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Exploring Key Performance Indicators in the Food Supply Chain: A survey, analysis and taxonomy

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Abstract

The present paper deals with an investigation on Key Performance Indicators in the Food Supply Chain and proposes a taxonomy for their classification. More into detail, a literature analysis was carried out on 207 documents in which KPIs are used, implemented, analyzed or newly proposed with reference to the food context. These documents were subject to bibliometric analyses (i.e., temporal evolution, journal analysis, authors and keywords analysis), and contents-related deepening. The output from the contents is a taxonomy for classifying documents which allows to investigate 4 specific issues: (i) product of the supply chain, (ii) activity measured by the KPIs, (iii) output of the measurement and (iv) the aim for which the specific KPI is involved. The 207 screened documents are then classified on the basis of the proposed taxonomy.

Keywords: Food Supply Chain; Key Performance Indicators; Survey-based Analysis; Taxonomy; Literature Review.

1. Introduction

Key performance indicators (KPIs, in the following) are simply defined as numbers designed to convey as much information as possible (Peterson, 2006). Normally, they are proposed as rates, ratios, percentages and averages instead of raw numbers, and can be involved for assessing countless elements and aspects, depending on the contexts in which they are determined and their aim.

Measuring something and consequently evaluating the related performance is extremely important for managers, since these results and trends may constitute the bases for relevant decision-making. Indeed, the role of KPIs is that of allowing the evaluation of an activity in order to determine the extent to which the goals have been achieved (Dominguez et al., 2019), thus permitting to wight up strategies and behaviors.

Depending on their nature, some authors propose different classifications for KPIs. For instance, Mikusova and Janeckova (2010) suggested to separate "hard" indicators from "soft" indicators, on the basis of the subject of the measurement; "continual" indicators from "discrete" indicators according to the reproducibility of the use; again, depending on the area of measurement, the same authors recognize indicators of "efficiency" (economic), indicators of "effectiveness", indicators of "result" and indicators of "process"; finally, reflecting the level of managerial decision-making, indicators can refer to a "strategic", "tactical" or "operative" aspects. Kaplan and Norton, again, differentiate "leading" (predictive) indicators from "lagging" indicators (Kaplan and Norton, 2000); basically, the difference among the two is that the

latter provide a feedback to a past performance.

Beyond the mere KPIs nature, other authors have analyzed the KPIs in accordance with the field/topic they refer to; for example, this is the case of Patidar et al. (2023), who recently investigated KPIs for resilience under Industry 4.0 and sustainability perspectives; of Mosca and Perini (2022) who reviewed the KPIs' role in architectural and urban design practices; of Alfarsi et al. (2022) and Barsalou (2018) who carried out an assessment of KPIs of the chemical and manufacturing industry, respectively. Several other examples could be mentioned, since KPIs can be involved everywhere, including, for instance, the tertiary sector.

In the last years, research on KPIs management has literally exponentially grown, as supported by Dominguez et al. (2019). In this last study, a taxonomy for KPIs management is proposed, and this work inspirated the authors of the present manuscript. Indeed, starting from here and from what turned out to be a gap to be filled in literature, in this work the topic of KPIs in the food supply chain (FSC in the following) is investigated.

More into detail, a literature analysis was carried out on 207 manuscripts that proposed KPIs for measuring performance of FSC and, starting from their contents, a taxonomy is then delineated and implemented on these documents.

The following contents can be found in the paper: section 2 deals with the methodology; section 3 presents the results, including bibliometric analyses and the resulted taxonomy, then implemented. Finally, section 4 proposes the conclusions, limitations and future research directions.

2. Methodology

The starting point was a literature search carried out in April 2023 on the Scopus database; 9 queries having kewords pertinent to the field of KPIs and FSC were involved. Only articles, conference papers and reviews written in English language and published between 2001 and 2023 were considered, and a first set of 312 scientific documents was obtained. As main inclusion criterium, that of using, implementing, analyzing or poposing new KPIs in the food context was considered, and all the 312 documents were individually checked by the authors for evaluating the consistency with that criterion. After having removed duplicates and checked the relevance for the study, the final sample of documents corresponds to 207.

