Perishable products supply chains: Research trends over the last decade

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Abstract: With the proliferation of standards and regulations on perishable products quality and safety and the increasing interest of consumers for the credence attributes of the products they purchase, the research on the topic of perishable products supply chain assumes a pivotal role in the supply chain management field. Nevertheless, in the last decades the research focused mainly on inventory management, while the management of the perishable products supply chain as a whole has caught the eyes of scholars just in the recent years. Therefore, this paper presents a survey on the extant literature on perishable products supply chain in order to identify the main research trends over the last ten years and propose future research questions. Firstly, in order to give to the reader an overview of the literature on perishable products supply chain a bibliometric analysis is presented. Particularly, a database containing all the abstracts on the topic over the period 2008-2018 is analyzed through a pattern classification tool. Then, a more detailed literature review of the most relevant papers is presented and finally future research topics are illustrated and summarized.

Keywords: perishable products, supply chain, literature survey.

1.Introduction

Perishability includes the set of physical and chemical phenomena, such as "decay, damage, spoilage, evaporation, obsolescence, pilferage, loss of utility or loss of marginal value of a commodity" (Amorim, Meyr, Almeder, and Almada-Lobo, 2013), which contributes to decrease the original utility (i.e. status) of a product. In supply chain management, the risk generated by the products perishability represents one of the main challenges to face with. However, this topic has caught the eye of scholars relatively late (Amorim, Antunes, and Almada-Lobo, 2011). In the last years, together with the proliferation of quality and safety standards (Council Regulation, 2002, European Commission, 2013), the global trade of perishable products has dealt with the increasing concern of consumers about what they purchase (Bernués, Olaizola, and Corcoran, 2003). Therefore, supply chain actors claim for a higher compliance with the standards (Trienekens and Zuurbier, 2008), as well as, for a major information disclosure on the products distribution (Marshall, McCarthy, McGrath, and Harrigan, 2016). From their side, scholars are called to develop sustainable solutions to handle products perishability, in order to support companies and managers during the daily manufacturing, storage, packaging, and transport operations (Accorsi et al., 2017, Accorsi et al., 2018, Gallo et al., 2017). Therefore, with the aim of exploring the extant literature on perishable products supply chains, we propose a bibliographic analysis (Van Nunen, Li, Reniers, and Ponnet, 2017). Particularly, this paper makes three contributions. First, it provides a microscopic overview of the literature on the topics, analysing the geographic distribution of publications, as well as, the publishing journals and the most important authors in the field. Second, the paper shows the main research trends over the last decade. Finally, it provides scholars with a tool to identify potential gaps in the literature and propose new research topics.

The paper is organized as follows. Session 2 describes the utilized methodology, Session 3 describes the results and Session 4 includes the conclusions and a brief research agenda.

2. Data and methodology

The dataset for this study was retrieved from Web of Science on February 26, 2018, which is one of the most widely used search engine among the scientific community. We conducted a search of "perishable products supply chain" in some of the most known search engines (i.e. Engineering Village, Scopus) and Web of Science revealed the highest number of publications. To explore the published papers over the last decade, the time horizon from 2008 to 2018 was selected. Among all types of publications, we limited the study to the articles and reviews and we obtain a sample database of 263 works. Then, such database was exported and analysed both through the Web of Science functionalities and the freely available software VOSviewer, for the construction and visualization of bibliometric maps (Van Eck and Waltman, 2010). The software is able to draw bibliometric distance-based maps, paying a lot of attention to their graphical appearance and, therefore, facilitating the users' understanding. We

conducted a set of analyses with the aim of identifying the main research trends across the scientific disciplines.

3. Results

The sample of 263 publications receives in total 2,847 citations (i.e. 2,406 without considering the self-citation practice) according to the Web of Science Core Collection, with an average number of citations per item of 10.78. Particularly, Figure 1 shows the total number of citations received by the analysed set of papers per year, while assigning the papers to the year of publication.

