FORUM

Submitted 05.31.2020. Approved 11.30.2020

Evaluated through a double-blind review process. Guest editors: Luciana Marques Vieira, Marcia Dutra de Barcellos, Gustavo Porpino de Araujo, Mattias Eriksson, Manoj Dora, and Daniele Eckert Matzembacher

Translated version | DOI: http://dx.doi.org/10.1590/S0034-759020210505x

FOOD WASTE AND PERFORMANCE MEASUREMENT SYSTEMS: A SYSTEMATIC REVIEW OF THE LITERATURE

Sistemas de medição de desempenho e desperdício de alimentos: Revisão sistemática da literatura

Sistemas de medición de desempeño y desperdicio de alimentos: Una revisión sistemática de la literatura

Paulo Henrique Amorim Santos[1] | phas223@gmail.com | ORCID: 0000-0003-4735-7747

Roberto Antonio Martins[1] | ram@dep.ufscar.br | ORCID: 0000-0002-9168-1416

[1]Universidade Federal de São Carlos, Departamento de Engenharia de Produção, São Carlos, SP, Brazil

ABSTRACT

This paper presents an analysis of the scientific production that deals with performance measurement and food waste, and examines the trends and challenges in the field. Food waste increases food insecurity and misuses scarce natural and financial resources. It is, however, very difficult to measure waste at the aggregate level, and the various ways companies use do not adopt a systemic approach. A systematic literature review was conducted using bibliometrics to guide content analysis. The results indicate that few articles focus on performance measurement systems for the whole supply chain, with a particular emphasis on sustainability. The use of digital technologies in performance measurement systems is a trend that was observed. This is an opportunity for research aimed at quantifying food waste better and helping reduce food insecurity.

KEYWORDS | Food waste, food loss, performance measurement systems, food security, literature review.

RESUMO

Este artigo apresenta uma análise da produção científica da medição de desempenho e do desperdício de alimentos, bem como as tendências e os desafios no campo. O desperdício de alimentos contribui para aumentar a insegurança alimentar e consome recursos financeiros e naturais escassos. Entretanto, existem inúmeras dificuldades para medir o desperdício em nível agregado, e as várias formas utilizadas nas empresas não têm abordagem sistêmica. Uma revisão sistemática da literatura foi realizada com o uso de bibliometria para direcionar análise de conteúdo. Os resultados apontam para uma falta de artigos com ênfase nos sistemas de medição de desempenho voltados para toda a cadeia de suprimentos com enfoque em sustentabilidade, melhoria e aprendizagem. A aplicação de tecnologias digitais nos sistemas de medição de desempenho é uma tendência observada. Isso é uma janela de oportunidades para desenvolvimento de pesquisas com o objetivo de quantificar melhor o desperdício de alimentos, que pode contribuir para a redução da insegurança alimentar.

PALAVRAS-CHAVE | *Desperdício de alimentos, perda de alimentos, segurança alimentar, sistemas de medição de desempenho, revisão de literatura.*

RESUMEN

Este artículo presenta un análisis de la producción científica sobre la medición de desempeño y el desperdicio de alimentos, así como las tendencias y desafíos. El desperdicio de alimentos contribuye a aumentar la inseguridad alimentaria y consume los escasos recursos financieros y naturales. Sin embargo, existen innumerables dificultades para medir el desperdicio a nivel agregado y las diversas formas utilizadas en las empresas no tienen un enfoque sistémico. Se realizó una revisión sistemática utilizando bibliometría para dirigir el análisis de contenido. Los resultados apuntan a la falta de artículos con énfasis en sistemas de medición de desempeño dirigidos a toda la cadena de suministro con un enfoque en la sostenibilidad, la mejora y el aprendizaje. Se observa una tendencia a la aplicación de tecnologías digitales en los sistemas de medición de desempeño. Esto es una ventana de oportunidades para el desarrollo de investigaciones con el fin de cuantificar mejor el desperdicio de alimentos que puede contribuir a reducir la inseguridad alimentaria.

PALABRAS CLAVE | *Desperdicio de alimentos, pérdida de alimentos, seguridad alimentaria, sistemas de medición de desempeño, revisión de la literatura.*

INTRODUCTION

Food waste occurs in the entire supply chain, from agricultural and livestock production to final consumption. With a focus on water waste, one of the first studies estimated that half of the food produced is wasted (Lundqvist, Fraiture, & Molden, 2008). The global estimate that is most cited in the literature, however, is that approximately one third of the food produced for human consumption is wasted, which equates to about 1.3 billion tons per year, while more than 820 million people go hungry (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011; Food and Agriculture Organization of the United Nations [FAO], 2019). Another study corroborates the previous estimate for food with an agricultural origin (Kummu et al., 2012). The UN Food and Agriculture Organization (FAO) has been coordinating an effort aimed at measuring food waste worldwide. This is necessary because of the growth in the global population, which is expected to reach almost 10 billion people by 2050, and will demand an increase in the food available for consumption (Searchinger et al., 2018). Although population growth occurs mainly in developing countries, developed nations are also facing food insecurity problems associated with distributing food to everyone (Buzby & Hyman, 2012). As a result, just increasing production and reducing waste are not enough. It is imperative to ensure food availability and economic and physical access to it (FAO, 2008). The efficient use of agricultural land and water, and biodiversity conservation are also global challenges caused by population growth (Lundqvist et al., 2008; Tscharntke et al., 2012).

Food waste is a central issue because of the financial and natural resources spent on food production, storage and transportation (Buzby & Hyman, 2012; Gustavsson et al., 2011). An example of this is annual water and fossil fuel consumption (Hall, Guo, Dore, & Chow, 2009; Lundqvist et al., 2008). It is also vital to consider water scarcity in order to forecast a realistic and desirable consumption level for food production (Lundqvist et al., 2008). Awareness of such losses is critical for reducing food waste and increasing efficiency in food supply chains. Negative externalities during the life cycle also affect society and the environment through greenhouse gas emissions, air and water pollution, soil erosion, salinization, and nutrient depletion (Buzby & Hyman, 2012).

Until 2009, food waste had not been a central issue in the food security debate (Hall et al., 2009). There are numerous possible causes of food waste, and they are highly dependent on the socioeconomic and cultural context in which the food chain actors operate (Cicatiello, Franco, Pancino, & Blasi, 2016). In almost all countries it is hard to estimate food waste at the national level (Hall et al., 2009). The data are scarce, dispersed, of poor quality, or of limited representativeness, which makes it crucial to improve data sources and to overcome the challenges of collecting the data (FAO, 2019). Overcoming these challenges will allow the "food loss index" (Indicator 12.3.1.a) and "food waste index" (Indicator 12.3.1.b) of the "Consumption and Responsible Production" Sustainable Development Goal, of the 2030 Agenda proposed by the 193 UN member countries to be measured. The UN recognizes that one of humanity's contemporary challenges is ensuring sustainable global food production. Reducing food waste, therefore, is one of the goals for achieving a more sustainable world by 2030 (Department of Economic and Social Affairs, 2016; West et al., 2014).

If it is difficult to quantify losses and waste on a worldwide level precisely, the same applies to supply chains and companies, because the performance measures currently used do not help identify the causes of waste, since they only measure cost, efficiency, and availability (Kaipia, Dukovska-Popovska, & Loikkaken, 2013).

Therefore, undertaking research into the performance of sustainable supply chains is important (Kaipia et al., 2013). The situation has changed little; waste management in the agri-food supply chain is still a promising subtopic for sustainable food supply chain studies (Luo, Ji, Qiu & Jia, 2018).

There is a lack of a systematic literature review that addresses food waste from the perspective of performance measurement systems. In this article, performance measurement systems (PMSs) is the process used for defining objectives, developing a set of performance measures, and collecting, analyzing, reporting, interpreting, reviewing and acting based on performance information (Bititci, Bourne, Cross, Nudurupati, & Sang, 2018). We pose and address, therefore, two research questions:

- QP1: What is the current state of scientific research into performance measurement systems for measuring food waste?
- QP2: What are the challenges and trends in implementing performance measurement systems for measuring food waste?

This paper aims to scrutinize the intellectual production dealing with performance measurement in measuring food waste, focusing on impacts and trends from a systematic literature review perspective.

THEORETICAL BACKGROUND

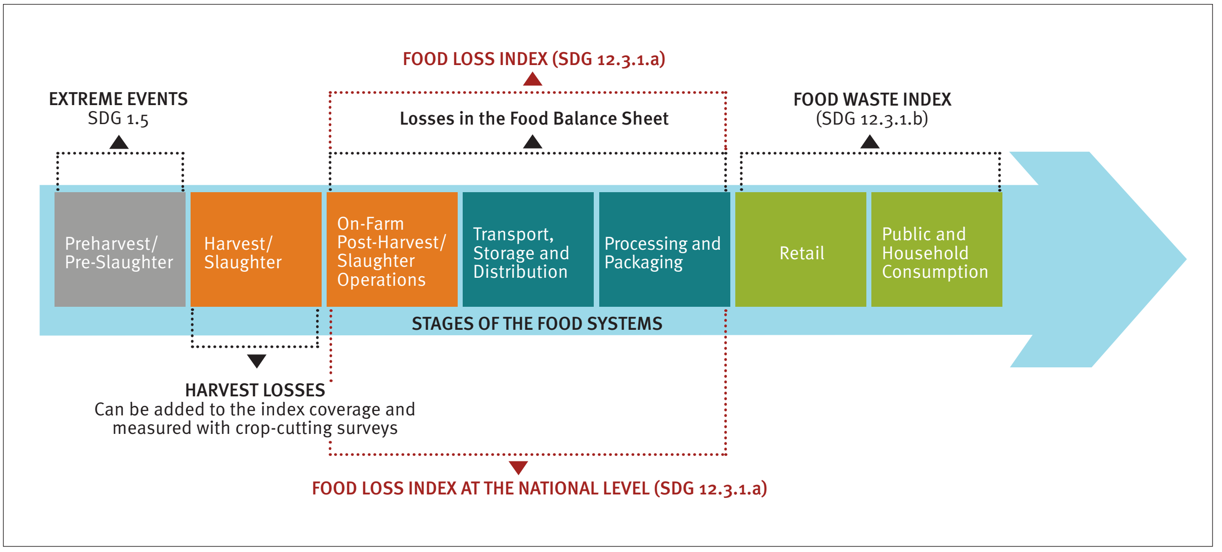
The two constructs that underlie this paper are food waste and performance measurement systems. We now provide a short review of the literature on those topics.

