 45,753 cited references were found and further reduced to references with a minimum of 18 citations, resulting in 61 articles cited 1,728 times. The co-citation analysis was performed on this reduced sample. Figure 4 shows how the articles that are the most frequently co-cited are connected together within a single cluster, and the size of the nodes indicates the frequency of citations of the given article by other articles in the reduced data set.

The "Application of planning models in the agri-food SC: A review" published by Ahumada and Villalobas (2009) and "An optimization approach for managing fresh food quality throughout the SC" published by Rong *et al.* (2011) came out as top co-cited articles (both co-cited 36 times). Besides, "An optimization approach for managing fresh food quality throughout the SC" published by Rong *et al.* (2011) and "SC strategies for perishable products: The case of fresh produce" published by Blackburn and Scudder (2009) appeared as second top co-cited articles (both co-cited 31 times). One of these three top co-cited articles is review-based and the other two contributions propose an optimization-based method and

Table 1 Clustering resulting for the most cited authors (number of citations in round brackets)

Cluster 1 (1,215 citations)		Cluster 2 (1,129 citations)		Cluster 3 (871 citations)		Cluster 4 (666 citations)	
Abad, E. (58)	Jedermann, R. (129)	Accorsi, R. (42)	Nagurney, A. (40)	Asche, F. (36)	Gustavsson, J. (60)	Aramyan, L.H. (35)	Manning, L. (39)
Aung, M.M. (55)	Koutsoumanis, K. (56)	Ahumada, O. (128)	Nahmias, S. (48)	Buzby, J.C. (52)	ISO (47)	Christoper, M. (44)	Reardon, T. (90)
Badia-Melis, R. (42)	Kuo, J.C. (35)	Aiello, G. (37)	Osvald, A. (37)	DEFRA (41)	Kader, A.A. (108)	Dolan, C. (38)	Shukla, M. (55)
Baranyi, J. (36)	Labuza, T.P. (51)	Akkerman, R. (50)	Rong, A.Y. (87)	Eriksson, M. (44)	Mean, C. (34)	Fearne, A. (40)	Taylor, D.H. (50)
Beuchat, L.R (41)	Laguerre, O. (42)	Amorim, R. (72)	Soysal, M. (47)	European Commission (48)	Nunnes, M.C.N. (57)	Gereffi, G. (48)	Thakur, M. (36)
Bogataj T. (36) (41)	Luning, P.A. (57)	Blackburn, J. (54)	Tijsken, I.M.M. (34)	FAO (139)	Parfitt, J. (54)	Henson, S. (70)	Trienekens, J. (42)
Dabbene, F. (47)	Montanari, R. (34)	Cai, X.Q. (39)	Van der Vorst, J.G.A.J. (84)	Garnett, T. (46)	USDA (48)	Hobbs, J.E. (44)	Yin, R.K. (35)
Defraeye, T. (61)	Regattieri, A. (35)	Diabat, A. (36)	Wang, X. (38)		WRAP (57)		
Giannakourou, M.C. (53)	Ruiz-Garcia, L. (71)	Govindan, K. (51)	Wang, X.J. (41)				
Hertog, M.L.A.T.M. (63)	Taoukis, P.S. (62)	Goyal, S.K. (38)	Zanoni, S. (35)				
Jacxsens, L. (44)	Xiao, X.Q. (34)	Hsu, C.I. (44)					
James, S.J. (68)		Manzini, R. (47)					

Figure 3 Co-citation network of authors

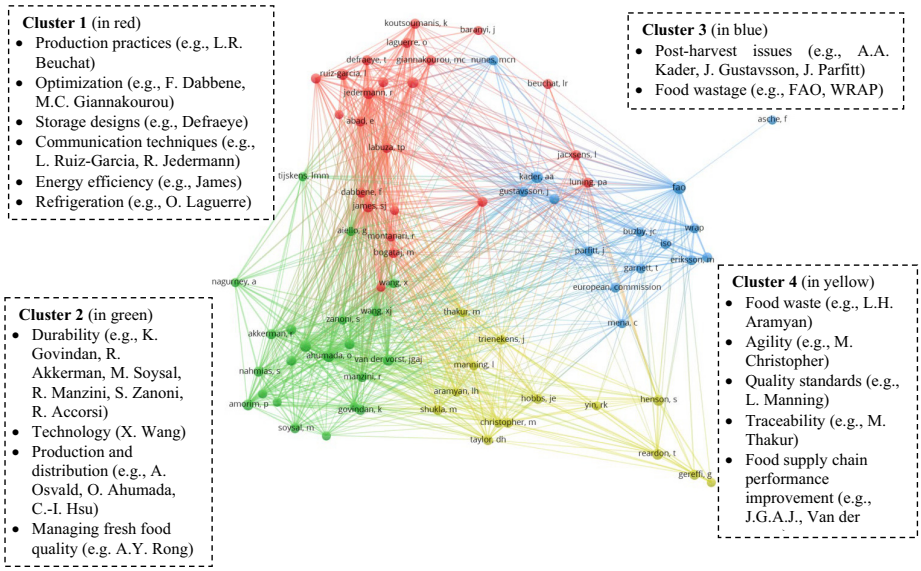
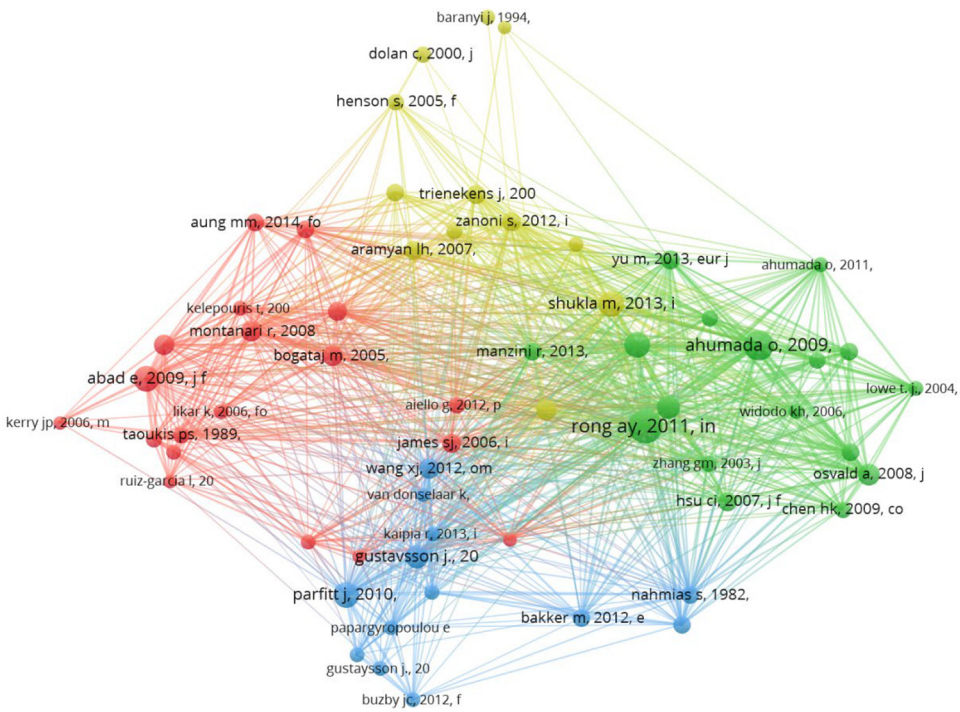


Figure 4 Co-citation network of articles



strategies to improve food freshness in FCC. Besides, they were all published during the stable period ranging from 2009 to 2011, and that makes the juncture between a phase of low publication and a phase of heavy publication (Figure 2). These results show that review and this new technological innovation inspired scholars to reshape their views on the domain, considering under-theorized themes, topics and perspectives, which altogether propelled the domain in an exponentially-growing field from 2012 onward.

According to Hjørland (2013), articles that are often cited in conjunction have a higher probability of sharing the same area of interest. Consequently, a thorough analysis of the articles that are part of a cluster informs on the research area of that cluster. Figure 4 shows four different clusters while Table 2 reports the details of the four clusters. The research areas and the contents of the leading articles were in-depth analyzed to identify the research focus area of each cluster.