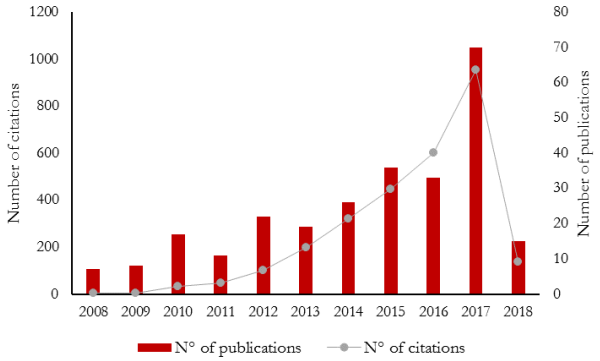

Figure 1: Total number of citations received per year

While the number of publications varies over the years, a general increasing trend can be recognized. Particularly, 2017 results the most prolific year. Therefore, a similar trend is expected in 2018, considering that 15 papers have been published only in January and February. It is worth noting how the citations number assumes a remarkable trend over the last decade. According to the Web of Science data, the analysed papers contribute to several research areas. However, five of them result more explored: Engineering, Operations Research Management Science, Business Economics, Computer Science, and Food Science Technology. Particularly, Engineering includes more than the half of the published papers. The following sub-sessions explore the research topics with a major level of detail. These deal with the geographical distribution of the authors' affiliations, the panel of the most publishing journals and that of the main authors working on the field. The specific methodology utilized for each of these analyses is discussed in the following.

3.1. Geographical distribution

The Web of Science dataset assigns each publication to one or more countries in agreement with the authors' affiliations. We utilize the VOSviewer functionalities to focus on the countries cumulating at least 5 publications. Moreover, we consider only the papers that are cited at least once. Under these constraints, 16 countries meet the threshold. Figure 2 shows the number of papers, represented by the orange bubbles, and the number of citations, represented by the red columns, per country.

Figure 2: geographic landscape

Particularly, USA and People's Republic of China are the most prolific countries, followed by Iran and England. However, if we consider the average number of citation per publication, Denmark, France, and Sweden produce the most cited papers, followed by Germany and Italy.

3.2. The journals

Figure 3 shows the landscape of journals included in the sample database through the item density visualization functionality of VOSviewer.

