The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1741-0401.htm

Managing the traceability system for food supply chain performance

Dimitrios Kafetzopoulos
Department of Business Administration, University of Macedonia, Thessaloniki, Greece
Spiridoula Margariti and Chrysostomos Stylios
Department of Informatics and Telecommunication, University of Ioannina - Arta, Arta, Greece
Eleni Arvaniti
Department of Environmental Engineering, University of Patras, Patras, Greece, and
Panagiotis Kafetzopoulos
Department of Business Administration of Food and Agricultural Enterprises, University of Patras - Agrinio Campus, Agrinio, Greece

Received 14 December 2021
Revised 5 July 2022
7 November 2022
Accepted 16 December 2022

Abstract

Purpose – The objective of this study is to improve the food supply chain performance taking into consideration the fundamental concepts of traceability by combining the current frameworks, its principles, its implications and the emerging technologies.

Design/methodology/approach – A narrative literature review of already existing empirical research on traceability systems was conducted resulting in 862 relevant papers. Following a step-by-step sampling process, the authors ended up with 46 final samples for the literature review.

Findings – The main findings of this study include the various descriptions of the architecture of traceability systems, the different sources enabling this practice, the common desirable attributes, and the enabling technologies for the deployment and implementation of traceability systems. Moreover, several technological solutions are presented, which are currently available for traceability systems, and finally, opportunities for future research are provided.

Practical implications – It provides an insight, which could affect the implementation process of traceability in the food supply chain and consequently the effective management of a food traceability system (FTS). Managers will be able to create a traceability system, which meets users' requirements, thus enhancing the value of products and food companies.

Originality/value – This study contributes to the food supply chain and the traceability systems literature by creating a holistic picture of where something has been and where it should go. It is a starting point for each food company to design and manage its traceability system more effectively.

Keywords Food manufacturing, Traceability, Digital technologies, Open innovation, Performance, Consumer

Paper type Research paper

1. Introduction

Traceability has been recognised within the context of food supply chain as a strategic decision-making method for food manufacturing management (Chen, 2017; Kumar *et al.*, 2015). It collects in a rigorous way all the information related to the displacement of the different products along the supply chain (Dabbene *et al.*, 2014). Food supply chain traceability is considered as the cornerstone of the increasingly complex, industrialised, global food system. It is useful for customers, producers and manufacturers to track items for the purpose of supply chain management (Dima *et al.*, 2022). Therefore, value-based food

This research is supported by Operational Program of Region of Western Macedonia 2014–2020 under the project "Ko-MEAT-IT: Developing a modern system of advanced traceability of the Kozani meat to improve productive performance, quality and hygiene using intelligent information systems" cofinanced by the European Union—European Regional Development Fund (ERDF) and National Resources.

1741-0401
DOI 10.1108/IJPPM-12-2021-0690

traceability is applied as a tool contributing to the assurance of food safety and food quality in order to ensure consumers' satisfaction (Chen, 2017).

However, due to the increasingly separated production and consumption of food products and the complexity of the supply system, traditional traceability methods are facing problems such as poor management and inefficiency. There is no common understanding of the principles of traceability, nor is there a sound and common theoretical framework with respect to the implementation of food traceability (Islam and Cullen, 2021; Karlsen *et al.*, 2013). Moreover, there is a need to present integrated traceability technologies for the identification of food products, to update the methods for information collection, and to expound traceability policies, guidelines and regulations between countries (Bai *et al.*, 2017). Despite the academic interest in the industrial practices and the increasing number of academic publications on food traceability, there is still no common understanding of the theoretical concepts, which underpin traceability itself (Li *et al.*, 2017; Karlsen *et al.*, 2013). Although there has been a technology breakthrough, studies on the development and applications of food traceability are still seriously lacking, thus leaving several research gaps (Feng *et al.*, 2020). Islam and Cullen (2021) identified the need of an extended literature review to expand and enhance the fundamental concepts of food traceability, its principles, its implications and the emerging technologies.

This paper is a response to the above-mentioned research gap, as it analyses and consolidates concepts already existing in the literature into a coherent synthesis of current frameworks of food traceability. It also presents, compares and assesses the up-to-date traceability technologies relating to the food supply chain (FSC). This study is the first one to bring together a set of traceability principles, guidelines and technologies, with which companies involved in the FSCs may comply in order to make their traceability system more effective and consequently deal with potential disadvantages. The present study contributes to the design and implementation of traceability systems by providing each food company with a starting point to manage its traceability system more effectively. We study the applications of emerging technologies, such as the Internet of things (IoTs), fog computing and cloud computing, in order to provide the digital architecture of traceability systems. We introduce a qualitative evaluation of the communication and networking in such systems, acknowledging their major role in the exchange of traceability data. Finally, we compare the relevant traceability technologies used to identify and verify the product and we identify the challenges and opportunities for future research in this field. We approached this study having six overarching questions in mind to achieve the interrelated objectives.