These documents were firstly subjected to bibliometric analyses, under Microsoft Excel™ tool. Into detail, (i) the temporal evolution according to their publication year was derived; (ii) most productive journals were identified; (iii) outstanding authors were found, depending on the number of documents they contributed to; (iv) a keywords analysis was carried out. With respect to this last analysis, frequency and persistence of keywords were preliminary identified. For frequency it is meant the number of mentionings of a keyword in the sample of papers reviewed; persistence, instead, refers to the number of years of presence of a specific keywords, computed considering the year of its first appearance and the year of the last one (Tebaldi et al. 2021). By combining these two information on an x/y graph, interesting research trends can be observed, as it will be discussed in the next section.

With respect to the contents, instead, partly starting from Dominguez et al.'s taxonomy and from the contents of the documents, the new taxonomy adapted for the food context was delineated and each document was classified according to it.

For the whole list of documents as well as for more details about the classification, the readers can refer to the corresponding author of the manuscript.

3. Results

In this section, results from the bibliometric analyses and the contents are proposed. The two subsections that follow recall this subdivision.

3.1. Bibliometric analyses

The 207 articles were classified according to the year of publication. Figure 1 presents the outcome and the trend.

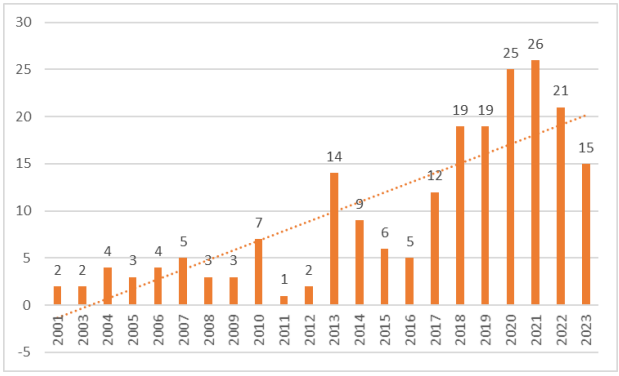

Figure 1. Number of publications per year

From Figure 1, it is possible to observe that the number of publications has increased over the period of analysis. Specifically, in 2017 the number of papers started growing significantly, reaching 19 publications in 2018 and 2019, 25 in 2020, 26 in 2021 and 21 in 2022. It is important to specify that 2023 presents partial data (15 papers until 30 April 2023).

The 207 papers reviewed have been published on a total of 145 different sources, suggesting that literature spans across various subjects and scientific categories. Figure 2 shows the main journals in which the reviewed articles have been published. To be more effective, the figure is limited to sources that published at least 3 papers.

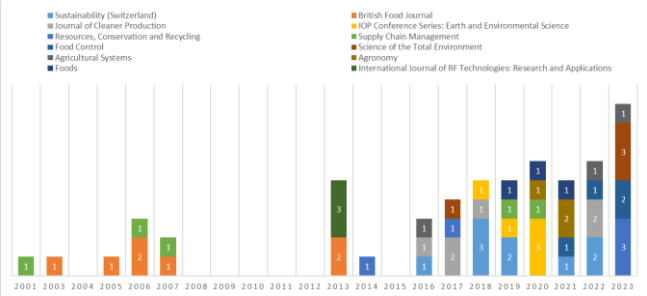

Figure 2. Trend of publications on FSC by journal.

Sustainability stands at the top by publishing the highest number of documents (9 papers out of 207). It is interesting to note that this journal has appeared in the sample only from 2016, despite the fact that it started its activity in 2009 (first document: Brunori, et al., 2016). *British Food Journal* and *Journal of Cleaner Production* hold second and third position, respectively with 7 and 6 contributions. From 2008 to 2012 no articles on KPI in the FSC were published in prominent journals.

The author field was extracted from the database and the frequency of appearance of all authors was recorded. Table 1 presents the outstanding researchers and the related number of papers published (including the citations received). To be more effective, the table is limited to the authors who published at least three papers.

Table 1. Most productive authors, their documents and citations.