Table 2 Clustering resulting for the most cited references (number of citations in round brackets)

Cluster 1: Application of RFID technologies (485 citations)

Abad *et al.* (2009) (50)
Aiello *et al.* (2012) (22)
Aung and Chang (2014a) (27)
Bogataj *et al.* (2005) (35)
Bosona and Gebresenbet (2013) (25)
Hertog *et al.* (2014) (18)
James *et al.* (2006) (30)
Jedermann *et al.* (2009) (22)
Jedermann *et al.* (2014) (21)
Kelepouris *et al.* (2007) (20)
Kerry *et al.* (2006) (18)
Kuo and Chen (2010) (30)
Likar and Jevsnik (2006) (21)
Montanari (2008) (34)
Qi *et al.* (2014) (19)
Regattieri *et al.* (2007) (34)
Ruiz-Garcia and Lunadei (2011) (18)
Taoukis and Labuza (1989) (23)
Tijskens and Polderdijk (1996) (18)

Cluster 2: Production and operation planning models (574 citations)

Ahumada and Villalobos (2009) (68)
Ahumada and Villalobos (2011a) (25)
Ahumada and Villalobos (2011b) (20)
Akkerman *et al.* (2010) (43)
Amorim *et al.* (2012) (28)
Blackburn and Scudder (2009) (53)
Chen *et al.* (2009) (24)
Govindan *et al.* (2014) (24)
Hsu *et al.* (2007) (29)
Lowe and Preckel (2004)(21)
Manzini and Accorsi (2013) (27)
Osvald and Stirn (2008) (37)
Rong *et al.* (2011) (83)
Soto-Silva *et al.* (2016) (22)
Widodo *et al.* (2006) (19)
Yu and Nagurney (2013) (29)
Zhang *et al.* (2003) (19) (22)

Current research in Cluster 1

Benefits of RFID technology for improving the FCC

- Traceability capabilities
- Temperature fluctuations management
- Shelf-life management
- Stocking and transportation functions

Economic and technical challenges delaying the use of RFID

- RFID applications in harsh environments
- Huge volumes of data
- Read range performance of tags
- Fault detection and isolation
- Lack of skilled personnel
- Physical limitations (e.g. water, metals)
- Incompatible standards due to proprietary systems
- Multi-granularity RFID data (e.g. item-level tagging, pallet-level tagging)
- Cost issues
- Trust and cooperation for information sharing
- Integration of chemical sensors on smart flexible tags
- Need for specific recycling programs

Current research in Cluster 2

Programming, simulation, optimization and statistical tools

- Development of algorithms (e.g. heuristic algorithms, Tabu search algorithm)
- Development of simulation (simulation procedures)
- Development of statistical models (e.g. time-windows model, linear programming)

Management and administration tools within a profitability and business-oriented perspective

- Procurement and harvesting planning
- Cost control frameworks
- Food distribution management
- Integrated planning models for production and distribution (e.g. integrated tactical planning model for production and distribution)
- Development of holistic approaches for the design and management of FCC
- Flowering-harvesting frameworks
- Optimization (e.g. multi-objective optimization model)

Cluster 3: Postharvest waste, causes of postharvest wastage and perishable inventory ordering polices and models (342 citations)

Bakker *et al.* (2012) (26)
Buzby and Hyman (2012) (21)
Ferguson and Toktay (2006) (19)
Goyal and Giri (2001) (26)
Gustavsson *et al.* (2011a) (42)
Gustavsson *et al.* (2011b) (19)
Kaipia *et al.* (2013) (19)
Mena *et al.* (2011) (19)
Nahmias (1982) (28)
Papargyropoulou *et al.* (2014) (20)
Parfitt *et al.* (2010) (51)
van Donselaar *et al.* (2006) (18)
Wang and Li (2012) (34)

Cluster 4: Critical issues in FCC (327 citations)

Aramyan *et al.* (2007) (30)
Aung and Chang (2014b) (25)
Baranyi and Roberts (1994) (19)
Cai *et al.* (2010) (20)
Dolan and Humphrey (2000) (23)
Henson and Reardon (2005) (24)
James and James (2010) (23)
Lynch *et al.* (2009) (18)
Shukla and Jharkharia (2013) (51)
Trienekens and Zuurbier (2008) (29)
Van der Vorst *et al.* (2009) (35)
Zanoni and Zavanella (2012) (30)

(***continued***)

Table 2

Current research in Cluster 3		Current research in Cluster 4	
Postharvest wastage management and strategies	• Food loss prevention • Food loss prepare for re-use • Food loss recycle • Food loss recovery • Food loss disposal • Food losses and waste in the food supply chain (agriculture, processing and manufacturing, retail and consumption) • Integrated food waste measurement • Food wastage management for social • responsibility and environmental sustainability • Treatment of food waste fit for human consumption • Treatment of food waste unfit for human consumption	***Approaches for the identification of problematic areas***	• Key indicators of problematic areas • Private standards for the identification of issues • Best practices for the identification of problematic areas • Measurement of problematic issues • Evaluating major issues • Tracing of problematic areas • Controlling of problematic areas
Perishable inventory policies and models	• Ordering policies • Pricing policies • Transportation policies • Recovery strategies by the manufacturer • Financial profitability and economic sustainability	***The negative impact of FCC on environmental sustainability and social responsibility***	• Triple Bottom Line perspective • Product life cycle analysis • Sustainable development • Corporate social responsibility

Researchers belonging to Cluster 1 have provided a thorough conceptual, theoretical and empirical perspective on RFID, a seemingly crucial technology in FCC. The main advantage of RFID for improving FCC is its traceability capabilities (Kelepouris *et al.*, 2007; Regattieri *et al.*, 2007; Abad *et al.*, 2009), temperature fluctuations management (Jedermann *et al.*, 2009; Montanari, 2008; Bogataj *et al.*, 2005; James *et al.*, 2006; Tijskens and Polderdijk, 1996) and shelf-life management (Qi *et al.*, 2014; Jedermann *et al.*, 2014). Other contributions reviewed the potential applications of RFID and demonstrated the various economic and technical challenges delaying the widespread use of RFID in the agricultural and food industry (Ruiz-Garcia and Lunadei, 2011). Importantly, most of these studies take a holistic SC perspective. For example, Aiello *et al.* (2012) framed CC as a pipeline of stocking and transportation functions starting from the farm and ending ultimately at consumer touchpoints, each of these functions being characterized by a deterministic temperature and a stochastic interval in which RFID could provide useful solutions to critical issues. Further with regard to RFID, Kerry *et al.* (2006) evaluated the potential of RFID use for meat and CC of meat products. By contrast, Kuo and Chen (2010) proposed a logistics service model based on multi-temperature joint distribution system for thermal protection in FCC. On another note, Bosona and Gebresenbet (2013) shed light on definition, drivers, hurdles in designing and implementing food tractability systems, paybacks, traceability technologies and related improvements, as well as their performances.

Research in Cluster 2 essentially revolved around the application of production and operations planning models in the context of FCC to resolve the problems of SC and distribution. There are two broad approaches presented in the literature. An important stream of studies focuses on the programming, simulation, optimization and statistical tools to solve FCC-related problems (e.g. stochastic vehicle routing, distribution planning). These include heuristic algorithms (Osvald and Stirn, 2008), simulation procedures (Van der Vorst *et al.*, 2009), Tabu search algorithm (Zhang *et al.*, 2003), time-windows model (Hsu *et al.*, 2007) or linear programming (Rong *et al.*, 2011). Studies in this cluster also analyzed how management and administration tools solve technical issues while maintaining broader profitability and business-oriented objectives. These studies cover agri-food business models on procurement and harvesting planning (Lowe and Preckel, 2004; Ahumada and Villalobos, 2009), cost control frameworks (Blackburn and Scudder, 2009), food distribution management (Akkerman *et al.*, 2010) and flowering-harvesting (Widodo *et al.*, 2006). The contributions by Ahumada and Villalobos (2011a, 2011b) focused on studying FCC from an integrated perspective. In fact, Ahumada and Villalobos (2011a) developed an operational model considering various factors (labor management cost, preservation value of fresh foods, transportations modes and products' quality) for short-period planning decisions. Likewise, Ahumada and Villalobos (2011b) proposed an integrated tactical planning model for production and distribution decisions based on traditional factors (price estimation, availability of resource, price dynamics, product decay, costs of transportation and inventory). Both studies pioneered a subsequent stream of research concentrating on developing multi-objective integrated frameworks (Amorim *et al.*, 2012) some even starting to incorporate sustainability concerns (Govindan *et al.*, 2014). However, such research remained scarce since Soto-Silva *et al.*'s (2016) review of operational research models applied to FCC, confirmed the unavailability of holistic approaches for the design and management of FCC.