(1) How is traceability defined and understood within the FSC?

(2) What does the food traceability practice tell us?

(3) What are the attributes of an effective and economic FTS?

(4) Which are the enabling technologies for the deployment of food traceability?

(5) What does the evaluation of the existing food traceability technologies tell us?

(6) What do we need to further explore in the future about food traceability?

With a view to achieving our objectives, we decided to use a literature review as our methodological tool in order to provide a replicable, rigorous and transparent assessment of the existing literature as well as to find out what we know and do not know about food traceability. Our review aims to study the food traceability literature to create a holistic picture of where something has been and where it should go. It addresses those specific actions required in order for a manager to implement and operate an effective and innovative FTS.

The present paper is structured as follows: Section two describes the methodology used for this study. Section three presents the content and data synthesis within the research framework on FTS. Section four discusses the findings and implications and finally, section five summarises the conclusions.

2. Methodological approach

In terms of methodology, we choose the narrative literature review as our research method, as it aims to summarise or synthesise what has been written on a particular topic but does not seek generalisation or cumulative knowledge from what is reviewed (Paré *et al.*, 2015). An exhaustive, effective and well-conducted literature review collects all available information and creates a firm foundation for advancing knowledge and facilitating theory development. By integrating findings and perspectives from many empirical findings, a literature review can address research questions with a power that no single study has (Snyder, 2019). In this study we followed the work of Tranfield *et al.* (2003) with the key points as summarised by Denyer and Neely (2004). The three steps include: the development of clear and precise aims and objectives; a comprehensive search of all potentially relevant articles; and a balanced, impartial and comprehensible presentation of the results (Centobelli *et al.*, 2019; Turner *et al.*, 2013). Our main objective is to reveal the concept, the current development as well as the applications of food traceability, the characteristics of the emerging technologies and the attributes of an effective and economic FTS. As a result, the literature on traceability will be strengthened. Following previous studies (e.g. Islam and Cullen, 2021; Khosravi *et al.*, 2019), this study included empirical studies from peer-reviewed journals as well as practitioner literature, as these can be considered as validated knowledge and are likely to have the highest impact on the field. As for the planning stage, a review protocol was designed based on the objectives of the study. The electronic databases searched were Emerald, ScienceDirect, Scopus and Web of Science, as the same databases have already been used in previous reviews (e.g. Nandankar and Sachan, 2020; Khosravi *et al.*, 2019) and they contain the major journals, in which this subject is discussed. Combinations of terms were used when searching the literature in order to identify various definitions, concepts and terminologies across different articles. As we are interested in the latest developments of food traceability, our review spans 11 years (from 2010 to the last issue of 2021, which was available online on May 15, 2021).

After deciding on the purpose and type of the review, as for the execution stage, we developed and searched keywords in the publications' titles, abstracts and keywords (Christofi *et al.*, 2021; Keupp *et al.*, 2012; Tranfield *et al.*, 2003). The searched keyword was "food traceability" as a broad, "umbrella", term. Moreover, all authors of this paper selected articles to ensure the quality and reliability of the search protocol. Based on the search criteria, we executed the main screening resulting in roughly 862 papers. Due to duplicates, a large number of hits are quite common in the first round of a literature review search. After removing the duplicates from the list of articles, the sample was reduced to 323 titles. To classify, which of these 323 articles fit the focus and scope of this study, the authors reviewed and analysed them (Denyer and Neely, 2004). Following the studies of Snyder (2019) and Keupp *et al.* (2012), the extent to which the articles focused on the traceability system in the food supply chain and traceability technology was assessed by reading and rating each article's title and abstract on separate four-point scales anchored at "not at all" and "clearly". The papers were evaluated for inclusion criteria; theoretical and empirical criteria; quality criteria; relevance; and a common data extraction format. We classified an article as relevant if the average score across all authors was 3.0 or above on both scales (Keupp *et al.*, 2012). This process brought down the number of studies to 257. Then, we classified the titles resulting in 85 papers. In order to minimise subjective interpretation biases, the authors read each of the 85 articles and independently analysed the research focus, data and methods, food traceability practices, technologies, the attributes of an effective FTS and the results. Finally, these combined efforts resulted in only 46 papers based on the inclusion criteria being retained for our review (Snyder, 2019). In the next stage, data from the 46 studies were extracted and synthesised (Khosravi *et al.*, 2019). This narrative literature review and rating process were as inclusive as possible to avoid eliminating potentially valuable contributions to the study. Figure 1 presents a flowchart of this literature search process.