Author	N° of articles	References	Citations (Scopus)
Van Der Vorst, J.G.A.J.	**5**	(Aramyan, Lansink, Van Der Vorst, & Kooten, 2007)	289
		(Soysal, Bloemhof-Ruwaard, Meuwissen, & van der Vorst, 2012)	80
		(Vlajic, Van Lokven, Haijema, & Van Der Vorst, 2013)	33
		(Soysal, Bloemhof-Ruwaard, Haijema, & van der Vorst, 2018)	187
		(Badraoui, Boulaksil, & Van der Vorst, 2022)	4
		Total	***593***
Manning, L.	**4**	(Manning, Baines, & Chadd, 2006)	25
		(Manning, Baines, & Chadd, 2007)	6
		(Manning, Baines, & Chadd, 2008)	31
		(Manning & Soon, 2013)	7
		Total	***69***
Rezitis, A.N.	**4**	(Rezitis, 2018)	4
		(Rezitis & Rokopanos, 2019)	1
		(Rezitis & Tsionas, 2019)	20
		(Rezitis & Rokopanos, 2021)	0
		Total	***25***
Accorsi, R.	**3**	(Accorsi, et al., 2013)	7
		(Accorsi, et al., 2013)	5
		(Penazzi, Accorsi, Ferrari, Manzini, & Dunstall, 2017)	13
		Total	***25***
Aramyan, L.H.	**3**	(Aramyan, Lansink, Van Der Vorst, & Kooten, 2007)	289
		(Gellynck, Molnár, & Aramyan, 2008)	24
		(Kataike, Aramyan, Schmidt, Molnár, & Gellynck, 2019)	20
		Total	***333***
Baines, R.N.	**3**	(Manning, Baines, & Chadd, 2006)	25
		(Manning, Baines, & Chadd, 2007)	6
		(Manning, Baines, & Chadd, 2008)	31
		Total	***62***
Chadd, S.A.	**3**	(Manning, Baines, & Chadd, 2006)	25
		(Manning, Baines, & Chadd, 2007)	6
		(Manning, Baines, & Chadd, 2008)	31
		Total	***62***
Manzini, R.	**3**	(Accorsi, et al., 2013)	7
		(Accorsi, et al., 2013)	5
		(Penazzi, Accorsi, Ferrari, Manzini, & Dunstall, 2017)	13
		Total	***25***
Soysal, M.	**3**	(Soysal, Bloemhof-Ruwaard, Meuwissen, & van der Vorst, 2012)	80
		(Sel, Soysal, & Çimen, 2017)	33
		(Soysal, Bloemhof-Ruwaard, Haijema, & van der Vorst, 2018)	187
		Total	***300***
Tsolakis, N.	**3**	(Aivazidou, Tsolakis, Iakovou, & Vlachos, 2016)	69
		(Tsolakis, Srai, & Aivazidou, 2018)	22
		(Tsolakis, Anastasiadis, & Srai, 2018)	19
		Total	***110***

As can be seen from the table above, the leading authors are Van Der Vorst, J.G.A.J., Manning, L. and Rezitis, A.N. with 5, 4 and 4 publications each. Interestingly, the dominant author is the one who has been cited the most times (593 citations). Among the most prominent authors, the papers with highest number of citations are Aramyan, Lansink, Van Der Vorst, & Kooten (2007) (289 citations) and Soysal, Bloemhof-Ruwaard, Haijema, & van der Vorst (2018) (187 citations). Collaboration networks can be easily identified from the results of Table 1. For example,

Baines, R.N. and Chadd, S.A. have worked together with Manning, L. in all their papers.

The analysis of the authors' keywords generated a list of 650 different terms. However, the analysis is based on 82 keywords, obtained by removing the general keywords that were used to generate the database (e.g., FSC and KPI), those with a frequency below 2 and merging similar terms or terms with the same meaning (e.g., Radio Frequency Identification with RFID). "*Supply chain management*" is the predominant keyword, with 26 results. "*Food safety*" and "*Performance management*" take second position both with frequency=16, followed by "*Supply chain*" with 12 results. According to Casella et al. (2022), by correlating the frequency of the keywords (mean of the frequencies=4.4) with their persistence (half of the timespan=11), we obtained the results in the figure below.