Food waste

There are no universally-standard definitions of food waste and food loss in literature (Buzby & Hyman, 2012). Food loss is the decrease in the quantity and quality of food, making it inadequate for human consumption. Food loss normally occurs at different stages in the agri-food supply chain (Parfitt, Barthel, & Macnaughton, 2010). Food waste is a food loss fraction, consisting of residue with a high organic concentration. Waste is generally derived from the processing of raw materials, resulting in secondary products in a liquid or solid form (Galanakis, 2012). For other authors, waste is losses at the end of the food supply chain (retail and final consumption), related to the behaviors of retailers and consumers (Parfitt et al., 2010). In this article, food waste includes low-quality products (rejected by the consumer) and waste generated during processing (Waarts et al., 2011). Finally, food waste measurement focuses only on products consumed by humans, excluding animal feed and the inedible parts of products (Parfitt et al., 2010).

In 2015, the United Nations published the 2030 Agenda for Sustainable Development that includes 17 Sustainable Development Goals (SDG), the aim being to raise awareness and lead international community actions over the next 15 years (2016-2030). The main performance measures for Objective 12, "Consumption and Responsible Production" are the food loss index (Indicator 12.3.1.a) and the food waste index (Indicator 12.3.1.b). Figure 1 gives the scope of the food supply chain considered by the SDG indices, whose objective is to enable policymakers to analyze the positive and negative trends in food waste by comparing it with the baseline to encourage improvements.

Figure 1. **Food loss index scope along the food supply chain**



Source: FAO (2019).

The FAO provides the Technical Platform on the Measurement and Reduction of Food Loss and Waste that facilitates food waste prevention, and the measurement and reduction of waste at the local, regional and national levels (FAO, 2017). Countries with the largest food surpluses tend to waste more (Stuart, 2009). In middle- and high-income countries, food is mainly wasted at the consumption stage when people dispose of food even if it is still suitable for human consumption. The percentage of food waste that occurs before the food reaches the retail area is around 13.8% (FAO, 2019). Based on a sample of 27 European countries, the European Commission (EC) estimated that 42% of food waste is produced by households, while 39% occurs in industry, 14% in the food service sector, and the remaining 5% in retail and distribution sectors (EC, 2010; Mirabella, Casstellani, & Sala, 2014; Raak, Symmank, Zahn, Aschemann-Witzel, & Rohm, 2017). Approximately 30 to 40% the food is wasted in developed and developing countries, although the causes of waste are very different (Godfray et al., 2010). In low-income countries, losses are much higher in the adjacent stages after the post-harvest period, while in developed countries, the greatest potential for reducing food waste lies in retail, food services, and in consumers' homes (Parfitt et al., 2010). Waste in South Africa is about 9.04 million tons per year (Oelofse & Nahman, 2013), while in Brazil it is 82.20 million tons per year (Dal'Magro & Talamini, 2019). Although food waste is present at all stages in the supply chain, the cause of food waste is often not at the same stage as where the waste was identified (Raak et al., 2017).

Food goes through several stages along the entire supply chain, from raw material production, processing and distribution to consumers. A quarter of the food is wasted in the supply chain due to physical damage to products or packaging, insect-related causes, and attack by microorganisms. Blackouts, equipment defects, waste from technical operations, human error, logistical limitations, hygiene regulations, and presumed causes of safety risks are other sources of food waste (Raak et al., 2017). Ineffective cold chains have recently been the cause of much of the food waste (Jedermann, Nicometo, Uysal, & Lang, 2014). It is worth mentioning that the three main food groups in terms of the value of the food lost at the end of the chain are: meat, poultry and fish (41%); vegetables (17%); and dairy products (14%) (Buzby & Hyman, 2012).

Reducing waste at each stage of the supply chain can reduce the total loss by 50%. This would help improve the food available to meet the future demands of approximately one billion people (Kummu et al., 2012). The use of technology, such as radio frequency identification, can also improve supply chain management, particularly for perishable goods. Data gathered by sensors and Internet of Things devices can help predict shelf-life throughout the supply chain.

Besides social factors and the depletion of natural and financial resources, food waste has an extreme impact on the environment and affects sustainability, a critical performance dimension in food supply chain management (Cicatiello et al., 2016; Kaipia et al., 2013). Food waste also contributes to the excessive consumption of fresh water and fossil fuels, which added to methane and CO_2 emissions from food decomposition, have a negative effect on global climate change (Hall et al., 2009). Food processing residue also requires treatment to minimize and prevent negative environmental effects due to its disposal (Galanakis, 2012). Incineration with other waste is a common disposal method of food waste, which is used for generating heat or energy (Kiran, Trzcinski, Ng, & Liu, 2014). Food waste is also a cheap source of valuable compounds, which become functional additives for other products after the recovery and recycling of some of their components (Galanakis, 2012). The bioconversion of food waste into energy (as ethanol, hydrogen, methane, and biodiesel) is economically viable and attractive (Kiran et al., 2014). As waste food requires additional processing before it can be used, intensifying research and integrating value-added product manufacturing processes are essential for improving efficiency and reducing production costs (Mirabella et al., 2014).

Following the three sustainability dimensions (environmental, economic, and social), the food waste hierarchy establishes the prioritization order as being: prevention, reuse, recycling, recovery, and disposal (Papargyropoulou, Lozano, Steinberger, Wright, & Ujang, 2014). A production surplus of approximately 30% is necessary to compensate for the waste, but currently this figure exceeds 50% (Papargyropoulou et al., 2014). Thus, the first step towards reducing food waste is adopting a more sustainable approach to production and consumption, by eliminating as much as possible of the surplus food produced and the food wasted in the entire food supply chain (Papargyropoulou et al., 2014).

Performance measurement systems

The basic assumption of most research related to performance measurement and management is that the environment of organizations is stable, while authors are still basing their works on the traditional control theory (Wamba, Akter, Edwards, Chopin, & Gnanzou, 2015). Nowadays, companies operate in increasingly complex environments that often require highly competitive capabilities to comply with the increasing dimensions that performance demands. Furthermore, performance depends heavily on stakeholders and supply chain partners (Bititci et al., 2018; Bourne, Franco-Santos, Micheli, & Pavlov, 2018). The result is an evolution in performance measurement; What should be measured for performance management; and How can performance measurement be used for managing organizations? Another change has been in the use of the terms "measurement" and "performance management" (Bititci, Garengo, Dörfler, & Nudurupati, 2012; Bititci et al., 2018; Melnyk, Bititci, Platts, Tobias, & Andersen, 2014), even though use of the term "performance measurement systems" (PMSs) still endures.

Several domains address performance measurement (Bititci et al., 2018; Franco-Santos et al., 2007; Neely, 1999). In this article, we have used the Operations Management domain. From this point of view, performance measurement is the process of quantifying or qualifying the efficiency and effectiveness of an action. Measurement

   eISSN 2178-938X

occurs on four levels – task, process, organization, and supply chain (Bititci et al., 2018). Performance measure is the metric used to quantify the efficiency and/or effectiveness of the action, while PMS is the set of metrics used to do the same (Neely, Gregory, & Platts, 1995).

Exhibit 1 shows the definitions coined by Bititci et al. (2018), who expand on the definitions used by Neely et al. (1995), with the addition of the definition of performance management.

Exhibit 1. **Key PMS definitions**

Concept	Definition
Performance	Efficiency and/or effectiveness of an action
Performance Measurement	Qualitative or quantitative evaluation of an action's efficiency and/or effectiveness
Performance Measurement System	Process (or processes) of defining objectives, developing a set of performance measures, collecting, analyzing, reporting, interpreting, reviewing, and acting on performance data (technical controls)
Performance Management	Cultural and behavioral routines that define how we use the performance measurement system to manage an organization's performance (social controls)

Source: Bititci et al. (2018).

Analyzing several PMS definitions, Franco-Santos et al. (2007) propose three groups of elements: *features*; *roles*; and *processes*. Features are essentially performance measures (financial and non-financial metrics) and the necessary infrastructure for system operation (manual or digital). Roles are common usages, such as measuring performance (usually for controlling purposes), managing strategy, communicating performance, influencing behavior, and leading learning and improvement. Processes are the sequence of activities used for developing performance measures, collecting and processing data, managing information, evaluating and rewarding performance, and reviewing the system. Scholars can use PMS elements to identify and clarify the focus and contribution of an investigation.

With regard to PMS processes, there is no consensus in the literature (Bititci & Nudurupati, 2002; Bourne, Mills, Wilcox, Neely, & Platts, 2000; Gutierrez, Scavarda, Fiorencio, & Martins, 2015; Helden, Johnsen, & Vakkuri, 2012; Maestrini, Maccarrone, Caniato, & Luzzini, 2018; Nudurupati, Bititci, Kumar, & Chan, 2011). PMS processes are generally associated with the system's life cycle (Gutierrez et al., 2015; Maestrini et al., 2018). Bourne et al. (2000) suggest three processes: development, implementation, and use/review. Gutierrez et al. (2015) and Maestrini et al. (2018), however, argue that use should be separated from review because of the importance of updating the system.

Performance information use is one of the pillars of PMS, while organizational culture and management style moderate it. Two common usages are diagnostic use for control, and interactive use for innovation and improvement (Bititci, Mendibil, Nudurupati, Garengo, & Turner, 2006; Ferreira & Otley, 2009; Henri; 2006; Simons, 1995; Simons et al., 2000). The major influence of PMS comes from people using the system properly (Hopwood, 1972; Nudurupati et al., 2011). Changing of the purpose of PMS use from controlling (traditional use) to improving may require an organizational change that is greater than system implementation or review (Blenkinsop & Burns, 1992; Henri, 2006; Simons, 1995).

IT-based systems are critical to the successful implementation of a PMS (Garengo, Nudurupati, & Bititci, 2007; Nudurupati et al., 2011), although they can also become a barrier if they exist, specifically in a review (Bourne, Neely, Mills, & Platts, 2003; Bourne, Neely, Platts, & Mills, 2002; Braz, Scavarda, & Martins, 2011; Gutierrez et al., 2015; Nudurupati et al., 2011). The better the data available and the more accurate the information, the more effectively the performance (of decision makers) can be achieved if it is linked to the business strategy (Sztmczak et al., 2018). Reliable data collection and analysis, and investments in infrastructure and human resources are necessary for appropriate performance measurement and management (Mishra, Gunasekaran, Papadopoulos, & Dubey, 2018). IT is increasingly supporting the life cycle of PMSs (Nudurupati, Tebboune, & Hardman, 2016), but the challenge for efficiently measuring and managing performance in the digital age is twofold: adapting to the continuous transformation occurring in the external environment, and managing a large volume of data in diverse formats (Nudurupati et al., 2016). Digital ubiquity, therefore, is expected to transform the operation and the role of performance measurement and management systems (Xu, He, & Li, 2014).