The keywords map from the literature review on traceability is shown in Figure 2. This time, colours ranging from blue to yellow indicate the research interest for traceability in recent years. It is obvious that researchers have discussed and focused on enabling

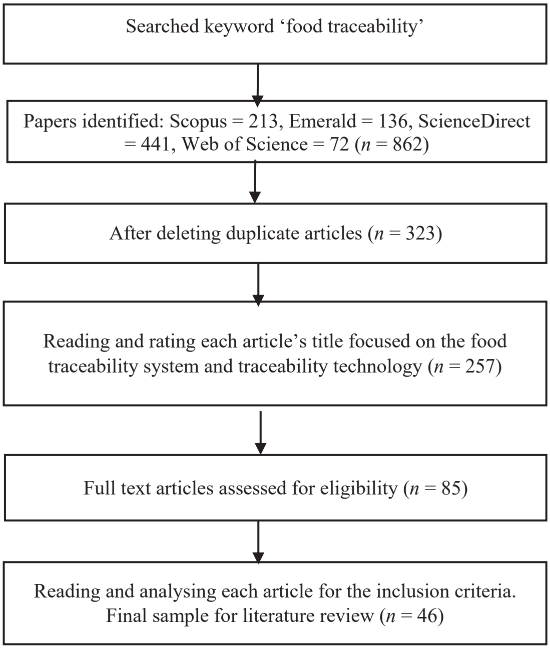

Figure 1.
Step-by-step process for sample selection

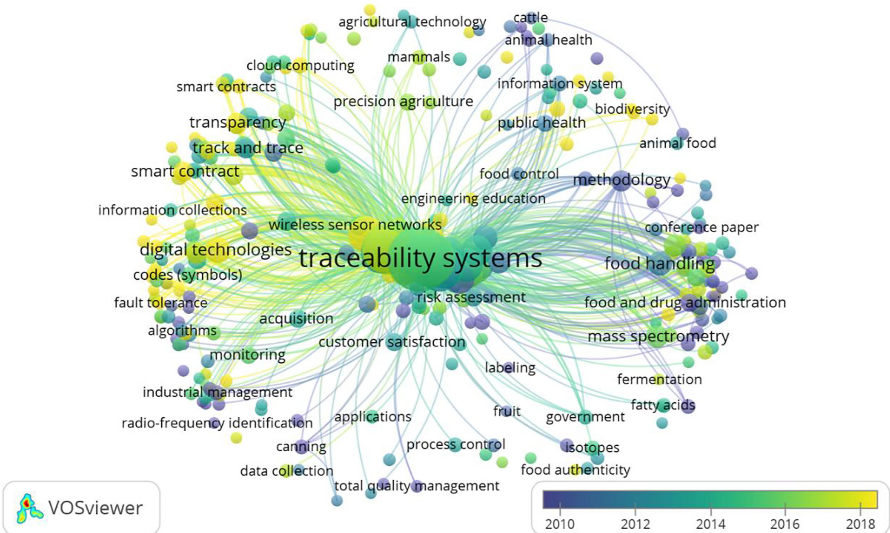

Figure 2.
The keywords map from the literature review about traceability

technologies (Figure 2) particularly in the last five years (yellow colour). These technologies include IoT, big data, blockchain and non-functional requirements for the system such as transparency, security, etc.

3. Content and data synthesis of the research: a multi-level approach

Traceability entails requirements capture, conceptual design, design and implementation, and validation (Heft-Neal *et al.*, 2016). In line with these vital concepts, this study considers various aspects of the integration of technology in traceability and the FSC as well as its implications, which are still inadequate in the literature. Our aim is to cover a wide range of the field and organise our study pursuant to the questions posed in the introduction. The selection of the topics to be investigated in relation to the development of traceability systems is based on the collective knowledge presented in the academic literature. We go through them as follows.