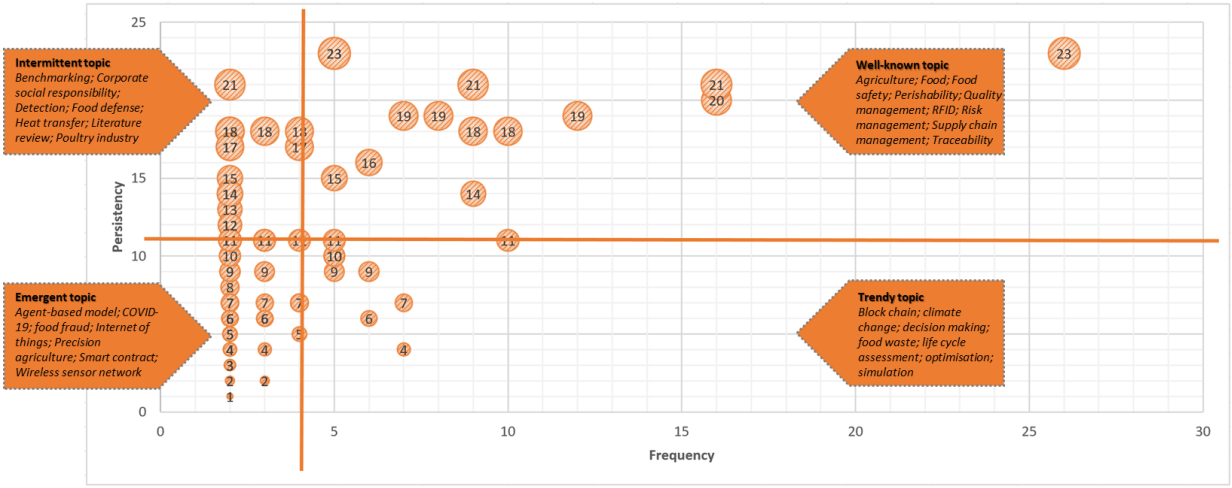

Figure 3. Frequency vs. persistence of the keywords.

The top-right quarter of the graph represent the "*well-known*" concepts (high frequency and persistence) - 14 keywords; the top-left quarter is instead labelled as "*intermittent*" research topics (high persistence but low frequency) - 14 keywords; the bottom-right and the bottom-left quarters are categorized as "*trendy*" (high frequency but low persistence) and "*emergent*" (low frequency and persistence) topics, respectively (9 and 45 keywords). As can be seen from Figure 3, the well-known concepts include general themes, such as "agriculture", "food" and "supply chain management", while the intermittent topics include, among many others, "benchmarking", "poultry industry" and "customer satisfaction". "Life cycle assessment", "food waste", "decision making" and other keywords were classified as trendy topics. Finally, "cold chain", "wireless sensor network", "precision agriculture" and other issues were categorized as emergent topics. These themes represent recent or poorly investigated concepts.

3.2. Contents analysis: the proposed taxonomy

As already stated, one of the main contributions of the present paper is the proposed taxonomy for analysing the KPIs in the food context, so that they can be used and implemented for other analyses and purposes. The taxonomy derives from 4 questions to be posed:

1. Which product is treated in the FSC in question? (in other words, the FSC niche);
2. Which activity/process is assessed by the KPI?
3. What is the output from the KPI?
4. What is a KPI measured for?

To answer the first question, on the basis of the sources analysed, the following categorization is proposed:

- Agricultural product
- Meat
- Fish
- Dairy product

As far as the activity/process is concerned, 10 different activities have been mapped. More into detail, in a FSC 3 different areas can be identified, namely (i) supply, (ii) production/tranformation and (iii) distrubution (Tebaldi et al., 2021); according to that, the 10 activites are properly allocated and the results are proposed in Table 2 below.

Table 2. Categories for activities assessed by a KPI.