Cluster 3 mainly focused on postharvest waste, causes of postharvest wastage and perishable inventory ordering polices and models. Bakker *et al.* (2012) summarized the inventory models with deteriorating items reported since 2001 by revisiting the Goyal and Giri's (2001) review. Ferguson and Toktay (2006) designed frameworks to support a manufacturer's recovery strategy. Mena *et al.* (2011) categorized the food waste roots into three groups: mega-trends in marketplace, general causes and management root causes. In this context, several studies started to frame food waste in the FCC as a sustainability issue. Parfitt *et al.* (2010) – also the most cited article – was one of the first to link food wastage with social responsibility and environmental sustainability aspects. They stressed that food waste reduction can accelerate both economic and social sustainability. Drawing on Parfitt *et al.*'s (2010) foundational paper, researchers subsequently studied the value of food wastage at retail and consumer levels and covered the economic dimension of FCC sustainability (Buzby and Hyman, 2012). For instance, Papargyropoulou *et al.* (2014) examined the factors of food wastage throughout the SC to propose a hierarchy to prioritize the practices to prevent and manage food waste from a triple bottom line perspective (i.e. environmental, social and economic). Albeit not focused directly on sustainability, another stream of research contributed to it indirectly by putting an emphasis on policies to improve food product quality. These include policies to ensure fresh products (Goyal and Giri, 2001), price policies according to shelf life (Wang and Li, 2012), with the overarching purpose of maximizing profits, as well as ordering policies (Nahmias, 1982). In the past decade, research in this cluster also started to harness the power of technology to improve FCC performance. For example, Kaipia *et al.* (2013) argued that efficient information sharing system and prompt deliveries can improve the FCC performance. Similarly, van Donselaar *et al.* (2006) concluded on how intelligence in automated store ordering systems in supermarkets can be enhanced to curb food perishability. Finally, Buzby and Hyman (2012) introduced the discussion of food waste value at the retail and consumer levels as well as economic incentives to reduce food waste in developed nations.

Studies in Cluster 4 were concerned with critical issues in FCC. A critical aspect is the identification of major operational issues (Shukla and Jharkharia, 2013; Lynch *et al.*, 2009), critical success factors of FCC performance (Dolan and Humphrey, 2000), and the subsequent proposition of key indicators to measure, evaluate and trace the evolution of problematic areas (Aramyan *et al.*, 2007). This cluster, therefore, discusses private standards (Henson and Reardon, 2005) and best practices (Cai *et al.*, 2010) to ensure food traceability and safety. In this regard, Trienekens and Zuurbier (2008) discussed the challenges and development of quality and safety standards and underscored that quality assurance will constitute an important aspect of FCC. Quality assurance and technological innovation are key topics to ensure FCC performance. Due to the inherent objective of combating wastefulness, the research in this topic presents some connections with the environmental sustainability research stream. For instance, Van der Vorst *et al.* (2009) provided a simulation tool for designing food SC by taking food quality change and environmental sustainability issues of different scenarios into the consideration. Tangentially close to sustainability, Aung and Chang (2014b) demonstrated the methods implemented for setting optimal target temperature for multi-commodity cold storage and supported that sensor-based methods are superior to traditional visual assessment method. Other contributions argued that the use of refrigerators in CC negatively impacts the environment as they require additional energy (James and James, 2010), while Zanoni and Zavanella (2012) covered the costs pertaining to additional energy requirement to run FCC operations. The debate on the sustainable nature of FCC is ongoing in this cluster but offers promising research avenues in this regard.

4.2.1 Findings and avenues for future research

The four clusters previously identified are analyzed more in-depth in Table 3 in terms of current research and suggestions for future research. The clusters need to be considered in relation to each other. More specifically, as an emerging theme, environmental sustainability needs to be considered as a key objective (Clusters 3 and 4). Yet, to build FCC for environmental sustainability, Clusters 1 and 2 have to be analyzed within the framework of environmental sustainability and to pursue environmental sustainability objectives.

Publications in Cluster 1 revolve around two major axes, namely, the benefits of RFID technologies in FCC and the limitations and challenges related to the use of RFID. Benefits consist of traceability capabilities and temperature fluctuations management. With further technological advancements, especially internet of things (IoT), which is part of the broader Web 4.0 comprising semantic Web, 5 G and cyber-physical systems, many more objects can now be traced and monitored efficiently along the FCC. Future research may therefore put a greater emphasis on the benefits of other sensor-based or wireless technologies in an industry 4.0 context. Besides, autonomous objects self-monitor themselves and implement retroactive actions according to the data sensed in the environment (Mahmud *et al.*, 2018). These intelligent items maybe machinery or transportation means and could thus remotely self-diagnose, self-coordinate or operate autonomously (Borgia, 2014) while providing real-time data about the food, crop or livestock they carry or interact with. This may also contribute to the standardization challenge identified as a limitation in past research (Ruiz-Garcia and Lunadei, 2011) since all connected objects would operate on the standard Web protocol. In fact, Web 4.0, and its corollary the semantic Web and 5 G may contribute to seamless data exchange through multiple devices and networks with the standard Web protocol at its core. Machine learning tools may then be used to analyze the large volume of data generated throughout the SC with those technologies. Besides, remote control of connected objects also means that "firms and users control product functionalities and personalize their experience remotely" (Alcayaga *et al.*, 2019, p. 628). This means greater opportunities for cooperation, trust, information sharing and even coopetition (cooperation between competitors) that may rise to solve the information sharing issues often associated with RFID (Ruiz-Garcia and Lunadei, 2011). Future research should therefore:

- Assess the benefits of technologies related to Web 4.0 and Industry 4.0 for the FCC.

Table 3 Proposed cluster classification with current and future research per cluster

Cluster no. and label	Current research	Future research suggestions
Cluster 1		
Application of RFID technologies	Benefits of RFID technologies in the FCC (e.g. traceability capabilities, temperature fluctuations management, shelf life management)	Benefits of other sensor-based or wireless technologies such as the connected objects or autonomous objects
	Economic and technical challenges delaying the use of RFID	Capacity building by linking the three areas of firm's resources (physical, human and organizational) big data analytics and creative thinking
		Harness machine learning tools to analyze large volumes of FCC data
		Limitations and challenges related to the use of the automated internet of things in the FCC
Cluster 2		
Application of production and operations planning models	Programming, simulation, optimization and statistical tools	Development, combination and comparison of a greater variety of relevant methodological approaches
	Management and administration tools within a profitability and business-oriented perspective	Development of tools for the strategic decision level, as well as tools assisting simultaneously the operational, tactical and strategic decision levels
		Integrated and holistic frameworks for management of FCC
Cluster 3		
Postharvest waste management, causes and inventory policies	Postharvest waste management and strategies	Integrated approach of food waste management across the food SC
		Consumer perspective with consumer behavior models
		Comprehensive food waste reduction strategies including prevention, re-use, recycling, recovery and disposal
	Perishable inventory policies and models	Technological opportunities for "*ex post*" waste management strategies involving food redistribution and waste prevention
Cluster 4		
Identification of major operational issues	Approaches for the identification of problematic areas	Improved measurement capabilities (standardization of norms, standards, best practices for measurement, evaluation and controlling of problematic areas)
		Better measurement for improved forecasts by identifying right issues predictors
	The negative impact of FCC on environmental sustainability and social responsibility	Connection with social responsibility and environmental sustainability

Past research emphasized a great variety of challenges and limitations related to RFID application (Ruiz-Garcia and Lunadei, 2011; Bosona and Gebresenbet, 2013). Future research might therefore focus on building IoT using RFID. This might be done by linking firm's physical capital resources (e.g. hardware, sensors, tags), human resources (e.g. training, education) and organizational resources (i.e. values, culture, processes) – of resource-based theory (Barney, 1991) – to big data capabilities (i.e. analytics capabilities), education and creative intensity, as suggested by Erevelles *et al.* (2016). Therefore, future studies might:

- *-Building IoT using RFID* by linking company resources to big data analytics capabilities and creative thinking.
- - Solving multi-granularity data issues by applying machine learning tools to analyze large quantities of FCC data and at multiple levels (e.g. pallet-level tagging, item-level tagging), to extract meaningful information and intelligence for managerial decision-making.
- - Assessing the value of *autonomous objects and internet of automated things for the FCC.*

Studies in Cluster 2 focus on FCC-specific programming methods, on the one hand, and management tools, on the other. Therefore, future research might grow further along these two axes. First, with regards to statistical tools, past research focused on a wide array of methodological approaches such as linear programming (Rong *et al.*, 2011), simulation models (Van der Vorst *et al.*, 2009), heuristics algorithms (Zhang *et al.*, 2003; Osvald and Stirn, 2008) or metaheuristics (Hsu *et al.*, 2007). Hence, most studies focus on a single methodological approach. Yet, methods and techniques tend to have advantages and disadvantages, thus the focus on any single one of them may not compensate for their limitations (Tufféry, 2011). A wider array of tools may also constitute a fruitful research avenue, to explore problem-solving from different perspectives and with different assumptions. Hence, the research avenues may include:

- Combining different methodological approaches and/or comparing them to solve specific FCC-related issues.
- Using a broader array of methodological approaches including non-linear programming, *stochastic optimization, dynamic programming or hybrid models with different assumptions and postulates to enrich problem-solving capabilities.*

Second, most methodological approaches focus on specific stages or decision variables in the FCC process. Several focus on two or more, such as procurement and harvesting (Lowe and Preckel, 2004; Ahumada and Villalobos, 2009), production and distribution (Ahumada and Villalobos, 2011b; Amorim *et al.*, 2012), flowering and harvesting (Widodo *et al.*, 2006) and some focus only on one stage such as distribution (Akkerman *et al.*, 2010). Studies adopting an integrated and holistic approach including the planting, harvesting, production, distribution and inventory variables, remain scarce. Besides, the proposed modeling approaches focus predominantly on the tactical and operational decision levels. However, focus on the strategic decision level appears not as well-addressed despite the importance of higher-order decision-making. Therefore, future research might consider the following avenues:

- *Developing methodological approaches that adopt an integrated and holistic* framework for FCC-related problem-solving.
- Developing methodological approaches that focus on the strategic levels of decision-making *or alternatively, integrate multiple decision levels including operational, tactical and strategic.*

Research in Cluster 3 focus on specific aspects related to the identification of major operational issues in FCC. One major facet involves the postharvest wastage and perishable inventory management. Currently, research tackles this issue from a great variety of perspectives which has produced a rich body of knowledge on ways to prevent, handle and measure food loss. For example, food losses and waste in the SC are considered from an integrated perspective including agriculture, food processing and manufacturing (Parfitt *et al.*, 2010; Lundqvist *et al.*, 2008). Since Parfitt *et al.* (2010), the study of food waste has started to cover both the retail and consumer levels as well (Buzby and Hyman, 2012). However, as emphasized by Papargyropoulou *et al.* (2014), the adoption of integrated approaches considering multiple stages simultaneously remains infrequent. Besides, the distinction between the retail-consumption nexus remains yet to be more thoroughly made. In fact, retail and consumption are often considered together (Parfitt *et al.*, 2010; Buzby and Hyman, 2012). However, food loss differs in means and magnitude across both stages. For instance, in retail, food loss may arise due to damage during transport, spoilage, poor handling, losses caused by lack of cooling or cold storage (Parfitt *et al.*, 2010). Some retailers also perform secondary processing functions (e.g. mixing, cooking, frying, molding, cutting extrusion), product evaluation (quality control) and packaging (weighing, labeling, sealing), when issues such as process losses, contamination, product discarding, destructive testing, or inappropriate packaging may arise (Parfitt *et al.*, 2010; Papargyropoulou *et al.*, 2014). In contrast, food loss at the consumption stage arises due to over-purchase or inappropriate purchasing, food loss during storage, preparation, portioning and cooking but also confusion over "best before" and "use by" dates (Parfitt *et al.*, 2010; Papargyropoulou *et al.*, 2014). Researchers may adopt a more consumer-centric perspective by considering consumer behavior models such as the model of goal-directed behavior (Perugini and Bagozzi, 2001). Further emphasis should be equally placed on the analysis of a variety of waste handling strategies especially prevention which is the most desirable option (European Parliament Council, 2008; Ali *et al.*, 2019) but also food preparation for re-use, recycling, recovery and disposal, whether with food that is fit or unfit for human consumption. Future studies might therefore consider:

- *Exploring operational issues from an integrated perspective involving all stages of the food SC (i.e.* agriculture, processing, retail, consumption).
- Establishing a clearer distinction between food loss at the retail stage and at the consumer stage and adopt the consumer perspective with consumer behavior models.
- Focusing on the optimal strategy of preventing food waste without neglecting less optimal *solutions including prepare for re-use, recycling/composting, recovery or disposal.*

Research on waste management has been more specifically studied from the angle of inventory policies and models. A broad array of policies has been considered in this regard, including ordering policies (Nahmias, 1982; Goyal and Giri, 2001), pricing policies (Wang and Li, 2012), transportation policies (Kaipia *et al.*, 2013). This approach can be qualified as "*ex ante*" since it seeks to reduce waste at ordering and planning level before food is actually purchased and/or delivered. Some research also investigated manufacturers' recovery strategies (Ferguson and Toktay, 2006). In this vein, a promising avenue of research relates to food waste management from an "ex-post" vantage point, that is, after items have been purchased and/or delivered. Recent technological advances that were not so prevalent over the past 20 years might constitute powerful enablers in this regard. Past research has shown that efficient information sharing systems are powerful means to manage food waste (Kaipia *et al.*, 2013). Likewise, recent studies showed for example how digital platforms acting as "circularity brokers" endorse matching roles to prevent food waste (Ciulli *et al.*, 2019, p. 1). Those typically involve the pairing of providers with obtainers (Ertz *et al.*, 2019). Such initiatives might be further investigated for applicability throughout the FCC:

- *Examining "ex post" opportunities offered by technology in general, and digital* platforms *(circular brokers), in particular, to spur food redistribution and waste prevention.*

Research in Cluster 4 is devoted to the identification of major operational issues. Yet, one of the major aspects to identify those issues and inform adequate decision-making relates to appropriate measurement (Wesana *et al.*, 2019). This involves the identification of key indicators to measure, evaluate and trace problematic areas (Aramyan *et al.*, 2007), standards and best practices (Henson and Reardon, 2005; Cai *et al.*, 2010), as well as quality measurement tools (Trienekens and Zuurbier, 2008). Measurement capabilities should be further developed along these lines with a specific focus on standardization of measurement norms, standards and best practices for measurement. More accurate measurement tools will also enable a more precise identification of factors of problematic issues and thus improve the forecasts by identifying the right predictors:

- Improved measurement capabilities (standardization of norms, standards, best practices for measurement, evaluation and controlling of problematic areas).
- Improve measurement to strengthen forecasts by identifying the right issues predictors.

Overall, the food waste issue has close connexions with ethics (Ciulli *et al.*, 2019), social responsibility and environmental sustainability (Parfitt *et al.*, 2010), and should be further framed by involving theoretical frameworks, tools and theories from cleaner production, sustainability, circular economy and waste management research areas. Recent studies have started this endeavor (Plazzotta *et al.*, 2020), such as by connecting FCC to the closed-loop SC literature (Russo *et al.*, 2019). Consequently, future research might consider the following:

- Establishing *closer connexions between the study of food waste management and social responsibility, as well as environmental sustainability areas.*

5. Conclusions and implications

This paper provides a unique contribution to the literature on FCC while extending previous reviews (James *et al.*, 2006; Raab *et al.*, 2011; Defraeye *et al.*, 2015; Mercier *et al.*, 2017; Chaudhuri *et al.*, 2018; Shashi *et al.*, 2018) in five original ways. First, the study goes beyond a systematic literature review of the FCC research field by applying bibliometric analysis (i.e. performance assessment and network analysis) to identify the most influential works and authors according to citations and co-citations.

Second, drawing on co-citation analysis of articles, this study identifies four clusters of articles ("application of RFID technologies," "production and operation planning models," "postharvest waste, causes of postharvest wastage and perishable inventory ordering polices and models" and "critical issues in FCC") focusing on specific areas of FCC. These research areas range from SC and distribution (Cluster 2) through performance evaluation (Cluster 3), while also considering technology (Cluster 1) and environmental sustainability as well as social responsibility (Cluster 4).

Third, an author co-citation analysis also identifies four clusters of authors that partially match the aforementioned clusters of articles. Through its emphasis on quality standards, risk assessment, consumers or performance measurement, Cluster 1 seemingly conflates with Cluster 3 (i.e. postharvest waste, causes of postharvest wastage and perishable inventory ordering polices and models) identified in the co-citation analysis of cited references. Based on co-citation analysis of cited authors, Cluster 2's emphasis on operations management and logistics, as well as quantitative methods (e.g. optimization, quality management), relates to Cluster 2 on production and operation planning models, in the co-citation analysis of cited references. Studies focused on the RFID technology (i.e. Cluster 1 in the co-citation analysis of cited references) are to be found in both Clusters 2 and 3, but more specifically in cluster 3 in the communication research stream where Ruiz-Garcia and Jedermann published extensively on this topic (Jedermannet al., 2009; Ruiz-Garcia and Lunadei, 2011). The focus on post-harvest issues analyzed in Cluster 4 matches almost completely Cluster 4 in co-citation analysis of cited references. Interestingly, in this cluster, the influence of institutions (e.g. FAO, European Commission) and organizations (e.g. WRAP) in FCC research, is comparatively higher than that of scholars. This may be due to the fact that environmental sustainability in FCC, although being addressed partially in the durability stream of Cluster 2, remains an emerging theme. Past bibliometric analysis showed that emerging themes are often broadly initiated outside of academia (e.g. consultants) and then strengthened theoretically and empirically within academia. This was the case for the collaborative economy (Ertz and Leblanc-Proulx, 2018) and for smart cities (Mora *et al.*, 2017), and it appears that the comprehensive and explicit study of environmental sustainability within FCC is following a similar pattern. This delineation of the literature coupled with advanced information on the most prolific and impactful FCC authors worldwide, which allows researchers to identify core areas of research interests and consider the development of conjoint research projects with other researchers, institutions and centers of researchers based on common research goals and objectives.