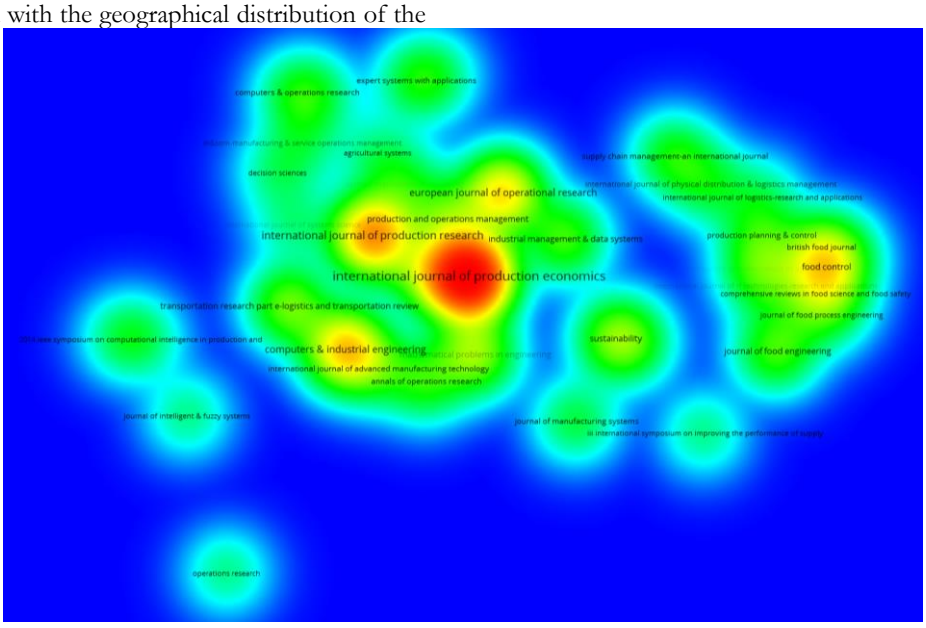

Figure 3: journals density visualization

To obtain this map, we conduct a bibliographic coupling analysis, where the relatedness between two items, i.e. journals, is determined by the number of references they share. To calculate the weight of a connection between two items we use the fractional counting, which weights their relationship according to the number of references they share with other journals. The map includes only those journals that published at least 2 papers that have been cited at least once. All other settings are given by default. The resulting journals are 41. Each point in the item density visualization has a color that indicates the density of items at that point. The density is calculated considering both the number of neighboring items and the distance among these items. The more the color tends to red, the higher the item density is. Particularly, the color scale in the figure represents the number of publications. As instance, the International Journal of Production Economics, with 31 published papers, is located in the central highest density zone of the map. On the contrary, the Operations Research Journal is in a lower density zone and presents weak connections with other journals, nevertheless it represents a target journals for operational researchers. This could be interpreted as a lack of models addressing perishable products supply chain instances in the extant literature. Similarly, the distance between journals focused on food (e.g. Food Control) and journals on computer applications (e.g. Computers and industrial Engineering) could reveal room for further developments in decision support systems and software tailored for food supply chain practitioners. Among the journals landscape, five revealed the highest number of publications: International Journal of Production Economics (impact factor 3.493), International Journal of Production Research (2.325), Computer and Industrial Engineering (2.623), European Journal of Operational Research (3.297), and Mathematical Problems in Engineering (0.802). Figure 4 represents the publication trend of these journals on the topic over the last decade.

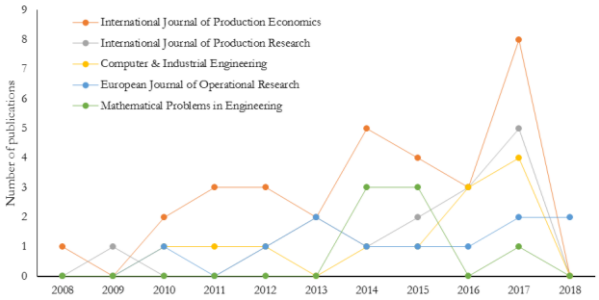

Figure 4: main journals trend

3.3. The authors

Aim of this analysis is the identification of the most important authors publishing in the field. To explore the authors landscape, we conduct a citation analysis, given the widespread assumption that the number of citations reflects the publication's notoriety and, therefore, the influence of an author's work (Van Nunen et al., 2017). In this type of analysis, the relatedness between two items is determined by the number of times they cite each other. Consequently, in Figure 5 the weight of the bubble representing an author reflects the number of his/her publications. The bubble colour showcases the average number of citations the publication received by the other authors in the map. The colour red corresponds to an average number of citations of more then 40, while the colour blue corresponds to a number inferior to 10. Moreover, the distance between two authors reflect the tendency of these authors to cite each other. Lines connecting items represent the links. VOSviewer, by default, shows the 500 strongest links between items only. All other settings are given by default.

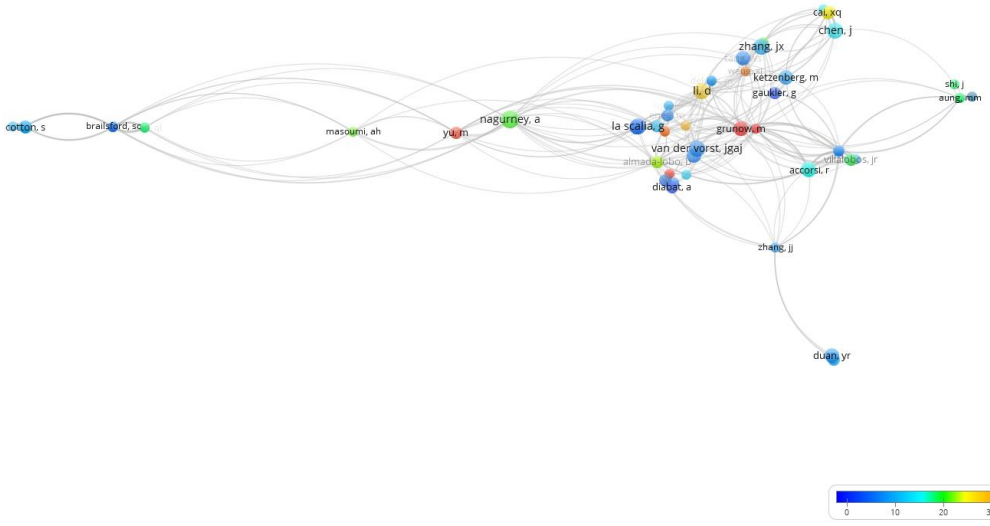

Figure 5: authors map

Based on these assumptions, the most influential contributions belong to six authors: Grunow, M., Akkerman, R., Govindan, K., and Yu, M., followed by Wang, X.J., and O' Brien, C. It is worth noting how Grunov, M., shares links with all the other authors, Akkerman, R., with four other authors, Govindan, K., and Wang, X.J., with three authors, and the remaining with two

other authors. Particularly, Yu, M., is the farthest from the others. Table 1 reports the nine most relevant contributions from these authors, according to the number of citations indicated by the Web of Science Core Collection. The table also indicates the research areas, which are: Engineering (E), Operations Research Management Science (ORMS), Business Economics (BE), and Transportation (T).