Supply	Production	Distribution
Raw material selection	Site selection	Transport
		Retail
Growing	Planting	
Harvesting	Processing	
Post-harvesting	Performance evaluation	

Regarding the output from a KPI, four different situation have been observed, which respectively

correspond to the four categories that follow:

- Improvement (the overall performance has improved);
- Worsening (the overall performance has worsened);
- Optimization (the target was met, and the optimum situation was reached)
- Comparison (scenarios comparison).

The fourth and last part of the taxonomy is related to effectively understanding what a KPI is measuring. According to the documents under study, 11 different elements were recognized. As done for the aforementioned activities, these 10 factors as well were categorized according to the triple bottom line (TBL) concept, depending on their being economic, evironment or social related. They are listed in Table 3.

Table 3. 11 factors for which a KPI can be measured.

Economic	Environment	Society (customer)	TBL
Efficiency	Carbon footprint	Food quality	Sustainability
Flexibility		Temperature check	
Reactivity		Customer satisfaction	
Food traceability		Food safety	
Error evaluation			

On the bases of this derived classification, built according to the contents of the 207 reviewed documents, the same documents were subjected to classification as well. Results are proposed and discussed in the subsections that follow.

3.2.1. *Which product is treated in the FSC?*

Figure 4 presents the trend in time of the product treated in the FSC.

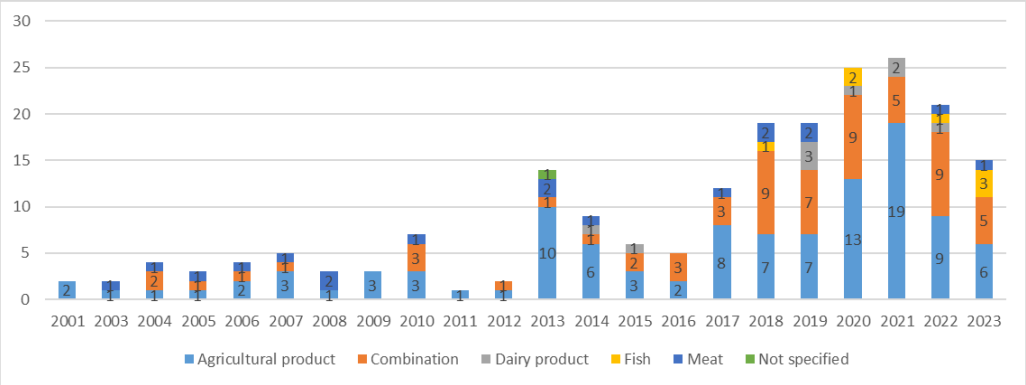

Figure 4. Trend of publications by product.

Agricultural products are the most spread in the analyzed sample (109 out of 207 contributions), followed by studies dealing with the combination of several types of products (63-30.43%) and meat (18 papers). Due to the high percentage of articles with product combinations, the figure below (Figure 5) details the different possible pairs of niches.

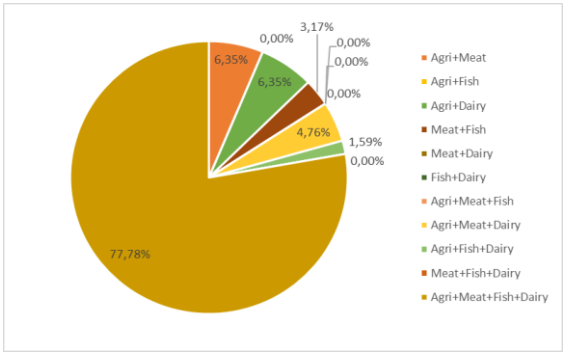

Figure 5. Types of product combinations.

As the figure above shows, the combination of all types of products (Agri+Meat+Fish+Dairy) is the most studied in literature (49 out of 63 papers). Agri+Fish, Meat+Dairy, Fish+Dairy, Agri+Meat+Fish and Meat+Fish+Dairy, conversely, are not discussed in the analyzed sample.

3.2.2. *Which activity/process is assessed by the KPI?*

Figure 6 displays the trend in time of the activities discussed in the FSC.