Fourth, this study related current research themes to emerging or under-explored ones. The approach undertaken to identify these "dead spots" and "research gaps" was a conventional process in which we analyzed each theme in-depth and related its content to the extant literature. The literature consisted of the most up to date corpus of publications on a given subject. In some cases, when available, the unaddressed research avenues proposed by authors at the end of their papers were also considered as potential candidates for the theory-based research agenda.

Fifth, the research reveals the relationships between the clusters of articles and authors. It also argues that an emerging research stream of environmental sustainability, and to a lesser extent, social responsibility, in the FCC is currently emerging. In sum, the current study argues that better integration of technological advances, namely, RFID technology (Cluster 1), and use of both management and quantitative tools and techniques (Cluster 2) to solve FCC-related issues that can be effectively evaluated (Cluster 3) will result in more environmental sustainability in the FCC (Cluster 4). Therefore, future research may include all these clusters starting from aiming at environmental sustainability and social responsibility in the FCC, considering technological tools and techniques, as well as the evaluation of performance.

5.1 Contribution to theory

This paper is expected to make significant theoretical contributions for several reasons. First, the present study applies bibliometric and network approaches to uncover the most influential articles, scholars, institutions and countries as per the number of articles published and citations. Second, scholars working on FCC may easily recognize the researchers, research institutions and countries conducting research on specific research areas and topics. Therefore, interested scholars can develop joint research projects, share their ideas and discuss their results with the leading authors. Third, the findings can assist the industries and governments to identify the main academic institutions and research centers working in the field of FCC for research projects. Finally, editors organizing special and regular issues on FCC topics can invite leading authors and institutions.

5.2 Contributions to policy and managerial practice

This research offers multiple opportunities to the public authorities, organizations and practitioners that are engaged in leveraging the advantages of SCs by using FCC. This paper

equips managers with different perspectives and schools of thought that allow them to harness the advantages from the FCC in their work. Such knowledge is important for managers because it allows them to locate precisely FCC expertise worldwide. Access to FCC insights and potential applied or even fundamental research projects could then be developed subsequently based on this information.

Besides, the four-cluster classification of articles enables managers to:

- assess the current state of FCC in terms of technology, tools and techniques, evaluation, as well as environmental sustainability; and
- reveal their future needs in the appropriate clusters to take relevant decisions on whether to leverage current technologies, tools and techniques, improve the evaluation of FCC, as well as re-think the implications for environmental sustainability strategies through FCC.

The result of this study may have important implications for both regional and national development, regarding the impact on global logistics, shipping activities of foods and environmental policies. Moreover, the results may inspire firms to promote the integration of the entire FCC partners for a common goal and improve the overall performance of the network. In fact, the population growth and the scarcity of resources needed to meet the increasing needs of people require a great attention from institutions and stakeholders. Based on the previous discussions, emerges the need for political action and feasible guidance by the government to enact policies able to guarantee high-quality standard in the management of CC. CC infrastructure and, consequently, the supply network integration, the partners' performance and the stakeholders' interests are deeply influenced by the policies implemented by the central governments since they are responsible for resources allocation. Therefore, they have to establish policy enforcement and offer incentives and favorable measures to regulate and promote the CCM.

5.3 Limitations of the study

Although great care has been taken to ensure the validity of the study procedure and its results, a number of limitations need to be mentioned. First, we used 1,189 articles published in the past 25 years. Yet, these articles have been selected according to selection criteria. Although we defined a selection criterion to validate the choice of search string and academic database, we only considered papers published in the WoS database in the initial search and excluded other databases such as Scopus, ABI/Inform or Business Source Complete, for example. Besides, only peer-reviewed journal articles were considered while other formats of publications such as conference proceedings, books, book chapters and reports, although possibly influential, have been excluded. Besides, a common issue in the bibliometric analysis is that we used specific keywords for this particular research, yet the use of other keywords and combinations thereof might have led to divergent results. Second, we performed the co-citation analysis using network analysis and VOSviewer software. However, other methods and software may be used, such as Gephi for example. Thirdly, the co-citation analyses of both articles and authors results in four research clusters each. Nevertheless, other methods may lead to other types of classifications. Finally, our study pertains to the FCC research area. However, future review research can be carried out considering CC management in the field of medical, chemical and pharmaceutical industries to underline the research advancements and highlight similarities and differences with FCC domain.

Notes

1 QS World University Rankings 2019. Available at: www.topuniversities.com/university-rankings/world-university-rankings/2019 (accessed on 15-04-2020).

2 Wageningen University and Research Center, China Agricultural University, Ghent University, University of Pretoria, KU Leuven, University of Bologna, University of Florida, Technical University of Madrid, University of South Florida, Stellenbosch University, Cornell University, University of Turin, University of Ljubljana, University of Tasmania, University of Bonn, Massey University, Polytechnic University of Valencia, Technical University of Denmark, University of Liverpool, Curtin University.

3 The World's Top 100 Universities. Available at: www.theguardian.com/higher-education-network/2018/jun/07/top-200-universities-in-the-world-2019-the-table (accessed on 15/04/2020).

4 www.vosviewer.com

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Appendix 1

Table A1 Top performing countries

Based on no. of articles published (Part 1)			Based on citations received (Part 2)				
Rank	Country	Articles	Rank	Country	Citations	Average citations per article	Median value of citations
1	USA	194	1	UK	4,902	33.12	10.00
2	China	178	2	USA	3,225	16.62	8.00
3	UK	148	3	Italy	1,710	15.13	8.50
4	Italy	113	4	Germany	1,687	20.08	9.00
5	Germany	84	5	The Netherlands	1,647	22.56	14.00
6	Australia	81	6	China	1,588	8.92	2.00
7	The Netherlands	73	7	Spain	1,374	20.50	11.00
8	Spain	67	8	Australia	1,267	15.64	5.00
9	South Africa	53	9	Belgium	1,031	25.14	12.00
10	India	49	10	Denmark	982	40.91	11.50
11	Canada	43	11	South Africa	850	16.03	9.00
12	France	42	12	France	744	17.71	8.00
13	Belgium	41	13	Sweden	737	23.77	17.00
14	Sweden	31	14	Canada	687	15.97	6.50
15	Brazil	29	15	India	602	12.28	3.00
16	Taiwan	25	16	Finland	533	48.45	22.00
17	Denmark	24	17	Iran	495	21.52	5.00
18	New Zealand	24	18	Portugal	485	32.33	8.00
19	Iran	23	19	Greece	476	28.00	18.00
20	South Korea	23	20	Norway	463	24.36	22.00

Appendix 2

Table A2 10 Most prolific authors and their current affiliations (as a first author)