Table 1: Main references

References	Citations	Research areas
(Rong, Akkerman, and Grunow, 2011)	130	ORMS, E
(Govindan, Jafarian, Khodaverdi, and Devika, 2014)	80	ORMS, E
(Yu and Nagurney, 2013)	71	BE, ORMS
(Wang and Li, 2012)	65	BE, ORMS
(Masoumi, Yu, and Nagurney, 2012)	43	BE, ORMS, T
(X. Wang, Li, and O'Brien, 2009)	42	ORMS, E
(Piramuthu, Farahani, and Grunow, 2013)	30	BE, ORMS
(Grunow and Piramuthu, 2013)	28	ORMS, E
(X. Wang, Li, O'brien, and Li, 2009)	26	ORMS, E

Rong et al. (2011) have a huge success in the field, because their innovative methodology to model food quality degradation is exploited by several other scholars in the development of a mixed-integer linear programming models used for production and distribution planning; among these we quote Grunow and Piramuthu (2013) and Yu and Nagurney (2013). The first focus on the role of sensor-enabled RFID-generated item-level information in a highly perishable food supply chain, assuming the perspective of retailers, distributors, and customers. The latter develop a fresh food supply chain management model for the determination of the optimal product flow throughout the supply chain, under the constraints of oligopolistic competition and perishability. Similarly, Masoumi et al. (2012) face the challenge of oligopolistic competition among the producers of pharmaceuticals, proposing a supply chain network management model. Wang, Li, and O'Brien (2009) and Piramuthu et al. (2013) explore the topic of traceability to control the products quality. The first propose an optimisation model that integrate traceability initiatives to achieve the desired product quality while reducing the products recalls. Piramuthu et al. (2013) study the recall dynamics generated by products contamination in a perishable food supply network through three different visibility levels, such as at supplier level, manufacturer level, and retailer level. The topic of traceability is also discussed by Wang and Li (2012), who propose a pricing approach based on the dynamic identification of the food shelf life, with the aim of enhancing the retailer's profit while reducing the food spoilage. Finally, Govindan et al. (2014) present a multi-objective optimization model that integrates the topic of sustainability in the decision-making process on distribution in a perishable food supply chain.

3.4. Research trends

To identify the main research trends over the last decade, we conduct a co-occurrence analysis of all the keywords in the database. Results are shown in a map (see Figure 6), where the relatedness between items is calculated with respect to the number of documents in which they occur together. Here the aim is to identify the papers where each keyword occurs at least ones. We set a threshold to 8 as the minimum number of occurrences and we limit the set to the most connected keywords. We obtain a total number of 62 keywords. However, some terms in the map result duplicated. Particularly, VOSviewer does not distinguish among singular and plural. Therefore, to overcome this problem, we remove nine of these keywords that correspond to the ones with a lower weight. All other settings are given by default. The distance among items is calculated based on the association strength (Van Eck and Waltman, 2009), representing the ratio between the number of co-occurrences of term *i* and term *j* and the total number of occurrences of *i* multiplied for the total number of occurrences of *j*. The higher the association strength between two nodes of the network, the shorter their distance is. The color scale refers to the average year of publications. Therefore, Figure 6 provides an overview of the most cited keywords over the years, enabling to infer the most debated research topics. A preliminary analysis showcases how the highest color variation is limited to the horizon between 2013 and 2016, therefore we re-set the color scale to such a period. This phenomenon is partly influenced by the selected threshold of occurrences and to the publication trend (see Figure 1). However, it is worth noting how, reducing the minimum number of occurrences to 3, we obtain a similar phenomenon. Therefore, we can assume an initial phase of *warmup* of the literature on perishable products supply chain (i.e. from 2008 to 2013) characterized by exploratory studies on different themes. Then, from 2013 scholars focus on some relevant topics, making the research trends more evident. Particularly, the years 2014 and 2015 see the majority of the keywords, while 2017 includes only two keywords.