Supply chains are complex, autonomous and interdependent systems, comprising companies and business units (Chan, 2011). Their success does not depend on the aggregation of individual operations and each company's performance, but on integrated and adaptive activities, and on relations between companies in the supply chain (Bourne et al., 2018). PMSs commonly improve the performance of firms indirectly, and socialization between companies (Cousins, Lawson, & Squire, 2008; Mahama, 2006). The number of effective approaches to managing supply chain performance is growing because of economic globalization and intensified competitiveness (Rezaei, Shirazi, & Karimi, 2017). Consequently, organizations need to change their performance evaluation to embrace a broader perspective (Nudurupati et al., 2016), so managers should pursue data integration along the entire supply chain information structure (Szymczak et al., 2018).

RESEARCH METHOD

The research method was a combination of bibliometric and content analyses of the literature (Luo et al., 2018; Morioka, Iritani, Ometto, & Carvalho, 2018; Lopes & Martins, 2021). Bibliometric analysis followed the steps proposed by Zupic and Čater (2015): (1) study definition: objective definition, database selection, and definition of the filters for delimiting the sample; (2) data compilation: selection, collection, and data processing after applying the filters in Step 1; (3) analysis: using software for bibliometric and statistical analysis; (4) visualization: selecting the method and software for visualizing the data; and (5) interpretation: interpreting and disseminating the results. Content analysis concentrated on performance measurement proposals for food waste.

We elected the Web of Science (WoS) scientific index for data collection because the metadata-cited references' format of the index is more suitable for data processing. We determined the following principles to ensure document consistency and eligibility:

- we considered journal articles, conference articles, reviews, and articles in early access;
- due to the lack of any similar studies, we did not apply a timespan filter.

We applied the following search strings: TS=(("performance measur*" OR "performance metric*" OR "key-performance indicator*" OR "measur* performance" OR "performance indicator*" OR "KPI *") AND ("food wast*" OR "food loss*" OR "waste* of food*" OR "waste* of the food*" OR "loss* of food*" OR "loss* of the food*"))). The combination of the terms associated with the two main topics, food waste and PMS, led to the search string composition. Applying the symbol * to some keywords means that the suffix words may vary. The aim was to cover term derivations in order to increase the return of registers.

We used the R Bibliometrix package, version 3.0.0, in the RStudio environment, version 1.2.5042 for bibliometric analysis and multivariate analysis of registers of the sample records extracted from the Web of Science (Aria & Cuccurullo, 2017). For charts and tables, we used Excel software, version 3.2.0. Finally, we used VOSViewer software, version 1.6.11, for analyzing the social networks (Eck & Waltman, 2013).

RESULTS

Bibliometric analysis

The bibliometric analysis enabled us to identify the main publications, their impact, the leading journals, and the top research issues related to PMS and food waste. On 5/25/2020, we searched the WoS, the result being 29 registers (23 journal articles, two conference articles, and four reviews). These registers had been published in 19 sources (journals and conference proceedings) between 2013 and 2020.

Figure 2 illustrates the scientific production and its impact (in terms of citations). Production is recent and driven by FAO publications (2013, 2014, 2015) and is the most significant since 2016, the peak being in 2018. With regard to impact, the average number of citations was at its most significant in 2013 (an average of 23.9 citations in the year), with subsequent values decreasing as expected, since recent publications have not yet had time to receive many citations.

Figure 2. **Number of documents published annually and average citations per year**

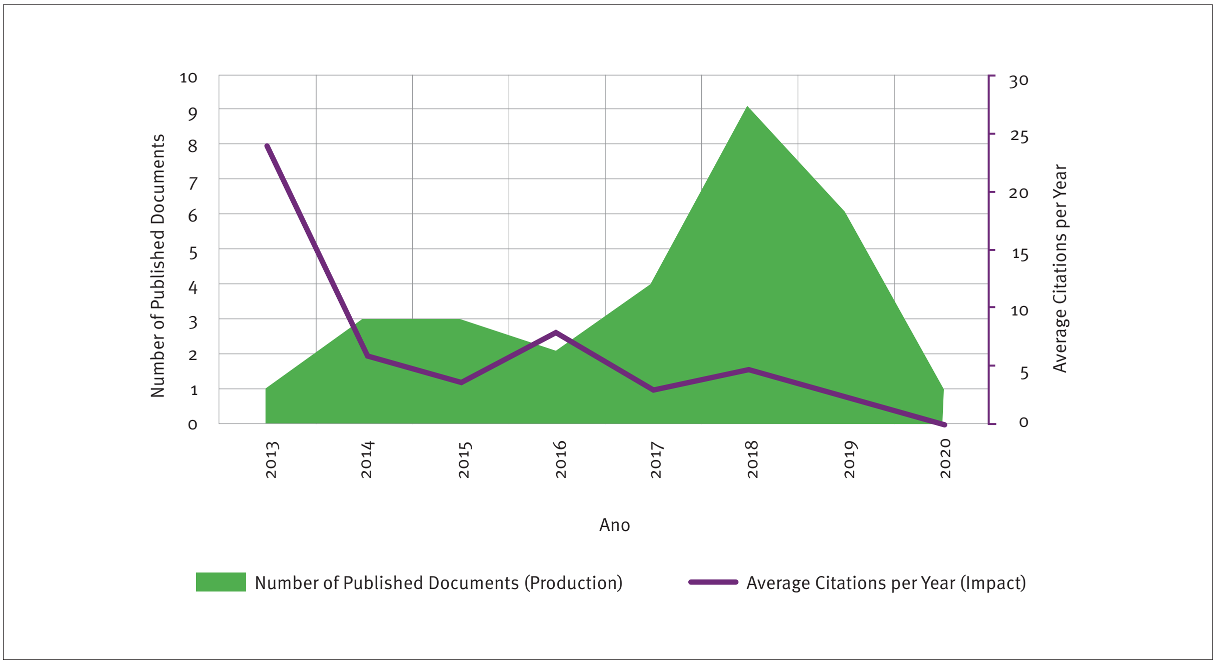


Table 1 details the impact of the scientific production, highlighting the documents with the greatest impact in terms of total citations and total citations per year. Brown and Li (2013) have the most cited article (167 citations), and the most citations per year (20.9). This explains the high average impact value per year in 2013 (Figure 2).

ElMekawy, Srikanth, Vanbroekhoven, Wever and Pant (2014) follow with 58 citations. Both works deal with the application of biotechnology for reducing food waste. Soysal, Bloemhof-Ruwaard, Haijema and Vorst (2018) (45 citations) and Hertog, Uysal, McCarthy, Verlinden and Nicolaï (2014) (41 citations) also stand out, with Soysal co-authoring both papers. Pirani and Arafat (2016) and Steur, Wesana, Dora, Pearce and Gellynck (2016) suggested management approaches to food waste.

Table 1. **Most cited sample articles**

First Author	Year	Journal	TC[1]	TC by Year	TC Ranking by Year
Brown D	2013	Bioresource Technol	167	20.9	1
Elmekawy A	2014	J Power Sources	58	8.3	3
Soysal M	2018	Comput Oper Res	45	15.0	2
Duke Mlatm	2014	Philos T T Soc A	41	5.9	5
Pirani Si	2016	J Clean Prod	40	8.0	4
Sturgeon H	2016	Waste Manage	23	4.6	7
Charlebois S	2015	Int J Cult Tour Hosp	20	3.3	9
Manser Nd	2015	Bioresource Technol	17	2.8	10
Martin-rilo S	2015	J Clean Prod	17	2.8	10
Menna F	2018	Waste Manage	14	4.7	6
Sun H	2017	Waste Manage	14	3.5	8

[1] The acronym TC refers to the total citations of each document

Changing the focus to journals and conference proceedings, Table 2 shows the central outlets that published sample articles. These journals published seven of the 11 most cited articles (Table 1), their domains being: Environmental Sciences [ES]; Industrial Engineering [IE]; and Energy [E]. *Journal of Cleaner Production* published the biggest number of the sample articles, followed by *Waste Management*. Although *Bioresource Technology* did not publish the largest number of articles, it has the greatest impact (number of citations).

Table 2. **Top journals in the field**

Journal	Articles	TC[1]	h index[2]	Areas[3]	Publisher
Journal of Cleaner Production	5	83	150	[ES] [IE] [E]	Elsevier B.V.
Waste Management	4	60	127	[ES]	Elsevier Ltd.
Bioresource Technology	3	193	251	[ES] [E]	Elsevier B.V.
Sustainability	2	0	53	[ES] [IE]	MDPI Open Access Publishing