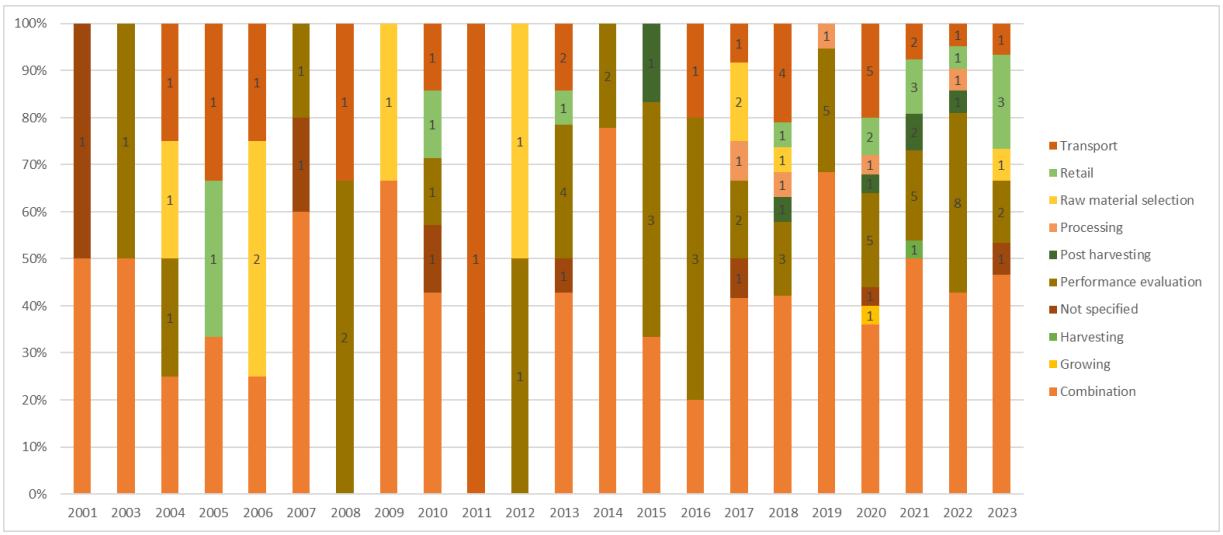

Figure 6. Trend of publications by activity.

Combinations of activities, performance evaluation and transport are the most frequent FSC stages in the reviewed sample, with 93, 49 and 23 articles, respectively. In addition, the site selection and planting have never been studied individually.

3.2.3. *What is the output from the KPI?*

The output returned by the studies reviewed is represented in Figure 7.

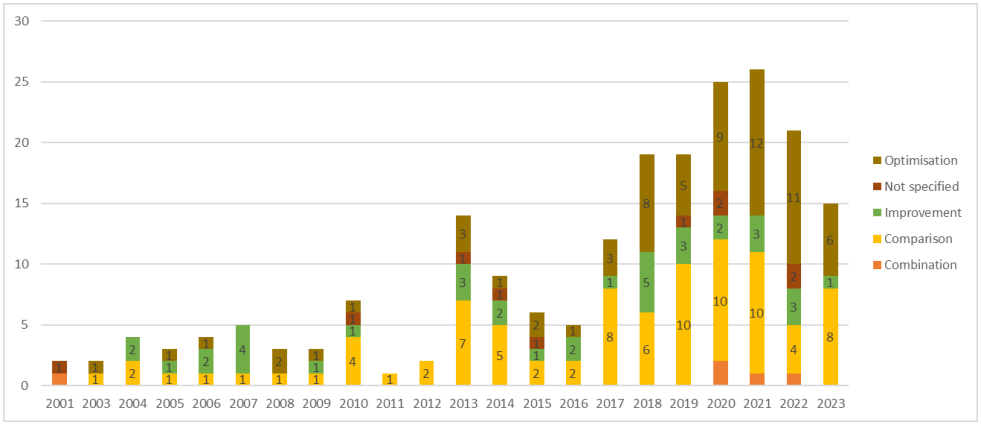

Figure 7. Trend of publications by output.