Author	Titles of the published articles	Citations	Total citations	Average citations per article	Current Affiliation (as per Scopus profile)
Xiao Xinqing	Developing an intelligent traceability system for aquatic products in cold chain logistics integrated WSN with SPC	6	72	9.00	China Agricultural University, Beijing, China
	Applying CS and WSN methods for improving efficiency of frozen and chilled aquatic products monitoring system in cold chain logistics	28			
	Improving traceability and transparency of table grapes cold chain logistics by integrating WSN and correlation analysis	18			
	Effect of the quality property of table grapes in cold chain logistics-integrated WSN and AOW	10			
	Carbon footprint constrained profit maximization of table grapes cold chain	1			
	Energy conservation potential assessment method for table grapes supply chain	0			
	Development and evaluation of an intelligent traceability system for frozen tilapia fillet processing	7			
	SMS-CQ: A quality and safety traceability system for aquatic products in cold-chain integrated WSN and QR code	2			
Stephen Wiedemann	Resource use and greenhouse gas emissions from grain-finishing beef cattle in seven Australian feedlots: A life cycle assessment	2	76	12.66	Integrity Ag and Environment, Australia
	Resource use and environmental impacts from beef production in eastern Australia investigated using life cycle assessment	18			
	Resource use and environmental impacts from Australian chicken meat production	19			
	Resource use and greenhouse gas emissions from three wool production regions in Australia	9			
	Environmental impacts and resource use from Australian pork production determined using life cycle assessment. Energy, water and land occupation	4			
	Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment	24			
Badía-Melis, Ricardo	Assessing the dynamic behavior of WSN motes and RFID semi-passive tags for temperature monitoring	21	160	32.00	Technical University of Madrid, Spain
	New trends in cold chain monitoring applications – A review	17			
	Data estimation methods for predicting temperatures of fruit in refrigerated containers	5			
	Refrigerated fruit storage monitoring combining two different wireless sensing technologies: RFID and WSN	31			
	Food traceability: New trends and recent advances. A review	86			
Kirezieva, Klementina	The role of cooperatives in food safety management of fresh produce chains: Case studies in four strawberry cooperatives	8	129	25.80	Wageningen University & Research Centre, The Netherlands
	Assessment of Food Safety Management Systems in the global fresh produce chain	41			
	Toward strategies to adapt to pressures on safety of fresh produce due to climate change	13			
	Factors affecting the status of food safety management systems in the global fresh produce chain	30			
	Context factors affecting design and operation of food safety management systems in the fresh produce chain	37			

(***continued***)

Table A2

Author	Titles of the published articles	Citations	Total citations	Average citations per article	Current Affiliation (as per Scopus profile)
Sivakumar Dharini	A review on the use of essential oils for postharvest decay control and maintenance of fruit quality during storage	113	227	56.75	Tshwane University of Technology, South Africa
	Influence of heat treatments on quality retention of fresh and fresh-cut produce	16			
	Maintaining mango (Mangifera indica L.) fruit quality during the export chain	87			
	Papaya fruit quality management during the postharvest supply chain	11			
Accorsi Riccardo	On the design of cooperative vendors' networks in retail food supply chains: A logistics-driven approach	5	92	23.00	University of Bologna, Italy
	Economic and environmental assessment of reusable plastic containers: A food catering supply chain case study	49			
	A climate driven decision-support model for the distribution of perishable products	16			
	A comparison of shipping containers from technical, economic and environmental perspectives	22			
Glowacz Marcin	Maintaining postharvest quality of cold stored 'Hass' avocados by altering the fatty acids content and composition with the use of natural volatile compounds – methyl jasmonate and methyl salicylate	11	66	16.50	Harper Adams University, United Kingdom
	The use of ozone to extend the shelf-life and maintain quality of fresh produce	32			
	The practicality of using ozone with fruit and vegetables	12			
	Using jasmonates and salicylates to reduce losses within the fruit supply chain	11			
Tromp Seth Oscar	A systematic approach to preventing chilled-food waste at the retail outlet	6	60	15.00	Wageningen University & Research Centre, The Netherlands
	Retail benefits of dynamic expiry dates – Simulating opportunity losses due to product loss, discount policy and out of stock	24			
	Reusing salad from salad bars – simulating the effects on product loss, microbial safety and product quality	1			
	Quantitative microbial risk assessment for Escherichia coli O157:H7, Salmonella enterica and Listeria monocytogenes in leafy green vegetables consumed at salad bars, based on modeling supply chain logistics	29			
Nakandala Dilupa	Cost-optimization modeling for fresh food quality and transportation	19	44	11.00	Western Sydney University, Australia
	Development of a hybrid fresh food supply chain risk assessment model	16			
	Innovative adoption of hybrid supply chain strategies in urban local fresh food supply chain	2			
	Modeling information flow and sharing matrix for fresh food supply chains	7			
La Scalia, G	Effect of vibration on the quality of strawberry fruits caused by simulated transport	12	36	9.00	University of Palermo, Italy
	Reducing waste and ecological impacts through a sustainable and efficient management of perishable food based on the Monte Carlo simulation	1			
	An innovative shelf life model based on smart logistic unit for an efficient management of the perishable	14			
	Predictive shelf life model based on RF technology for improving the management of food supply chain: A case study	9			

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Appendix 3

Table A3 Top performing institutions

Based on no. of articles (Part 1)					Based on number of citations (Part 2)						
Rank	**Organizations**	**Country**	**No. of articles**	**QS ranking**	**Rank**	**Organization**	**Country**	**Citations**	**Average citations per article**	**Median value of citations**	**QS ranking**
1	Wageningen University & Research Center	The Netherlands	44	125	1	Wageningen University& Research Center	The Netherlands	1,013	23.02	12.50	125
2	China Agricultural University	China	37	651–700	2	Cranfield University	UK	630	39.37	15.50	–
3	Ghent University	Belgium	19	138	3	Katholieke Universiteit Leuven (KU Leuven)	Belgium	488	30.50	25.00	81
4	University of Pretoria	South Africa	18	561–570	4	Ghent University	Belgium	486	25.57	13.00	138
5	Cranfield University	UK	16	–	5	Technical University of Denmark	Denmark	481	60.12	10.50	112
6	Katholieke Universiteit Leuven (KU Leuven)	Belgium	16	81	6	Technical University of Madrid	Spain	424	38.54	25.00	470
7	University of Bologna	Italy	13	180	7	Tshwane University of Technology	South Africa	348	34.80	19.00	–
8	University of Florida	USA	12	180	8	China Agricultural University	China	335	9.05	4.00	651–700
9	Technical University of Madrid	Spain	11	470	9	Technical University of Munich	Germany	334	55.66	35.00	61
10	University of South Florida	USA	11	521-530	10	University of York	UK	314	104.66	95.00	134
11	Tshwane University of Technology	South Africa	10	–	11	Aalborg University	Denmark	293	73.25	62.00	343
12	Stellenbosch University	South Africa	10	405	12	University of Bologna	Italy	288	22.15	19.00	180
13	Cornell University	USA	10	14	13	University of Strathclyde	UK	259	86.33	18.00	268
14	University of Turin	Italy	10	571-580	14	University of Birmingham	UK	253	126.5	126.5	79
15	University of Ljubljana	Slovenia	10	651–700	15	Harper Adams University	UK	253	50.6	10.00	–
16	University of Tasmania	Australia	10	287	16	University of Barcelona	Spain	251	62.75	13.50	166
17	University of Bonn	Germany	9	255	17	Stellenbosch University	South Africa	250	25.00	17.00	405
18	Massey University	New Zealand	9	332	18	National Institute of Veterinary Research	Vietnam	239	79.66	93.00	–
19	Polytechnic University of Valencia	Spain	9	310	19	Scientific Veterinary Institute Novi Sad	Serbia	239	79.66	93.00	–
20	Technical University of Denmark	Denmark	8	112	20	University of New England	Australia	232	58.00	2.00	801–1,000
21	University of Liverpool	UK	8	164	21	University of Liverpool	UK	232	29.00	6.00	164
22	Curtin University	Australia	8	250	22	Curtin University	Australia	226	28.25	9.00	250
23	Chinese Academy of Sciences	China	8	–	23	Fdn Tekniker	Spain	224	112.00	112.0	–
24	University of Padua	Italy	8	–	24	University of Florida	USA	224	18.66	15.50	180
25	Irstea	France	8	–	25	National Technical University of Athens	Greece	211	42.2	25.50	445

Appendix 4

Table A4 The Top 25 contributing journals as per number of articles

Journal	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total no. of articles
Food Control																1	2	2	4	2	3	10	8	5	5	*42*
Journal of Cleaner Production																				2	2	6	6	7	11	*34*
British Food Journal													1	2	3	4	2		5	3	5	2	2	2	2	*33*
International Journal of Production Economics		1										1					1	3	2	5	4	5	1		5	*28*
Postharvest Biology and Technology													1		3	1	1	1	1	2		4	4	3	5	*26*
Sustainability																					1	2	6	7	9	*25*
Journal of Food Engineering							1	1			1		1	1	1		1	1		1	4	2	4	2	2	*23*
Computers and Electronics in Agriculture															1	1			2	1	2	1	2	5	4	*19*
International Journal of Production Research															1			1			1		4	4	6	*17*
International Journal of Food Microbiology										1	1			1					2	1	3		3	2	2	*16*
Journal of Food Protection												1			1	3	1		2	2	1	1	3	1		*16*
Trends in Food Science Technology													1	1					3		2	1	1	1	3	*13*
Supply Chain Management: An International Journal									1	1		1	1	1	2				1	1	1			1	1	*12*
European Journal of Operational Research									1										2		1	1	2	1	3	*11*
Journal of the Science of Food and Agriculture															1				1	1	2	2	1	2	1	*11*
International Journal of Logistics Management																1				1	1		1	7		*11*
Science of the Total Environment																							1	3	7	*11*
International Journal of Life Cycle Assessment											1		1		1	1	3		1		1				1	*10*
Food Policy				1							2				2				3	1	1					*10*
Packaging Technology and Science												1		1		1	1		1		3	1		1		*10*
Computers & Industrial Engineering																						2	2	2	4	*10*
Industrial Management & Data Systems																						1	8	1		*10*
Meat Science								1				1						1	1	1			1	2	1	*9*
Resources, Conservation and Recycling														1							1	1	1	2	3	*9*
International Food and Agribusiness Management Review																	3		1	2	1		1	1		*9*
Total	0	1	0	1	0	0	1	2	2	2	5	5	6	8	16	13	15	9	32	26	40	42	62	62	75	*425*