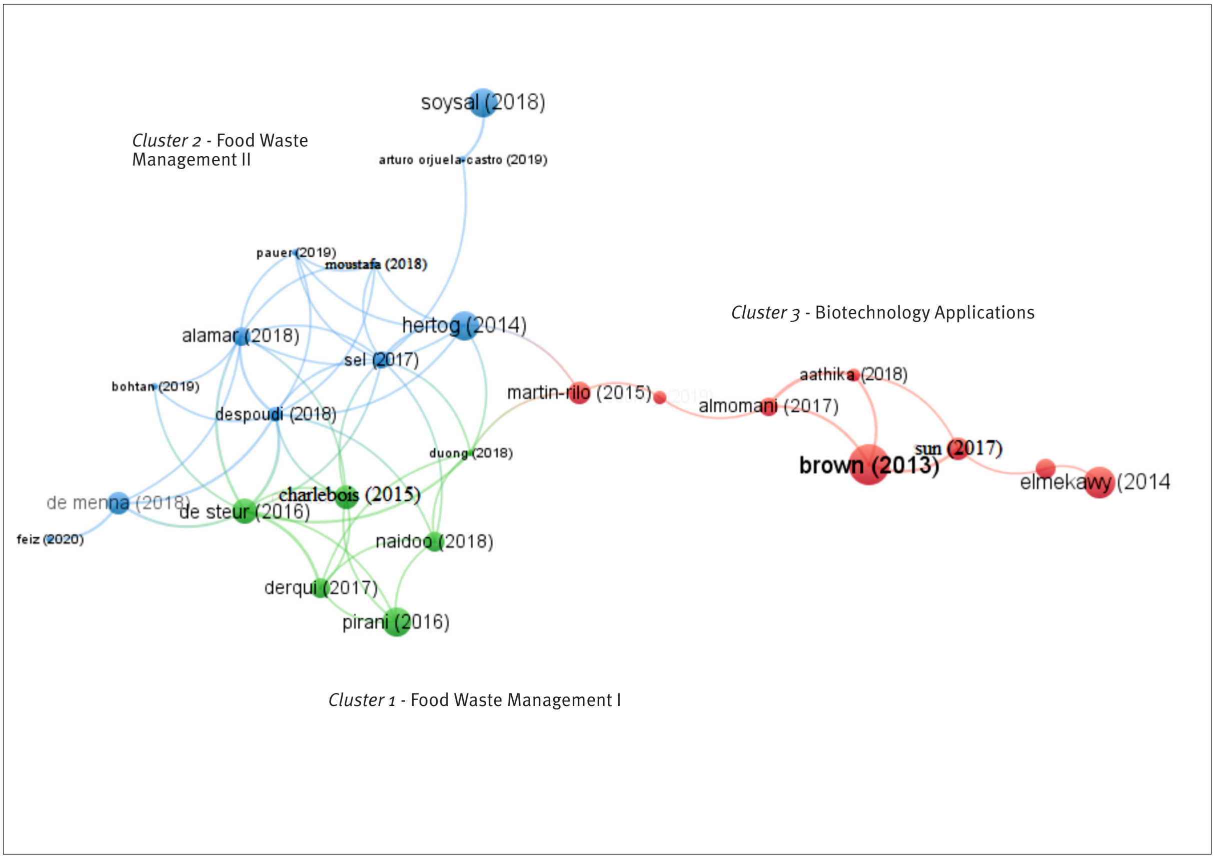
[1] TC means the total citations of each document.

[2] The Hirsch index (or h index) estimates the importance, significance and impact of accumulated scientific production (Hirsch, 2005).

[3] Research areas: [ES] - Environmental Sciences; [IE] - Industrial Engineering; and [E] - Energy.

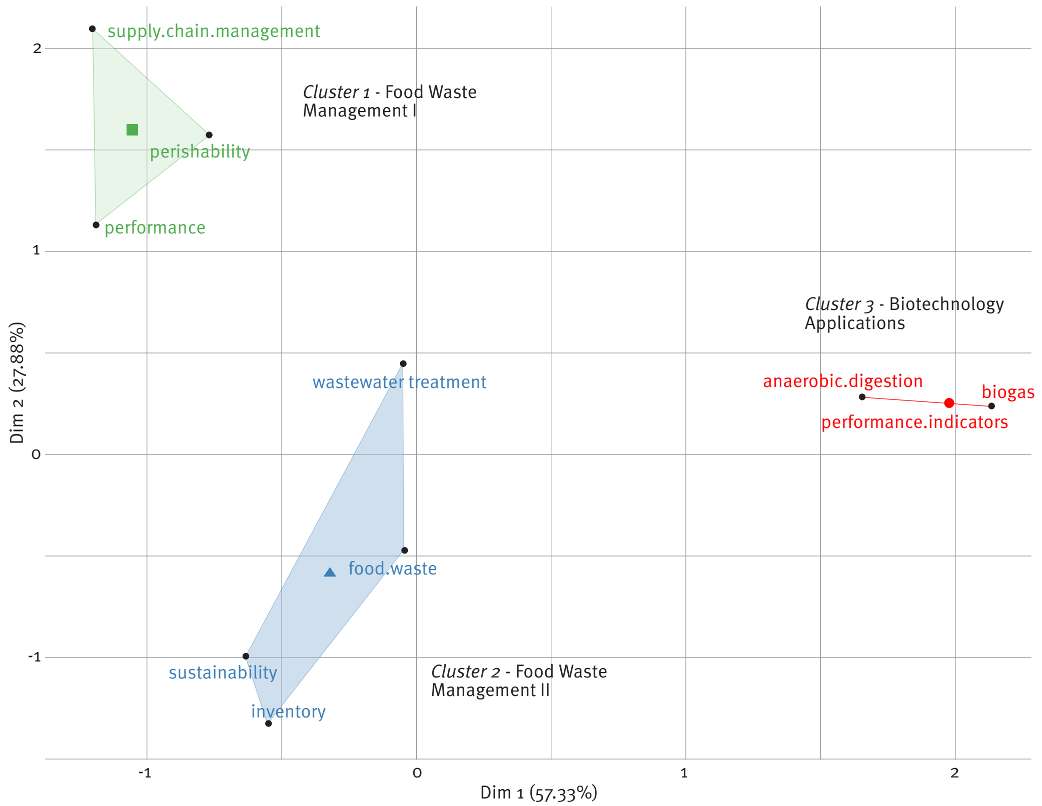
To identify the research themes of the sample documents, we used a bibliographic coupling network that enabled the similarities between the documents to be identified from their theoretical framework (Zupic & Čater, 2015). After clustering, we checked the research themes of the articles to name the clusters. At this point, our method is different from the methods used by Luo et al. (2018) and Morioka et al. (2018), but follows Lopes & Martins (2021). Figure 3 shows three clusters. Based on document titles, we identified that Cluster 1 (green) and Cluster 2 (blue) deal with food waste management approaches, while Cluster 3 (red) refers to the use of biotechnology in food waste.

Figure 3. **Bibliographic coupling network**



Analysis of the documents' keywords enabled the conceptual structure of a field to be mapped out, thus creating a map with multiple correspondence analysis application (Cobo, López- Herrera, Herrera- Viedma, & Herrera, 2011). Figure 4 shows the conceptual map of the domain with the authors' keywords; we identified three research streams. We assigned the cluster numbers in alignment with the findings of Figure 3. Cluster 1 in green encompasses *supply chain management, perishability,* and *performance*; Cluster 2 in blue, *sustainability*, *inventory, wastewater treatment* and *food waste;* finally, Cluster 3 in red, *anaerobic digestion, performance indicators,* and *biogas)*. Figure 4 differentiates between Clusters 1 and 2 that were identified earlier in Figure 3.

Figure 4. **Conceptual map of the field**



Due to the small number of articles in the sample, we used text mining with document abstracts to improve our understanding of the contents of the clusters (Eck & Waltman, 2013). This kind of analysis differentiates our method from that of Luo et al. (2018), Morioka et al. (2018), and Lopes & Martins (2021), although Liboni, Cezarino, Jabbour, Oliveira and Stefanelli (2019) did the same. Figure 5 illustrates the three distinct clusters that detail the previous results (Figures 3 and 4). We identified the clusters as follows: food supply chain performance measurement and product quality and safety in food distribution (Cluster 1 – green); food waste performance measures associated with business strategy and sustainability (Cluster 2 – blue); and the use of metrics and indicators in the application of biotechnology used for reducing food waste (Cluster 3 – red).

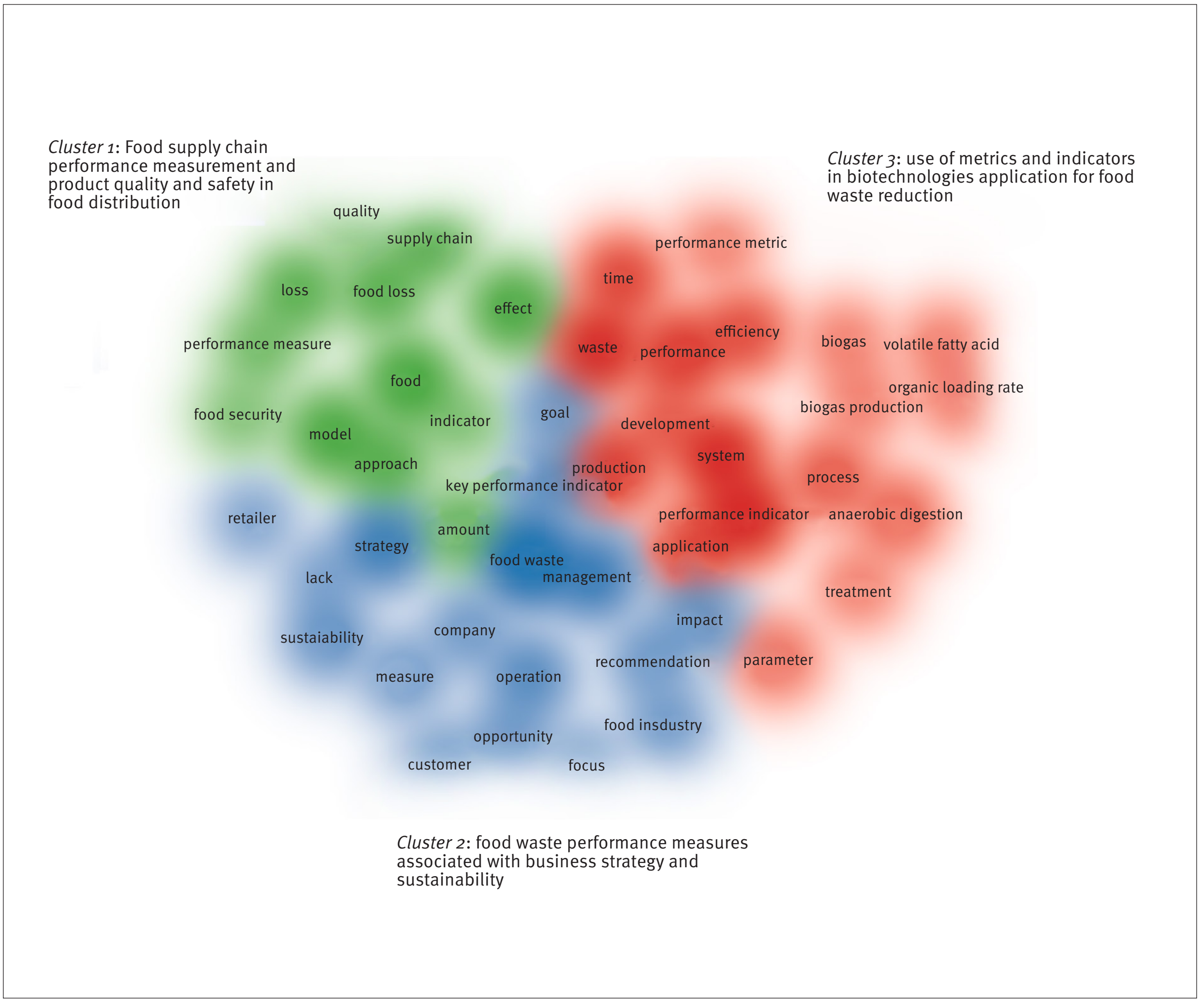
Cluster content analysis

Content analysis provides the domain details on the research themes that were identified: food supply chain performance measurement: product quality and safety in food distribution (Cluster 1 – green); food waste performance measures associated with business strategy and sustainability (Cluster 2 - blue); and the use of

eISSN 2178-938X

metrics and indicators in the application of biotechnology for reducing food waste (Cluster 3 - red). Content analysis in this paper focuses on Clusters 1 and 2, because they have an intrinsic association with food waste and performance measurement. Cluster 3 is about the application of technology for reducing food waste. We therefore ignore it because the topic is not the focus of this article.