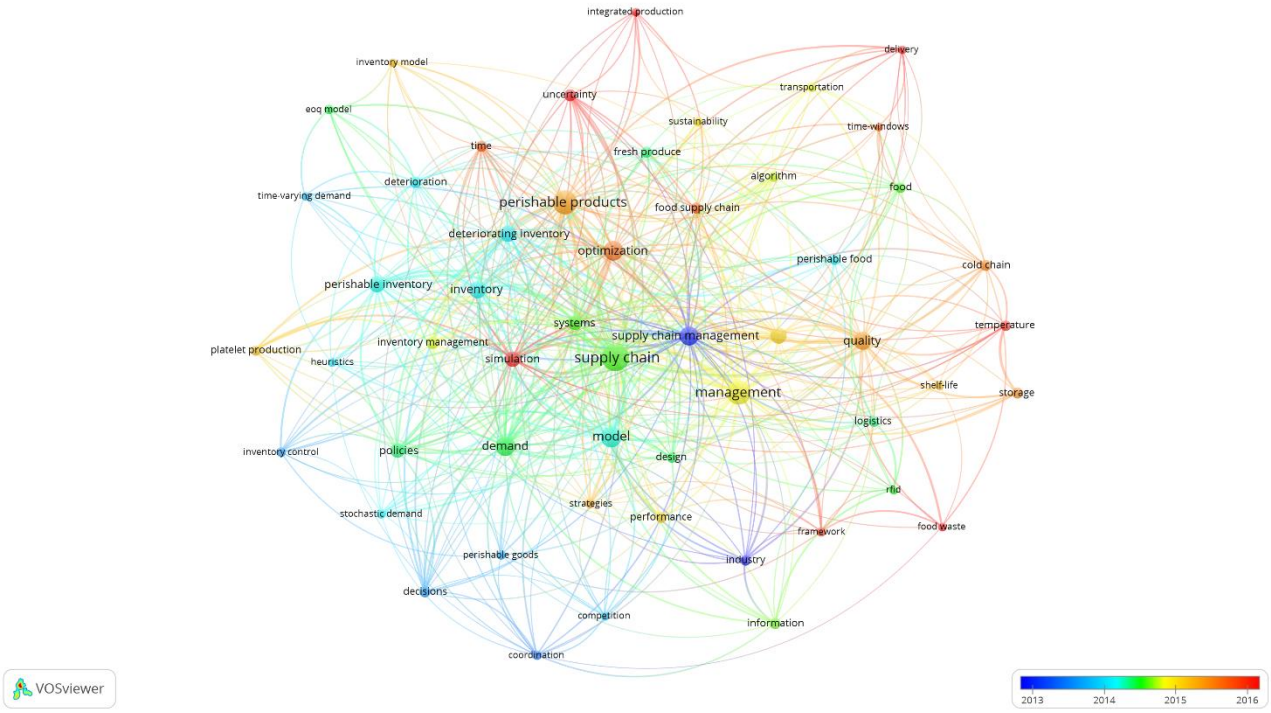

Figure 6: map of keywords

Based on the map of keywords, the identified research trends are the following:

- The impact of the adoption of a *competitive* approach vs. a *cooperative* approach among supply chain actors (2013)
- The *inventory* management in presence of *perishable* products (2013-2014)
- The handling of the *variability* in the products *demand* (2013-2014)
- The implementation of *traceability systems* (i.e. RFID) for the tracking and tracing of *information* along the products journey (2014)
- *Sustainability* of products and processes (2014)
- *Transportation* (2014)
- *Food products* and *fresh produce* (2014)
- The *Platelet production* (2014)
- The handling of *shelf life* of products (2014-2015)
- The management of the *cold chain* (2015)
- The *quality* of products (2015)
- The management of the *Food Supply Chain* (2015)
- The handling of *time-windows* for the deliveries (2015)
- The monitoring and the control *temperature* (2016)
- *Integrated production* processes (2016)
- The *deliveries* planning (2017)
- The *food waste* reduction (2017)

4. Conclusions

This paper explores the extant literature on "perishable product supply chain" to identify the main research trends over the last decade. Despite the limitations related to the narrow panel of search keys used to build the database, the obtained results provide a macroscopic overview of the extant literature on the topic. Moreover, Figure 6 allows visualizing the past research trends, and could even support researchers in the identification of potential gaps in the literature. Particularly, the distance among nodes in the map could show unexplored connections among research topics, while the bubble size could indicate a still little debated topic. As instance, future research could involve the deepening of the topic of food waste in relation with the environmental sustainability, as well as the impact of the information transparency along the supply chain to prevent waste production. Moreover, further developments could include the comparison of the results obtained through other databases (such as Scopus), to provide an overarching analysis of the extant literature.

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