As can be seen from the figure above, the comparison of scenarios is very frequent, with 87 out of 207 papers suggesting results in this form, followed by optimization with 68 studies. It is interesting to note that the combination of scenarios appeared with a good continuity: only in 2001 there were no publications. Optimization, instead, has increased especially in recent years, starting in 2018.

3.2.4. *What is a KPI measured for?*

Figure 8 shows the elements that can be measured with a KPI.

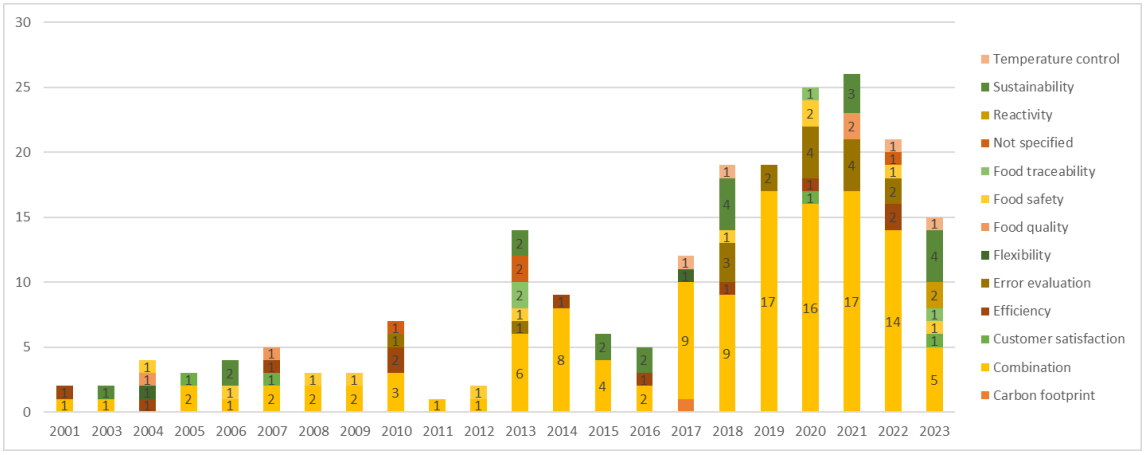

Figure 8. Trend of publications by KPI factors.

As can be deduced, the combination of factors is the most common option (123 publications), followed by sustainability with 20 papers and error evaluation with 17.

As a further last insights, Figure 9 relates the KPI factors to the type of products, followed by Figure 10 which instead relates KPI factors with the activities discussed in the FSC.

Note that in both figures, among the KPI factors, category "Combination" was removed so as to make the deepening more meaningful; it was only considered, for completeness, among the products and the type of activity.

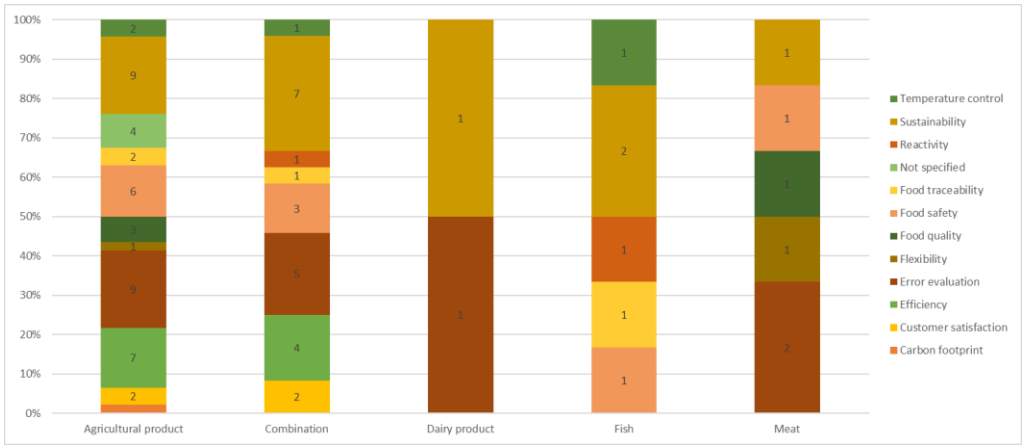

Figure 9 Correlation between KPI factors and type of products.