Figure 5. **Abstract co-occurrent words**



Food supply chain performance measurement: product quality and safety in food distribution

Several of the sample articles focus on the performance measurement role in ensuring product quality throughout the supply chain. Steur et al. (2016) show the potential of value stream mapping for identifying and reducing food waste and improving nutrient retention in the supply chain. These authors present the state-of-the-art in the application of lean practices in the agri-food industry. They identify lead time as the most suitable performance measure. A reduction in lead times increases customer satisfaction because of faster responses to demand, which is important for perishable products. These authors also point out that most waste occurs during the processing stage.

   eISSN 2178-938X

Naidoo and Gasparatos (2018) explore the major factors for adopting environmental sustainability strategies in the food retail sector, and present the typical strategies and performance measures employed. The authors approach the subject from a PMS perspective. Their results suggest that the primary motivation for retailers in implementing sustainable strategies is the expected economic benefit associated with reducing resource use. These authors also identify the lack of studies on sustainability performance measures in the retail sector, particularly in developing countries. They also argue that big data should be used as a source of information for sustainable strategies and measuring performance.

The agricultural sector must implement new technologies to increase food production in order to comply with the growing demand for food because of population growth. Duong, Wood, and Wang (2018) investigate the three perishable food stock effects on performance: uncertain consumer demand, product life, and lost sales. Using a simulation model these authors evaluate the performance of different scenarios from the perspective of non-financial measures (average stock, supply rate, and proportion of order variation). Analytic Hierarchy Process (AHP) weighted performance measures relevance, and Data Envelopment Analysis (DEA) evaluates and classifies the performance of all scenarios. For these authors, managers should consider using non-financial performance measures to improve communication flow along the perishable products supply chain. They recommend more research for identifying and analyzing possible communication structures for promoting sustainability in this kind of supply chain.

Regarding food waste in services, Charlebois, Creedy and Massow (2015) identify the key determinants of food waste at points of sale. From a case study involving a well-known restaurant chain in Canada, these authors offer a perspective on the relationship between waste and factors such as cooking practices, services, cost management, risk mitigation, menu development, and technical knowledge in hospitality. Although those authors do not deal with performance measures, they identify measurement dimensions and the need to use metrics for a sharper analysis and for validating findings.

Pirani and Arafat (2016) evaluate the current practice of food waste management in the hospitality sector in the UAE. They establish that the style and hours of service, the type of food served, and inaccuracy in predicting the number of customers contribute most to the generation of food waste. Based on these parameters, they introduced an aggregate performance measure to assess service sustainability, “FRESH” (Food Waste Rating for Events vis-à-vis Sustainability in the Hospitality sector). To calculate the metric, the authors use five performance measures that reflect a dimension of the food service process and have an influence on the amount of food wasted. FRESH enables establishments, authorities, and customers to assess food service sustainability.

Derqui and Fernandez (2017) developed standardization guidelines for auditing and self-assessment in measuring food waste in school cafeterias. The authors obtained basic performance measures from public and private schools, and from outsourced companies. The metrics selected were: the planned number of meals vs. the actual number; aggregate waste by food type; the number of trays without waste; waste disposal; and the cost of food waste. Four schools then used these performance measures. The study indicates that if managers and employees are unaware of the amount of food wasted in the cafeterias, they will not be inclined to implement audits and actions for reducing waste. Institutions that focus on sustainability allocate more resources for reducing food waste, and so they are more likely to use these performance measures.

Food waste performance measures associated with business strategy and sustainability

Menna, Dietershagen, Loubiere and Vittuari (2018) focus on the life cycle of food products. Based on different aspects of life cycle cost analysis, the authors evaluate food waste management and product value. The food waste management perspective, however, requires a consistent integration between life cycle analysis and costs to avoid choosing between environmental or economic impacts. Therefore, interpretation of the results of the life cycle cost of food waste should acknowledge the effect on larger economic systems.

Pauer, Wohner, Heinrich and Tacker (2019) summarize the methods used for assessing the environmental sustainability of food packaging, whose function is both to protect food and increase shelf life. The proposed model defines three aspects of food packaging sustainability: direct environmental effects; losses and food waste generated during packaging; and circularity. The major circularity performance measures are:

- input: recycled content; reuse rate; renewable content;
- output: recyclability; recycling rate; recycling production rate; downcycling factor; reuse rate; compostability;
- energy: share of renewable energy.

Feiz et al. (2020) offer their recommendations for improving life cycle analysis modeling and simulations by aggregating environmental and economic performance analysis in the production of biogas from food waste. The suggested method and metrics consider the multiple functions of biogas production from food waste: waste management, renewable energy transportation, and nutrient recycling. Among the performance measures are: the effective yield of methane, climate impact, energy balance, the potential for nitrogen recycling, the potential for phosphorus recycling, the improvement in nitrogen available in the plant, and the cost of the resource.

Regarding collaboration within the food chain, Alamar, Falagán, Aktas and Terry (2018) encourage the development and implementation of collective solutions to better preserve and use food. If the quality of the post-harvest waste data available is questionable, the information generated using performance measures may be inaccurate. In order to reduce food waste there needs to be research into supply chains, an exchange of knowledge, and training.

From this same perspective, Despoudi, Papaioannou, Saridakis and Dani (2018) investigate the effects of different levels of collaboration on food waste in the post-harvest period. The authors also use a measurement model to identify the effect of different levels of collaboration on food waste. Findings suggest that high levels of collaboration between producers and cooperatives lead to low levels of food waste. The relationship between collaboration and performance requires more investigation in the context of food supply chains. Best practices for long-term collaboration also need to be identified.

With regard to the development of a mathematical model, Sel, Pınarbaşı, Soysal and Çimen (2017) model a food supply chain considering production and service management. The authors develop a stochastic programming model to solve demand problems, considering metrics like total amount of waste, total scarcity, and the total cost of production and distribution. Such metrics enable the sustainability performance of supply chains to be evaluated. The model relates food waste to economic performance and to environmental and social impacts.

Moustafa, Galal and El-Kilany (2018) investigate dynamic pricing strategies to maximize revenue and minimize food waste for driving sustainability. Price and product shelf life are the foundation of a stochastic on-demand simulation model. The authors analyze the inventory replacement effect on performance measures. Simulation results show the superiority of a dynamic pricing strategy over a fixed pricing strategy in relation to retailer profit and food waste.

Garcia-Garcia, Stone and Rahimifard (2019) model waste flow to achieve two goals: to provide data on manufacturing and food waste; and to analyze existing food waste management practices for implementing alternative value solutions. The most relevant metrics are: eco-efficiency, eco-intensity, the waste/product ratio, and the waste/raw materials ratio. The conclusion is that opportunities for food waste inventory management exist. They make recommendations for an improved food waste management system that focuses on assessment opportunities.

Other studies emphasize how to avoid waste during transportation. Hertog et al. (2014) propose a model for monitoring the quality and validity of perishable products. They differentiate traditional supply chain planning from the proposed use of metrics that relate shelf life to cost. The model offers strategic responses to supply chain management using product expiry and quality metrics in a real-time monitoring system. One critical factor that they identified is the willingness of all chain agents to participate and share information.

Soysal et al. (2018) develop a decision support model to evaluate the benefits of collaboration. They relate it to perishability, the energy use of transportation operations, and logistics costs. The proposed model enables collaboration benefits to be analyzed using various performance measures: emissions; driving time; and total cost, comprising routing, inventory, and the cost of waste when demand is uncertain. The results show that horizontal collaboration between suppliers contributes towards the total aggregate cost and leads to a reduction in emissions in the logistics system.

Exhibit 2. **Summary of performance measurement elements in Clusters 1 and 2**

Cluster	Article	Research Type	Performance Measures	Performance Measurement System	Performance Measurement Scope	Performance Measurement Use	PMS Processes
1	Pirani and Arafat (2016)	Empirical	Sustainability Indicator	Does not address	Public and Household Consumption	Control	Measurement Selection and Design
	Duong et al. (2018)	Empirical	Set of Sustainability Indicators	Does not address	Transportation, Storage and Retail Distribution	Improvement	Measurement Selection and Design
	Charlebois et al. (2015)	Empirical	Waste Sources only	Does not address	Retail	Control	Measurement Selection and Design
	Sturgeon et al. (2016)	Theoretical	Set of Indicators with Causal Relations in the Economic Dimension	Does not address	Transportation, Storage and Distribution to Public and Household Consumption	Improvement	Measurement Selection and Design
	Derqui e Fernandez (2017)	Empirical	Social, Economic and Sustainability Indicators	Does not address	Public and Household Consumption	Improvement	Data Collection and Manipulation
	Naidoo and Gasparatos (2018)	Theoretical	Set of Sustainability Indicators	Yes	Retail	Strategic Management	Measurement Selection and Design Information Management