Appendix 5

Table A5 The Top 25 cited journals as average citations per article

No.	Journal	Citations	No. of Publications	Average citations per article	Median value of citations
1	*International Journal of Production Economics*	1,089	28	38.89	16.50
2	*Journal of Food Engineering*	858	23	37.30	19.00
3	*Food Control*	827	42	19.69	13.00
4	*Trends in Food Science & Technology*	588	13	45.23	36.00
5	*British Food Journal*	458	33	13.87	9.00
6	*International Journal of Life Cycle Assessment*	431	10	43.1	43.50
7	*Postharvest Biology and Technology*	412	26	15.84	15.00
8	*Journal of Cleaner Production*	398	34	11.70	7.50
9	*Food Policy*	336	10	33.6	24.50
10	*European Journal of Operational Research*	324	11	29.45	27.00
11	*Meat Science*	324	9	36.00	13.00
12	*International Journal of Food Microbiology*	315	16	19.68	13.00
13	*Computers and Electronics in Agriculture*	310	19	16.31	14.00
14	*Supply Chain Management: An International Journal*	287	12	23.91	22.00
15	*International Journal of Production Research*	281	17	16.52	5.00
16	*Food Research International*	259	8	32.37	17.50
17	*Journal of Food Protection*	243	16	15.18	11.50
18	*OR Spectrum*	211	2	105.5	105.50
19	*Philosophical Transactions of the Royal Society A-Mathematical Physical and Engineering Sciences*	205	7	29.28	25.00
20	*Industrial Marketing Management*	194	2	97.00	97.00
21	*Resources, Conservation and Recycling*	192	9	21.33	10.00
22	*Omega: The International Journal of Management Science*	170	4	42.50	28.00
23	*Environment and Planning A-Economy and Space*	168	2	84.00	84.00
24	*Biosystems Engineering*	167	8	20.87	16.00
25	*Packaging Technology and Science*	166	10	16.60	13.00

Appendix 6

Table A6 Distribution of top 25 contributing journals

Journal	Publisher	Journal country	Coverage	H index 2018	SJR score 2018	Impact factor 2018	Energy	Business, Management and Accounting	Decision Sciences	Engineering	Computer Science	Economics, Econometrics and Finance	Environmental Science	Social Sciences	Agricultural and Biological Science	Biochemistry, Genetics and Molecular Biology
Food Control	Elsevier	The Netherlands	1990-Ongoing	103	1.45	4.24									•	•
Journal of Cleaner Production	Elsevier	The Netherlands	1993-Ongoing	150	1.62	**6.39**	•	•		•			•			
British Food Journal	Emerald	UK	1899-Ongoing	69	0.48	1.71		•							•	
International Journal of Production Economics	Elsevier	The Netherlands	1991-Ongoing	**155**	**2.47**	**4.99**		•	•	•		•				
Postharvest Biology and Technology	Elsevier	The Netherlands	1991-Ongoing	123	1.66	3.92									•	
Sustainability	MDPI	Switzerland	2009-Ongoing	53	0.54	2.59	•						•	•		
Journal of Food Engineering	Elsevier	The Netherlands	1982-Ongoing	**156**	1.27	3.62									•	
Computers and Electronics in Agriculture	Elsevier	The Netherlands	1985-Ongoing	96	0.95	3.17					•				•	
International Journal of Production Research	Taylor & Francis	UK	1961 1963–1968 1970-Ongoing	115	1.58	3.19		•	•	•						
International Journal of Food Microbiology	Elsevier	The Netherlands	1984-Ongoing	**170**	1.38	4.00				•					•	
Journal of Food Protection	International association for food protection	USA	1977–1980 1982–1989 1993-Ongoing	125	0.61	1.54									•	
	Elsevier	The Netherlands	1990-Ongoing	**162**	**2.55**	**8.51**									•	•

(***continued***)

Table A6

Journal	Publisher	Journal country	Coverage	H index 2018	SJR score 2018	Impact factor 2018	Energy	Business, Management and Accounting	Decision Sciences	Engineering	Computer Science	Economics, Econometrics and Finance	Environmental Science	Social Sciences	Agricultural and Biological Science	Biochemistry, Genetics and Molecular Biology
Trends in Food Science & Technology																
Supply Chain Management: An International Journal	Emerald	UK	1996-Ongoing	98	**2.10**	4.29		•								
European Journal of Operational Research	Elsevier	The Netherlands	1977-Ongoing	**226**	**2.20**	3.80			•							
Journal of the Science of Food and Agriculture	Wiley & Sons	USA	1950-Ongoing	121	0.82	2.42									•	
International Journal of Logistics Management	Emerald	UK	1990-Ongoing	66	0.87	2.22		•						•		
Science of the Total Environment	Elsevier	The Netherlands	1972-Ongoing	205	1.53	5.58							•			
International Journal of Life Cycle Assessment	Springer	Germany	1976-Ongoing	89	1.53	**4.86**							•			
Food Policy	Elsevier	The Netherlands	1975-Ongoing	85	**1.78**	3.78						•	•	•	•	
Packaging Technology and Science	Wiley & Sons	USA	1988-Ongoing	42	0.51	1.88				•						
Computers & Industrial Engineering	Elsevier	The Netherlands	1976-Ongoing	111	1.33	3.51				•	•					
Industrial Management & Data Systems	Emerald	UK	1980-Ongoing	88	1.13	3.72		•		•	•					
Meat Science	Elsevier	The Netherlands	1977-Ongoing	142	1.39	3.48								•		
Resources Conservation and Recycling	Elsevier	The Netherlands	1988-Ongoing	103	1.54	**7.04**						•	•			
International Food and Agribusiness Management Review	International Food and Agribusiness Management Association	USA	1998-Ongoing	30	0.39	**0.937**								•		

Appendix 7

Table A7 Most cited articles

Rank	TC	Title	Author(s)	Country of first author	Journal/book	Year	TC/Y
1	788	Food waste within food supply chains: Quantification and potential for change to 2050	Parfitt, J., Barthel, M., Macnaughton, S.	UK	*Philosophical Transactions of the Royal Society B-Biological Science*	2010	78.8
2	243	Follow the thing: Papaya	Cook, I.	UK	*Antipode*	2004	15.19
3	228	Factors influencing rheological and textural qualities in chocolate: A review	Afoakwa, E.O., Paterson, A., Fowler, M.	UK	*Trends in Food Science & Technology*	2007	17.54
4	228	Managing meat tenderness	Thompson, J.	Australia	*Meat Science*	2002	12.67
5	223	RFID smart tag for traceability and cold chain monitoring of foods: Demonstration in an intercontinental fresh fish logistic chain	Abad, E., Palacio, F., Nuin, M., de Zarate, A.G., et al.	Spain	*Journal of Food Engineering*	2009	20.27
6	214	An optimization approach for managing fresh food quality throughout the supply chain	Rong, A., Akkerman, R., Grunow, M.	Finland	*International Journal of Production Economics*	2011	23.78
7	208	Quality, safety and sustainability in food distribution: A review of quantitative operations management approaches and challenges	Akkerman, R., Farahani, P., Grunow, M.	Denmark	*OR Spectrum*	2010	20.8
8	206	Two-echelon multiple-vehicle location-routing problem with time windows for optimization of sustainable supply chain network of perishable food	Govindan, K., Jafarian, A., Khodaverdi, R., Devika, K.	Denmark	*International Journal of Production Economics*	2014	34.33
9	189	Food waste biomass: A resource for high-value chemicals	Pfaltzgraff, L.A., De Bruyn, Cooper, E.C., Budarin, V., Clark, J.H.	UK	*Green Chemistry*	2013	27.00
10	171	Product safety and security in the global supply chain: Issues, challenges and research opportunities	Marucheck, A., Greis, N., Mena, C., Cai, L.	USA	*Journal of Operations Management*	2011	19.00
11	171	The application of biosensors to fresh produce and the wider food industry	Terry, L.A., White, S.F., Tigwell, L.J.	UK	*Journal of Agriculture and Food Chemistry*	2005	11.4
12	168	Power to all our friends? Living with imbalance in supplier-retailer relationships	Hingley, M.K.	UK	*International Marketing Management*	2005	11.2
13	164	Changing governance patterns in the trade in fresh vegetables between Africa and the United Kingdom	Dolan, C., Humphrey, J.	UK	*Environment and Planning A-Economy and Space*	2004	10.25
14	129	Agri-fresh produce supply chain management: A state-of-the-art literature review	Shukla, M., Jharkharia, S.	India	*International Journal of Operations & Production Management*	2013	18.43
15	124	Supermarket revolution in Asia and emerging development strategies to include small farmers	Reardon, T., Timmer, C.P., Minten, B.	USA	*Proceedings of the National Academy of Sciences of The United States of America*	2012	15.50
16	122	Toward a third food regime: Behind the transformation	Burch, D., Lawrence, G.	Australia	*Agriculture and Human Values*	2009	11.09
17	119	Competitive food supply chain networks with application to fresh produce	Yu, M., Nagurney, A.	USA	*European Journal of Operational Research*	2013	17.00
18	112	A review on the use of essential oils for postharvest decay control and maintenance of fruit quality during storage	Dharini, S., Silvia, B.-B.	South Africa	*Crop Protection*	2014	18.67
19	112	A dynamic product quality evaluation based pricing model for perishable food supply chains	Xiaojun, W., Dong, L.	UK	*Omega: The International Journal of Management Science*	2012	14.00
20	111	Tracing enteric viruses in the European berry fruit supply chain	Maunula, L., Kaupke, A., Vasickova, P., Soderberg, K., et al.	Finland	*International Journal of Food Microbiology*	2013	15.85
21	107	The relative importance of transport in determining an appropriate sustainability strategy for food sourcing	Sim, S., Barry, M., Clift, R., Cowell, S.J.	UK	*The International Journal of Life Cycle Assessment*	2007	8.23