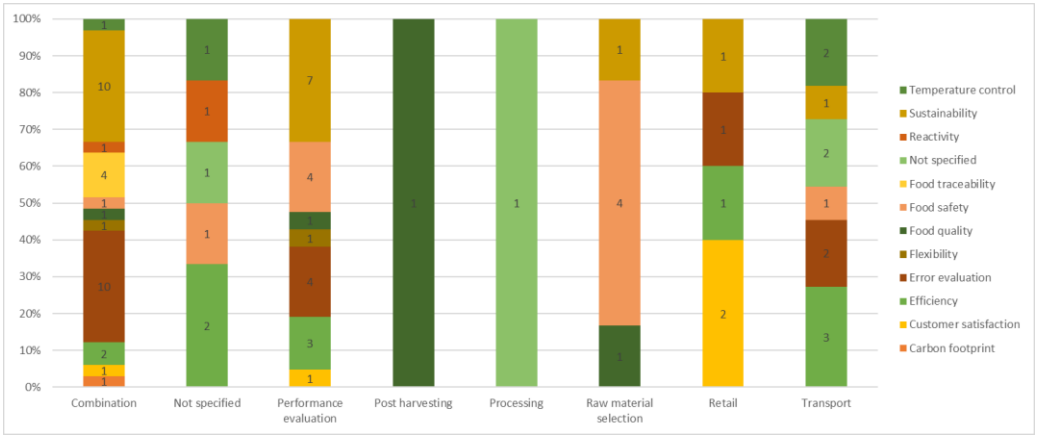

Figure 10 Correlation between KPI factors and type of activities.

4. Conclusions

This paper proposed an accurate analysis of a sample of 207 articles in the field of Food Supply Chain (FSC), with the aim of finding, analyzing, and classifying the main Key Performance Indicators (KPIs) related to this sector. The work is mainly structured in 3 major strands. It starts with a massive literature review conducted on Scopus: through the research of some keywords, 312 articles were found (between 2001 and 2023), which were then analyzed and filtered to obtain a total of 207 significant articles object of study. The work continues with the bibliometric analysis. The documents have been catalogued according to the years of publication; the most productive journals are shown; the authors who have contributed most frequently to the writing of the articles and how many times over the years they have been cited are reported; finally, an analysis of the main keywords present in the articles is reported, categorized according to their frequency and persistency. The last step was to propose a taxonomy for the classification of KPIs. To do this it was necessary to study the selected articles from different points of view. Which products are processed in these FSCs? Which activities/processes are typically evaluated by KPIs? What are the outputs of KPIs? What elements can be measured by KPIs? Starting from these simple questions can occur various intertwined scenarios, which highlight the different potential of KPIs. From the results obtained it can be noted that first it is necessary to distinguish the type of product that is being treated. Even though there are universal KPIs, suitable for every sector and type of production, there are others that make sense to be measured only in relation to their field of competence. In this sense the study categorizes 4 main product types: agricultural, meat, fish, dairy products. A filter can then be applied according to the type of activity, as there are specific KPIs of the supply phase (raw material selection, harvesting, etc.), others of the production phase (planting, processing, etc.) and others related to the distribution phase (transport, retail). As for the output of KPIs, 4 categories have been identified: Improvement (performance improved), Worsening (performance worsened), Optimization (target met) and Comparison (scenarios comparisons). Finally, 11 elements were reported recognized as actually measurable by KPIs (such as temperature control, food quality, customer satisfaction, etc.). All these aspects were then analyzed individually and finally combined together, giving rise to intertwined graphs in which are shown the trend of publications per product (considering also the combination of several products), per activity, per output, per factors, the correlation between KPI factors and type of products and the correlation between KPI factors and type of activities. A limitation of this study concerns the sample of selected articles: the taxonomy has been outlined starting from the contents of the revised documents. As a future development it might be useful to expand the taxonomy case, making it *super partes*.

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