Continue

Exhibit 2. Summary of performance measurement elements in Clusters 1 and 2

Concludes

Cluster	Article	Research Type	Performance Measures	Performance Measurement System	Performance Measurement Scope	Performance Measurement Use	PMS Processes
2	Duke et al. (2014)	Theoretical	Indicators with Causals Relations in the Economic Dimension	Does not address	Transportation, Storage and Distribution	Strategic Management Communication	Measurement Selection and Design Data Collection and Manipulation
	Alamar et al. (2018)	Theoretical	Measures with Causal Relations in the Economic Dimension	Does not address	Harvest/ Slaughter Processing and Packaging	Improvement	Data Collection and Manipulation
	Soysal et al. (2018)	Empirical	Set of Economic and Sustainability Indicators	Does not address	Transportation, Storage and Distribution	Control Communication	Measurement Selection and Design
	Despoudi et al. (2018)	Empirical	Tons wasted, as Economic and Sustainability Indicator	Does not address	Post-Harvest/ Slaughter Operations	Control	Information Management
	Orjuela-Castro et al. (2019)	Empirical	Set of Economic Indicators	Does not address	Transportation, Storage and Distribution	Improvement	Measurement Selection and Design
	Feiz et al. (2020)	Empirical	Set of Economic and Sustainability Indicators	Does not address	Processing and Packaging	Control	Measurement Selection and Design
	Salt et al. (2017)	Empirical	Set of Economic Indicators	Does not address	Public and Household Consumption	Control	Measurement Selection and Design
	Menna et al. (2018)	Theoretical	Set of Economic Indicators	Does not address	All Supply Chain Stages	Control	Unidentified
	Moustafa et al. (2018)	Theoretical	Set of Economic Indicators	Does not address	Retail	Control	Measurement Selection and Design
	Pauer et al. (2019)	Theoretical	Set of Sustainability Indicators	Yes	Processing and Packaging	Control	Measurement Selection and Design
	Bohtan et al. (2019)	Empirical	Set of Indicators with Causal Relations in the Economic Dimension	Yes	Post-Harvest/ Retail Slaughter Operations	Control Improvement	Measurement Selection and Design Data Collection and Manipulation
	Garcia-Garcia et al. (2019)	Empirical	Set of Sustainability Indicators	Does not address	Transportation, Storage and Distribution to Processing and Packaging	Control	Measurement Selection and Design

Orjuela-Castro, Orejuela-Cabrera and Adarme-Jaimes (2019) present a mathematical vehicle routing model for perishable foods, which models: a fleet of heterogeneous vehicles; the fixed cost of transport; a variable cost per distance traveled; and the cost of fruit waste associated with transportation time. The model also considers the perishability of fruit in an explicit relationship with travel time and vehicle capacity. The findings show the need to investigate multi-objective models, using performance measures of efficiency, quality, and responsiveness.

Bohtan, Mathiyazhagan and Vrat (2019) address food chain management using performance and productivity objectives to develop a PMS for a public food distribution system in India. The proposed PMS covers all transportation stages, because fast transport is vital for reducing food perishability. The system goal is to evaluate the effectiveness (meeting customer requirements) and efficiency (resource savings) of the supply chain. The authors recognize that performance measurement and improvement studies are fundamental for standardizing and optimizing the entire supply chain.

Exhibit 2 summarizes the elements of the performance measurement system found in the articles in Clusters 1 and 2. We analyzed each paper with regard to: the nature of the research (theoretical or empirical); the performance measures used (isolated or joint, economic or sustainability); the PMS approach; the scope of performance measurement (links in the food supply chain – Figure 1); the use of performance measurement (control, strategy, communication, influence on behavior, or improvement); and PMS processes (measurement selection and design, data collection and manipulation, information management, performance evaluation, and systems review). Franco-Santos et al. (2007) established the basis of the last two categories.

DISCUSSION OF RESULTS

The analysis first concentrates on the type of research described in the articles (Exhibit 2). Most papers are empirical (61.1%), as opposed to theoretical papers, like literature reviews, modeling or axiomatic simulations. Another point are the performance measures. We identify two types of performance measure; stand-alone, and sets of metrics, whose clustering does not reveal a logic. Many non-financial metrics establish a causal relationship between financial performance measures for assessing the impact of food waste, and loss (Buzby & Hyman, 2012; Gustavsson et al., 2011; Hall et al., 2009). An exception to this are Charlebois et al. (2015), who ignore performance measures, but indicate the sources of waste for developing metrics. Despoudi et al. (2018) substantiate their analysis of the economic and sustainability performance based on a single non-financial performance measure (the amount of food wasted). Pirani and Arafat (2016) propose an aggregate performance measure derived from six other measures, all of them non-financial.

The performance measures taken from the sample documents form an association with the financial, sustainability, and eco-financial dimensions (Exhibit 2). An exception to this are Derqui and Fernandez (2017), who include social performance measures from a triple bottom line perspective. The importance of the financial dimension is clear in Exhibit 2 (column "Performance Measures"), notably in the articles in Cluster 2. These articles deal with those food waste performance measures that are associated with business strategy and sustainability. Only three articles follow Bititci et al.'s (2018) PMS definition (Exhibit 1) that deals with a proposal for performance measurement systems and how to use them. This finding is alarming because scholars have been addressing performance measurement from a narrow perspective by emphasizing the performance measures used. This evidence corroborates the previous result. The sample documents cited 1,618 references, even though they only once cited traditional references to PMS, such as those by Kaplan and Norton (1992), Neely *et al.* (1995), Kaplan and Norton (1995), and Bititci, Carrie and McDevitt (1997). The absence of a theoretical background for PMS may explain the narrow approach adopted by the authors of the papers in Clusters 1 and 2.

A third point is the scope of performance measurement that deals with supply chain links in the sample documents (Exhibit 2). Menna *et al.* (2018) are the only ones to present a broad perspective involving all the links in the food supply chain, according to the FAO (2019). Most articles, especially those in Cluster 1, address those elements that are commonly found towards the end of the supply chain, like retailers, and public and household consumption. Even those authors who address PMS do so from the limited scope of the immediate supply chain (an upstream or downstream link with the coordinating link). Naidoo and Gasparatos (2018) and Pauer et al. (2019) focus only on one link, while Bohtan et al. (2019) consider the intermediate part of the supply chain.

A fourth point is the use of performance measurement. The findings deal with using PMS for control and improvement purposes (Exhibit 2). Hertog et al. (2014) propose using it for strategic management (emphasis on control) and communication with other links in the supply chain. Soysal et al. (2018) focus on suppliers. Finally, Bohtan et al. (2019) recommend using PMS for controlling and improving, and deal with its use from a broader perspective. This result corroborates the fact that the sample documents are lacking a broad performance measurement perspective. Scholars need to change and study the latest uses for PMS that focus on influencing agents and people's behaviors. These uses also highlight the lack of an approach looking at the whole of the supply chain, which is another alarming result.

The fifth point has to do with PMS processes. The findings show the dominance of the process for selecting and designing measures. Most articles present proposals for performance measures that reinforce previous findings. No article, however, develops the Bohdan metrics in accordance with PMS literature. Derqui and Fernandez (2017) and Naidoo and Gasparatos (2018) are exceptions in Cluster 1 because they deal with data collection and manipulation, the selection and design of measures, and communication management. Similarly, in Cluster 2, Hertog et al. (2014), Alamar et al. (2018) and Bohtan et al. (2019) deal with data collection and manipulation. Despoudi et al. (2018) is the only paper to address information management. The sample documents do not address performance evaluation or system review.

A sixth and final point is the scant attention that is paid to Industry 4.0 and its related terms, such as smart manufacturing or digitization, taken from sample authors. Only Naidoo and Gasparatos (2018) claim that retailers could take advantage of big data to improve their environmental performance by optimizing the supply chain. Hertog et al. (2014) also recognize radio frequency identification (RFID) as an enabler of rapid communication in the supply chain. The authors also admit that the application of cyber-physical systems is essential for a responsive and flexible supply chain and for reducing waste. There is no mention of communication technologies using cloud computing, blockchain, machine learning, artificial intelligence or human-machine interface. The sample articles do not mention techniques like additive manufacturing, virtual factories, or digital twins.

CONCLUSIONS

Using bibliometric and content analysis, the systematic literature review enabled us to respond to QP1: "What is the current state of experimental research into performance measurement systems for measuring food waste?" Current scientific production is incipient and has a low impact. Despite all the efforts by FAO/UN at the company and food chain level, the sample document authors developed or used performance measures for several aims. They evaluate performance using mathematical models or empirical research, as well as showing the potential for sustainable benefits for economic purposes. Cluster 1 and Cluster 2 articles follow the literature recommendations on food waste and try to connect food waste and natural resources with the financial dimension. Performance measures are also elements of waste management and food losses.

With relation to QP2: "What are the challenges and trends in implementing performance measurement systems for measuring food waste?", few articles address performance measurement for proposing metrics or systems, or how to use them. Controlling essentially dominates the use of performance measurement, followed by improving. The traditional view of how to use PMS probably prevails over using it for improving and learning. The most common PMS processes are selecting and designing metrics, while performance evaluation and system review are unexplored by Cluster 1 and Cluster 2 authors. This emphasis is in line with the focus on performance measures rather than on PMS. Performance measures are generally used in isolation, with the financial dimension predominating. Even sustainable metrics are often used merely to establish causal relationships with financial measures. Results point to the need to move towards performance management, focusing on PMS and the influence of agents and people's behaviors. Finally, among the many challenges, the central goal is to move from measuring the performance of supply chain links to using a PMS for the entire supply chain. The findings indicate an avenue for developing research to reduce waste and mitigate the effects, thus helping reduce food insecurity.

Many opportunities for future investigations emerge in the search for answers to the proposed research questions. Most articles in the sample, especially in Cluster 1, address the final links in the supply chain (retailers, and public and household consumption). Even authors who deal with PMSs do so from a narrow supply chain scope, and often only address the immediate supply chain. Undertaking research that moves the scope to include the whole of the food supply chain is a demanding task. Data collection and manipulation, and information management processes were not the focus of the sample articles. These PMS processes can benefit from Industry 4.0 digital technologies. Digital technologies could measure food waste more accurately from the perspective of the entire food supply chain. Finally, the use of performance information should influence attitudes towards reducing waste, with mitigation of the environmental and economic effects. The focus when using a PMS should be on improvement and learning, with the intensive application of digital technologies in PMS processes. Although choosing the WoS scientific index might have limited our investigation, we believe that the additional number of papers that might have been included in the sample would not have substantially changed the results.