(***continued***)

Table A7

Rank	TC	Title	Author(s)	Country of first author	Journal/book	Year	TC/Y
22	105	Spatial temperature profiling by semi-passive RFID loggers for perishable food transportation	Jedermann, R., Ruiz-Garcia, L., Lang, W.	Germany	*Computers and Electronics in Agriculture*	2009	9.54
23	103	Acetic acid and lithium chloride effects on hydrothermal carbonization of lignocellulosic biomass	Lynam, J.G., Coronella, C. J., Yan, W., Reza, M.T., Vasquez, V.R	USA	*Bioresource Technology*	2011	11.44
24	100	Food safety issues in fresh produce: Bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain	Van Boxstael, S., Habib, I., Jacxsens, L., De Vocht, M., et al.	Belgium	*Food Control*	2013	14.28
25	95	Multi-objective integrated production and distribution planning of perishable products	Amorim, P., Gunther, H.O., Almada-Lobo, B.	Portugal	*International Journal of Production Economics*	2012	11.87
26	95	An environmental assessment of food supply chains: A case study on dessert apples	Jones, A.	UK	*Environmental Management*	2002	5.28
27	94	A review on agri-food supply chain traceability by means of RFID technology	Costa, C., Antonucci, F., Pallottino, F., Aguzzi, J., et al.	Italy	*Food and Bioprocess Technology*	2013	13.43
28	93	Harmonised investigation of the occurrence of human enteric viruses in the leafy green vegetable supply chain in three European countries	Kikkinos, P., Kozyra, I., Lazic, S., Bouwknegt, M., et al.	Greece	*Food and Environmental Virology*	2012	11.63
29	93	Truck scheduling at zero-inventory cross docking terminals	Boysen, N.	Germany	*Computers & Operations Research*	2010	9.30
30	92	Active and intelligent packaging in meat industry	Fang, Z., Zhao, Y., Warner, R.D., Johnson, S.K.	Australia	*Trends in Food Science & Technology*	2017	30.67
31	92	Agricultural value chains in developing countries a framework for analysis	Trienekens, J.H.	The Netherlands	*International Food and Agribusiness Management Review*	2011	10.22
32	91	Robust closed-loop supply chain network design for perishable goods in agile manufacturing under uncertainty	Hasani, A., Zegordi, S.H., Nikbakhsh, E.	Iran	*International Journal of Production Research*	2012	11.37
33	89	The Haber Bosch-harmful algal bloom (HB-HAB) link	Glibert, P.M., Maranger, R., Sobota, D.J., Bouwman, L.	USA	*Environmental Research Letters*	2014	14.83
34	88	A meta-heuristic algorithm for the efficient distribution of perishable foods	Tarantilis, C.D., Kiranoudis, C.T.	Greece	*Journal of Food Engineering*	2001	4.63
35	87	Maintaining mango (Mangifera indica L.) fruit quality during the export chain	Sivakumar, D., Jiang, Y., Yahia, E.M.	South Africa	*Food Research International*	2011	9.67
36	87	Global standards, local realities: Private agrifood governance and the restructuring of the Kenyan horticulture industry	Ouma, S.	Germany	*Economic Geography*	2010	8.70
37	86	Food traceability: New trends and recent advances.	Badia-Melis, R., Mishra, P., Ruiz-Garcia, L.	Spain	*Food Control*	2015	17.20
38	86	Stakeholder, citizen and consumer interests in farm animal welfare	Verbeke, W.	USA	*Animal Welfare*	2009	7.82
39	83	Strategic use of private standards to enhance international competitiveness: Vegetable exports from Kenya and elsewhere	Jaffee, S., Masakure, O.	USA	*Food Policy*	2005	5.53
40	82	System dynamics modeling and simulation of a particular food supply chain	Minegishi, S., Thiel, D.	France	*Simulation Practice and Theory*	2000	4.1
41	79	Chilled or frozen? Decision strategies for sustainable food supply chains	Zanoni, S., Zavanella, L.	Italy	*International Journal of Production Economics*	2012	9.87
42	77	Virtualization of food supply chains with the internet of things	Verdouw, C.N., Wolfert, J., Beulens, A.J.M., Rialland, A.	The Netherlands	*Journal of Food Engineering*	2016	19.25
43	76	Developing an advanced multi-temperature joint distribution system for the food cold chain	Kuo, J-C., Chen, M-C.	Taiwan	*Food Control*	2010	7.6

(***continued***)

Table A7

Rank	TC	Title	Author(s)	Country of first author	Journal/book	Year	TC/Y
44	76	Performance of ZigBee-Based wireless sensor nodes for real-time monitoring of fruit logistics	Ruiz-Garcia, L., Barreiro, P., Robla,	Spain	*Journal of Food Engineering*	2008	6.33
45	75	Determination of GHG contributions by subsystems in the oil palm supply chain using the LCA approach	Choo, Y.M., Muhamad, H., Hashim, Z., Subramaniam, V., Puah, C.W., Tan, Y.	Malaysia	*International Journal of Life Cycle Assessment*	2011	8.33
46	75	Food traceability from field to plate	Opara, L.U., Mazaud, F.	New Zealand	*Outlook on Agriculture*	2001	3.94
47	74	Outbreak of hepatitis A in the USA associated with frozen pomegranate arils imported from Turkey: An epidemiological case study	Collier, M.G, Khudyakov, Y. E., Selvage, D., Adams-Cameron, M., et al.	USA	*Lancet Infectious Diseases*	2014	12.33
48	73	Missing Food, Missing Data? A Critical Review of Global Food Losses and Food Waste Data	Xue, L., Liu, G., Parfitt, J., Liu, X., et al.	China	*Environmental Science & Technology*	2017	24.33
49	71	Cold chain tracking: A managerial perspective	Montanari, R.	Italy	*Trends in Food Science & Technology*	2008	5.91
50	70	Quantifying relative fish abundance with eDNA: A promising tool for fisheries management	Lacoursière-Roussel, A., Côté, G., Leclerc, V., Bernatchez, L.	Canada	*Journal of Applied Ecology*	2016	17.5

Notes: TC = Total citations; TC/Y = Total citations/year

Appendix 8

Table A8 Frequently cited keywords

Keywords	Frequency	Keyword	Frequency
Quality	181	Shelf-life (shelf life)	83
Supply chain(s)	176	Sustainability	81
Management	140	Supply chain management	77
Model(s)	133	Logistics	71
Temperature	117	Traceability	69
Food	111	Product(s)	66
System(s)	109	Performance	64
Food safety	105	Framework	62
Cold chain(s)	101	Storage	61
Carbon/CO_2 emission	91	Optimization	59

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