3.1 Defining and understanding traceability within the FSC literature

The FSC refers to the processes from food production, processing, and distribution to consumption and disposal (Li *et al.*, 2017). Food traceability is a part of the logistics management (Mahroof *et al.*, 2022) that captures, stores and transmits adequate information about food, feed, food-producing animal, or substance at all stages in the FSC so that the product can be checked for safety and quality control, traced upward and tracked downward at any time (Bosona and Gebresenbet, 2013). An FTS is a platform that can convey food quality and safety information to consumers, while it can also reveal or identify sources of food safety risks (Aung and Chang, 2014). Over the last decade, the FTS has become a popular recognised method for food manufacturing management (Chen, 2017), as food safety is one of the major problems currently facing the world. The main goal of the FTS is to ensure product safety and quality management in the FSC, providing consumers with timely information to assess and enhance their experience, thus helping companies improve consumers' perceptions of the reliability of their products (Wang *et al.*, 2017). The existing FTS is considered as a continuous challenge for supply chain managers in the food industry. They focus on an effective traceability system with a quality evaluation function to mainly assist companies in ensuring food quality and improving customer satisfaction as well (Wang *et al.*, 2017). The policy makers of the public health sectors in many countries have accepted the FTS or food traceability information as mandatory. A lot of research has been done by using various emerging technologies to guarantee the traceability of food products along the FSC process (Li *et al.*, 2017). Rapid development of information and communication technologies provides an effective way to improve food traceability (Qian *et al.*, 2017).

3.2 The main practical conclusions about food traceability through existing research

With the purpose of finding out what the main practical conclusions of food traceability are, we have made a research on published articles related to this concept. We have identified two main viewpoints: firstly, the one that describes traceability as a company's source of differentiation and competitive advantage; and secondly, the set of articles dealing basically with the technological aspects of traceability.

With regard to the first viewpoint, food traceability can be a tool to increase consumers' confidence in food safety and trade-related issues (Yuan *et al.*, 2020). Providing consumers with relevant information along their consumption journey enhances their experience and helps companies improve consumers' perceptions of the reliability of their products (Wang *et al.*, 2017). Previous studies have found that consumers are willing to pay a premium price for quality and food safety associated with traceability information attributes (e.g. Dandage *et al.*, 2017; Liu *et al.*, 2015). This gives producers a better opportunity to apply for traceable food-safety certification and labelling in order to satisfy the demands of middle- and high-end markets. The findings of the research of Yuan *et al.* (2020) show that the information quality, perceived reliability and product diagnosticity of an FTS affect consumer perceived value and purchase intention. Wang *et al.* (2017), using the method of fuzzy classification, proposed an improved FTS, which can not only achieve forward tracking and diverse tracing as the existing systems do, but may also timely evaluate food quality along the supply chain. This new approach provides consumers with information, which enhances their experience and helps companies gain the trust of consumers. Thus, many European companies implemented FTSs based on customers' needs well before legal requirements were introduced.

From a technological viewpoint, the literature illustrates advanced technologies and applications, which are used to improve traceability systems (Rainero and Modarelli, 2021). For example, there are barcodes, temperature and humidity sensors, radio-frequency identification (RFID) tags, wireless sensor networks, blockchain and Internet of things (IoT), which aim at continuously monitoring the physical flow of food products and reporting management, cost and safety stressors (Gallo *et al.*, 2021). With the boom in IoT technologies, many real-time tracking and tracing systems for FSC have been developed to guarantee food safety (Bresciani, 2017). Based on IoT technologies, Li *et al.* (2017) proposed an integrated tracking and tracing platform for pre-packaged food. Furthermore, they proposed the use of both the QR code and RFID in order to reduce the implementation costs. Peng *et al.* (2018) presented a QR code-based traceability method for a quality tracing system. Their results show that a QR code may store large amounts of traceability information, with strong error correction capability and may provide a great advantage in scanning recognition. Yiying *et al.* (2019) also suggest that an FTS, which uses RFID to achieve food safety management (Yi *et al.*, 2021), food traceability and quality assessment, makes the whole process of agricultural product circulation transparent. Qian *et al.* (2017) presented a novel agro-food FTS model, based on comprehensive and quantifiable granularity. Granularity comprehensiveness was indicated in a 3D framework, which combined precision, breadth and depth. As far as blockchain technology is concerned, it can significantly contribute to the supply chain area (Sharma, 2023). It has been considered as a promising solution to address food traceability issues, but there is a very limited understanding of its specific characteristics and functionalities for food traceability management as well as of the benefits and challenges faced by food traceability researchers and practitioners (Feng *et al.*, 2020).