REFERENCES

Alamar, M. D. C., Falagán, N., Aktas, E., & Terry, L. A. (2018). Minimising food waste: A call for multidisciplinary research. *Journal of the Science of Food and Agriculture*, *98*(1), 8-11. doi:10.1002/jsfa.8708

Aria, M. & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959-975. doi: 10.1016/j.joi.2017.08.007

Bititci, U., Garengo, P., Dörfler, V., & Nudurupati, S. (2012). Performance measurement: Challenges for tomorrow. *International Journal of Management Reviews*, *14*(3), 305-327. doi:10.1111/j.1468-2370.2011.00318.x

Bititci, U., & Nudurupati, S. (2002). Driving continuous improvement. *Manufacturing Engineer*, *81*(5), 230-235. doi:10.1049/me:20020506

Bititci, U. S., Bourne, M., Cross, J. A., Nudurupati, S. S., & Sang, K. (2018). Towards a theoretical foundation for performance measurement and management. *International Journal of Management Reviews*, *20*(3), 653-660. doi:10.1111/ijmr.12086

Bititci, U. S., Carrie, A. S., & McDevitt, L. (1997). Integrated performance measurement systems: A development guide. *International Journal of Operations & Production Management, 17*(5), 522-534. doi:10.1108/01443579710167230

Bititci, U. S., Mendibil, K., Nudurupati, S., Garengo, P., & Turner, T. (2006). Dynamics of performance measurement and organisational culture. *International Journal of Operations & Production Management*, *26*(12), 1325-1350. doi:10.1108/01443570610710579

Blenkinsop, S. A., & Burns, N. (1992). Performance measurement revisited. *International Journal of Operations & Production Management, 12*(10), 16-25. doi:10.1108/01443579210017213

Bohtan, A., Mathiyazhagan, K., & Vrat, P. (2019). Modeling the public distribution system: A PO-P approach. *OPSEARCH*, *56*(3), 1024-1066. doi:10.1007/s12597-019-00384-1

Bourne, M., Franco-Santos, M., Micheli, P., & Pavlov, A. (2018). Performance measurement and management: A system of systems perspective. *International Journal of Production Research*, *56*(8), 2788-2799. doi:10.1080/00207543.2017.1404159

Bourne, M., Mills, J., Wilcox, M., Neely, A., & Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations & Production Management, 20*(7), 754-771. doi:10.1108/01443570010330739

Bourne, M., Neely, A., Mills, J., & Platts, K. (2003). Implementing performance measurement systems: A literature review. *International Journal of Business Performance Management*, *5*(1), 1-24. doi:10.1504/IJBPM.2003.002097

Bourne, M., Neely, A., Platts, K., & Mills, J. (2002). The success and failure of performance measurement initiatives: Perceptions of participating managers. *International Journal of Operations & Production Management*, *22*(11), 1288-1310. doi:10.1108/01443570210450329

Braz, R. G. F., Scavarda, L. F., & Martins, R. A. (2011). Reviewing and improving performance measurement systems: An action research. *International Journal of Production Economics*, *133*(2), 751-760. doi:10.1016/j.ijpe.2011.06.003

Brown, D., & Li, Y. (2013). Solid state anaerobic co-digestion of yard waste and food waste for biogas production. *Bioresource Technology*, *127*, 275-280. doi:10.1016/j.biortech.2012.09.081

Buzby, J. C., & Hyman, J. (2012). Total and per capita value of food loss in the United States. Food Policy, *37*(5), 561-570. doi:10.1016/j.foodpol.2012.06.002

Chan, H. K. (2011). Supply chain systems: Recent trend in research and applications. *IEEE Systems Journal*, *5*(1), 2-5. doi:10.1109/jsyst.2010.2100191

Charlebois, S., Creedy, A., & Massow, M. von. (2015). "Back of house" – Focused study on food waste in fine dining: The case of Delish restaurants. *International Journal of Culture, Tourism and Hospitality Research, 9*(3), 278-291. doi:10.1108/ijcthr-12-2014-0100

Cicatiello, C., Franco, S., Pancino, B., & Blasi, E. (2016). The value of food waste: An exploratory study on retailing. *Journal of Retailing and Consumer Services*, *30*, 96-104. doi:10.1016/j.jretconser.2016.01.004

Cobo, M. J., López-Herrera, A. G., Herrera-Viedma, E., & Herrera, F. (2011). Science mapping software tools: Review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology*, *62*(7), 1382-1402. doi:10.1002/asi.21525

Comissão Europeia. (2010). *Preparatory study on food waste across EU 27*. Available at https://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf

Cousins, P. D., Lawson, B., & Squire, B. (2008). Performance measurement in strategic buyer- supplier relationships. *International Journal of Operations & Production Management, 28*(3), 238-258. doi:10.1108/01443570810856170

Dal'Magro, G. P., & Talamini, E. (2019). Estimating the magnitude of the food loss and waste generated in Brazil. *Waste Management & Research*, *37*(7), 706-716. doi:10.1177/0734242X19836710

Derqui, B., & Fernandez, V. (2017). The opportunity of tracking food waste in school canteens: Guidelines for self-assessment. *Waste Management*, *69*, 431-444. doi:10.1016/j.wasman.2017.07.030v

Department of Economic and Social Affairs , UN (2016). *Transforming our world: The 2030 agenda for sustainable development*. Retrieved from https://sdgs.un.org/2030agenda

Despoudi, S., Papaioannou, G., Saridakis, G., & Dani, S. (2018). Does collaboration pay in agricultural supply chain? An empirical approach. *International Journal of Production Research*, *56*(13), 4396-4417. doi:10.1080/00207543.2018.1440654

Duong, L. N., Wood, L. C., & Wang, W. Y. (2018). Effects of consumer demand, product lifetime, and substitution ratio on perishable inventory management. *Sustainability*, *10*(5), 1559. doi: 10.3390/su10051559

Eck, N. J. Van, & Waltman, L. (2013). *VOSviewer manual.* Retrieved from https://www.vosviewer.com/download/f-33t2.pdf

ElMekawy, A., Srikanth, S., Vanbroekhoven, K., Wever, H. De, & Pant, D. (2014). Bioelectro-catalytic valorization of dark fermentation effluents by acetate oxidizing bacteria in bioelectrochemical system (BES). *Journal of Power Sources*, *262*, 183-191. doi:10.1016/j.jpowsour.2014.03.111

Feiz, R., Johansson, M., Lindkvist, E., Moestedt, J., Påledal, S. N., & Svensson, N. (2020). Key performance indicators for biogas production: Methodological insights on the life-cycle analysis of biogas production from source-separated food waste. *Energy*, *200*, 117462. doi:10.1016/j.energy.2020.117462

Ferreira, A., & Otley, D. (2009). The design and use of performance management systems: An extended framework for analysis. *Management Accounting Research*, *20*(4), 263-282. doi:10.1016/j.mar.2009.07.003

Food and Agriculture Organization of the United Nations. (2008). *An introduction to the basic concepts of food security*. Retrieved from https://www.fao.org/3/a-al936e.pdf

Food and Agriculture Organization of the United Nations. (2013). *Food wastage footprint: Impacts on natural resources*. Retrieved from https://www..fao.org/3/i3347e/i3347e.pdf

Food and Agriculture Organization of the United Nations. (2014). *Mitigation of food wastage: Societal costs and benefits*. Retrieved from https://www.fao.org/3/a-i3989e.pdf

Food and Agriculture Organization of the United Nations. (2015). *The state of food and agriculture*. Retrieved from https://www.fao.org/3/a-i4910e.pdf

Food and Agriculture Organization of the United Nations. (2017). *Save food: Global initiative on food loss and waste reduction*. Retrieved from https://www.fao.org/3/a-i7657e.pdf

Food and Agriculture Organization of the United Nations. (2019). *The state of food and agriculture 2019: Moving forward on food loss and waste reduction*. Retrieved from http://www.fao.org/3/ca6030en/ca6030en.pdf

Franco-Santos, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., ... Neely, A. (2007). Towards a definition of a business performance measurement system. *International Journal of Operations & Production Management*, *27*(8), 784-801. doi:10.1108/01443570710763778

Galanakis, C. M. (2012). Recovery of high added-value components from food wastes: Conventional, emerging technologies and commercialized applications. *Trends in Food Science & Technology*, *26*(2), 68-87. doi: 10.1016/j.tifs.2012.03.003

Garcia-Garcia, G., Stone, J., & Rahimifard, S. (2019). Opportunities for waste valorisation in the food industry: A case study with four UK food manufacturers. *Journal of Cleaner Production*, *211*, 1339-1356. doi:10.1016/j.jclepro.2018.11.269

Garengo, P., Nudurupati, S., & Bititci, U. (2007). Understanding the relationship between PMS and MIS in SMEs: An organizational life cycle perspective. *Computers in Industry*, *58*(7), 677-686. doi:10.1016/j.compind.2007.05.006

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, *327*(5967), 812-818. doi:10.1126/science.1185383

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R. Van, & Meybeck, A. (2011). *Global food losses and food waste*. Retrieved from http://www.fao.org/3/i2697e/i2697e.pdf

Gutierrez, D. M., Scavarda, L. F., Fiorencio, L., & Martins, R. A. (2015). Evolution of the performance measurement system in the logistics department of a broadcasting company: An action research. *International Journal of Production Economics*, *160*, 1-12. doi:10.1016/j.ijpe.2014.08.012

Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The progressive increase of food waste in America and its environmental impact. *PloS One*, *4*(11), e7940. doi:10.1371/journal.pone.0007940

Helden, G. J. V. Van, Johnsen, Å., & Vakkuri, J. (2012). The life-cycle approach to performance management: Implications for public management and evaluation. *Evaluation*, *18*(2), 159-175. doi:10.1177/1356389012442978

Henri, J. F. (2006). Organizational culture and performance measurement systems. *Accounting, Organizations and Society*, *31*(1), 77-103. doi: 10.1016/j.aos.2004.10.003

Hertog, M. L., Uysal, I., McCarthy, U., Verlinden, B. M., & Nicolaï, B. M. (2014). Shelf life modelling for first-expired-first-out warehouse management. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372*(2017), 20130306. doi:10.1098/rsta.2013.0306

Hirsch, J. E. (2005). An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences*, *102*(46), 16569-16572. doi:10.2307/4152261

Hopwood, A. G. (1972). An empirical study of the role of accounting data in performance evaluation. *Journal of Accounting Research*, *10*, 156-182. doi:10.2307/2489870

Jedermann, R., Nicometo, M., Uysal, I., & Lang, W. (2014). Reducing food losses by intelligent food logistics. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 372*(2017), 20130302. doi:10.1098/rsta.2013.0302

Kaipia, R., Dukovska- Popovska, I., & Loikkanen, L. (2013). Creating sustainable fresh food supply chains through waste reduction. *International Journal of Physical Distribution & Logistics Management* , *43*(3), 262-276. doi:10.1108/IJPDLM-11-2011-0200

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard: Measures that drive performance. *Harvard Business Review*, *70*(1), 71-79. Retrieved from https://www.hbs.edu/faculty/Pages/item.aspx?num=9161

Kaplan, R. S., & Norton, D. P. (1995) Putting the balanced scorecard to work. In D. G. Shaw, C. E. Schneier, R. W. Beatty, & L. S. Baird (Eds.), *Performance measurement, management, and appraisal sourcebook* (Vol. 66, pp. 66-79). Amherst, USA: Human Resource Development.

Kiran, E. U., Trzcinski, A. P., Ng, W. J., & Liu, Y. (2014). Bioconversion of food waste to energy: A review. *Fuel*, *134*, 389-399. doi:10.1016/j.fuel.2014.05.074

Kummu, M., Moel, H. De, Porkka, M., Siebert, S., Varis, O., & Ward, P. J. (2012). Lost food, wasted resources: Global food supply chain losses and their impacts on freshwater, cropland, and fertiliser use. *Science of the Total Environment*, *438*, 477-489. doi:10.1016/j.scitotenv.2012.08.092

Liboni, L. B., Cezarino, L. O., Jabbour, C. J. C., Oliveira, B. G., & Stefanelli, N. O. (2019). Smart industry and the pathways to HRM 4.0: Implications for SCM. *Supply Chain Management: An International Journal, 24*(1), 124-146. doi:10.1108/SCM-03-2018-0150

Lopes, M. A., & Martins, R. A. (2021). Mapping the impacts of Industry 4.0 on performance measurement systems". *IEEE Latin America Transactions,* 19(11), 1912–1923. Retrieved from https://latamt.ieeer9.org/index.php/transactions/article/view/4807

Lundqvist, J., Fraiture, C. de, & Molden, D. (2008). *Saving water: From field to fork: Curbing losses and wastage in the food chain*. Stockholm, Sweden: Stockholm International Water Institute. Retrieved from

https://www.siwi.org/wp-content/uploads/2015/09/PB_From_Filed_to_fork_2008.pdf

Luo, J., Ji, C., Qiu, C., & Jia, F. (2018). Agri-food supply chain management: Bibliometric and content analyses. *Sustainability*, *10*(5), 1573. doi:10.3390/su10051573

Maestrini, V., Maccarrone, P., Caniato, F., & Luzzini, D. (2018). Supplier performance measurement systems: Communication and reaction modes. *Industrial Marketing Management*, *74*, 298-308. doi: 10.1016/j.indmarman.2018.07.002

Mahama, H. (2006). Management control systems, cooperation and performance in strategic supply relationships: A survey in the mines. *Management Accounting Research*, *17*(3), 315-339. doi: 10.1016/j.mar.2006.03.002

Melnyk, S. A., Bititci, U., Platts, K., Tobias, J., & Andersen, B. (2014). Is performance measurement and management fit for the future? *Management Accounting Research*, *25*(2), 173-186. doi:10.1016/j.mar.2013.07.007

Menna, F. De, Dietershagen, J., Loubiere, M., & Vittuari, M. (2018). Life cycle costing of food waste: A review of methodological approaches. *Waste Management*, *73*, 1-13. doi:10.1016/j.wasman.2017.12.032

Mirabella, N., Castellani, V., & Sala, S. (2014). Current options for the valorization of food manufacturing waste: A review. *Journal of Cleaner Production*, *65*, 28-41. doi:10.1016/j.jclepro.2013.10.051

Mishra, D., Gunasekaran, A., Papadopoulos, T., & Dubey, R. (2018). Supply chain performance measures and metrics: A bibliometric study. *Benchmarking: An International Journal, 25* (3), 932-967. doi:10.1108/*BIJ-08-2017-0224*

Morioka, S. N., Iritani, D. R., Ometto, A. R., & Carvalho, M. M. D. (2018). Revisão sistemática da literatura sobre medição de desempenho de sustentabilidade corporativa: Uma discussão sobre contribuições e lacunas. *Gestão & Produção*, *25*(2), 284-303. doi:10.1590/0104-530x2720-18

Moustafa, G. Y., Galal, N. M., & El-Kilany, K. S. (2018, December). *Sustainable dynamic pricing for perishable food with stochastic demand.* In IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). Bangkok, Thailand.

Naidoo, M., & Gasparatos, A. (2018). Corporate environmental sustainability in the retail sector: Drivers, strategies and performance measurement. *Journal of Cleaner Production*, *203*, 125-142. doi:10.1016/j.jclepro.2018.08.253

Neely, A. (1999). The performance measurement revolution: Why now and what next? *International Journal of Operations & Production Management*, 19(2), 205-228. doi:10.1108/01443579910247437

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. International *Journal of Operations & Production Management*, *15*(4), 80-116. doi: 10.1108/01443579510083622

Nudurupati, S. S., Bititci, U. S., Kumar, V., & Chan, F. T. (2011). State of the art literature review on performance measurement. *Computers & Industrial Engineering*, *60*(2), 279-290. doi: 10.1016/j.cie.2010.11.010

Nudurupati, S. S., Tebboune, S., & Hardman, J. (2016). Contemporary performance measurement and management (PMM) in digital economies. *Production Planning & Control*, *27*(3), 226-235. doi:10.1080/09537287.2015.1092611

Oelofse, S. H., & Nahman, A. (2013). Estimating the magnitude of food waste generated in South Africa. *Waste Management & Research*, *31*(1), 80-86. doi:10.1177/0734242X12457117

Orjuela-Castro, J. A., Orejuela-Cabrera, J. P., & Adarme-Jaimes, W. (2019). Last mile logistics in mega-cities for perishable fruits. *Journal of Industrial Engineering and Management*, *12*(2), 318-327. doi:10.3926/jiem.2770

Papargyropoulou, E., Lozano, R., Steinberger, J. K., Wright, N., & Ujang, Z. bin. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, *76*, 106-115. doi:10.1016/j.jclepro.2014.04.020

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 3065-3081. doi:10.2307/20752997

Pauer, E., Wohner, B., Heinrich, V., & Tacker, M. (2019). Assessing the environmental sustainability of food packaging: An extended life cycle assessment including packaging-related food losses and waste and circularity assessment. *Sustainability*, *11*(3), 925. doi:10.3390/su11030925

Pirani, S. I., & Arafat, H. A. (2016). Reduction of food waste generation in the hospitality industry. *Journal of Cleaner Production*, *132*, 129-145. doi:10.1016/j.jclepro.2015.07.146

Raak, N., Symmank, C., Zahn, S., Aschemann-Witzel, J., & Rohm, H. (2017). Processing-and product-related causes for food waste and implications for the food supply chain. *Waste Management*, *61*, 461-472. doi:10.1016/j.wasman.2016.12.027

Rezaei, M., Shirazi, M. A., & Karimi, B. (2017). IoT-based framework for performance measurement. *Industrial Management & Data Systems, 117*(4), 688-712. doi: 10.1108/IMDS-08-2016-0331

Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., & Matthews, E. (2018). *Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050*. World Resources Institute. Retrieved from https://www.wri.org/research/creating-sustainable-food-future

Sel, Ç., Pınarbaşı, M., Soysal, M., & Çimen, M. (2017). A green model for the catering industry under demand uncertainty. *Journal of Cleaner Production*, *167*, 459-472. doi:10.1016/j.jclepro.2017.08.100

Simons, R., Russ-Eft, D., Preskill, H., Tejada, R. A., Negrini, S. D., Corrales, M. M., ... Román, I. (2000). *Performance measurement and control systems for implementing strategy* (N. D10 276). Tegucigalpa, Honduras: IICA.

Simons, T. (1995). Top management team consensus, heterogeneity, and debate as contingent predictors of company performance: The complimentarity of group structure and process. In *Academy of Management Proceedings*, *1995*(1), 62-66. doi:10.5465/AMBPP.1995.17536282

Soysal, M., Bloemhof-Ruwaard, J. M., Haijema, R., & Vorst, J. G. van der. (2018). Modeling a green inventory routing problem for perishable products with horizontal collaboration. *Computers & Operations Research*, *89*, 168-182. doi:10.1016/j.cor.2016.02.003

Steur, H. De, Wesana, J., Dora, M. K., Pearce, D., & Gellynck, X. (2016). Applying value stream mapping to reduce food losses and wastes in supply chains: A systematic review. *Waste Management*, *58*, 359-368. doi:10.1016/j.wasman.2016.08.025

Stuart, T. (2009). *Waste: Uncovering the global food scandal*. W. W. Norton & Company. New York, Estados Unidos.

Szymczak, M., Ryciuk, U., Leończuk, D., Piotrowicz, W., Witkowski, K., Nazarko, J., & Jakuszewicz, J. (2018). Key factors for information integration in the supply chain–measurement, technology and information characteristics. *Journal of Business Economics and Management*, *19*(5), 759-776. doi.org/10.3846/jbem.2018.6359

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., ... Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, *151*(1), 53-59. doi:10.1016/j.biocon.2012.01.068

Waarts, Y. R., Eppink, M., Oosterkamp, E. B., Hiller, S. R. C. H., Sluis, A. A. Van Der, & Timmermans, T. (2011). *Reducing food waste: Obstacles experienced in legislation and regulations* (N. 2011-059). Landbouw-Economisch Institut (LEI), Wageningen University and Research Centre (WUR). Wageningen, Países Baixos.

Wamba, S. F., Akter, S., Edwards, A., Chopin, G., & Gnanzou, D. (2015). How 'big data' can make big impact: Findings from a systematic review and a longitudinal case study. *International Journal of Production Economics*, *165*, 234-246. doi:10.1016/j.ijpe.2014.12.031

West, P. C., Gerber, J. S., Engstrom, P. M., Mueller, N. D., Brauman, K. A., Carlson, K. M., ... Siebert, S. (2014). Leverage points for improving global food security and the environment. *Science*, *345*(6194), 325-328. doi:10.1126/science.1246067

Xu, L., He, W., & Li, S. (2014). Internet of things in industries: A survey. *IEEE Transactions on Industrial Informatics*, *10*(4), 2233-2243. doi:10.1109/TII.2014.2300753

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429-472. doi:10.1177/1094428114562629

CONTRIBUIÇÃO DOS AUTORES

Paulo Henrique Amorim Santos and Roberto Antonio Martins worked on the conceptualization and approach theoretical-methodological. The authors together conducted the theoretical review, data collection and analysis. They participated in the writing and final review of the manuscript.