There are several studies dealing with the development of FSC and traceability frameworks. Some of them investigate the conceptual framework of traceability and focus on specific issues (e.g. performance, transparency, etc.) while others explore the use of certain technology in the practical implementation of traceability systems.

Siddh *et al.* (2017) indicated "information management" among the critical issues for achieving the organisation's long-term performance. The companies need "a path plan" to drive them in the development of perishable food supply chain quality to improve sustainable organisational performance (Siddh *et al.*, 2018). Bougdira *et al.* (2019) consider traceability as the synthesis of complementary components and their elements and propose a conceptual framework as the basic initial solution for its implementation. Their main aim is to provide interoperability between the different traceability systems used by stakeholders. Siddh *et al.* (2021a) were based on agri-fresh FSC quality (AFSCQ) practices and considered the various dimensions affecting its effectiveness to propose a conceptual framework for AEFSQ. The theoretical framework of Islam and Cullen (2021) is governed by four solid principles of how to identify, record, access and integrate traceability units and their data. Sharma *et al.* (2021) described a methodological guidance approach capable of solving traceability problems (e.g. interoperability) while many participants are involved.

Olsen and Borit (2018) described and distinguished the components of traceability systems depending on the different functionalities occurring over each traceability unit (identification, recording of split/join process and recording unit attributes). From a technological perspective, the integration of blockchain and IoT into traceability systems is a feasible solution, which offers benefits in terms of information transparency, security and traceability management (Hao *et al.*, 2020; Feng *et al.*, 2020). The definition of the framework for the implementation of traceability and FSC is driven by the requirement for enhancing its performance and achieving greater client satisfaction (Siddh *et al.*, 2021b; Bosona and Gebresenbet, 2013). Although a conceptual framework may be universally applicable, its actual implementation stumbles on the limitations introduced by each individual technology, the different standards and the heterogeneous systems, respectively. Technology solutions or architectures describe the technical solutions on how companies will develop a technology architecture which, however, is largely dependent on the needs of each company.

In contrast to the aforementioned studies, our study is trying to close this gap. Thus, we propose an integrated solution based on the combination of the benefits of all these approaches bounded by the main principles of traceability and technological solution. To achieve this, we set a number of guidance criteria, present the possible technologies and underline the open issues.

3.3 The attributes of an effective and economic FTS

The proper use of various digital technologies contributes to building an effective FTS. An effective FTS response to consumer demands for traceability reduces the overall traceability cost (Hao *et al.*, 2020) and improves the food production transparency (Astill *et al.*, 2019). Moreover, it helps to "store, share, transmit, process, display" information and provides "connectivity, coordination, facilitation, efficiency, effectiveness, prevention, improvement" regarding the services needed in the supply chain (Annosi *et al.*, 2021). In order for a food company to adopt an effective and efficient FTS, the FDA mandates the companies to.

(1) Respond to any request within a 24-h time limit.

(2) Maintain documentation for at least 2 years after the date the products were produced.

(3) Record and document information about the implicated food product.

(4) Have a labelling, removal, recall and notification process.

However, the notion of a good traceability system involves two axes: the technical effectiveness and the process efficiency, while it is arranged by cost variable (Bobinis *et al.*, 2013). The first of them includes attributes such as functionality, connectivity, availability, transparency and visibility. The second term refers to the total operation, the maintenance and the logistics. Maintaining traceability means capturing changes and updating system relations accordingly and involves actions to prevent decay while the system evolves (Mäder and Gotel, 2012). The common attributes of a successful traceability system include:

(1) *Functional attributes:* Traceability is not just a tracking and tracing process, but a composition of processes, functions and technological tools. Traceability information can be collected, transmitted, unified, stored and shared among all participants involved. The objective of traceability is to satisfy customers' demands and facilitate risk assessment, safety and quality issues, regulatory compliance, documentation, integrity and brand protection, and lastly, to achieve a seamless, problem-free operation (Sharma *et al.*, 2021).

(2) *Visibility*: Visibility is defined as "the ability of a firm to collect, access, and share useful, accurate, trusted, secure and timely information across its internal functions as well as the supply chain partners and market" (Ben-Daya *et al.*, 2021).

(3) *Transparency:* Transparency means operating in such a manner that makes it easy for all network users to understand which and how actions are performed along the production pathway. Transparency improves traceability due to the wealth of available data and the underpinning of advanced technologies (Astill *et al.*, 2019). Transparency determines the degree of openness, communication and liability. Visibility and transparency throughout the delivery of information can build trust in customers, remove fears and potentially increase gains.

(4) *Credibility*: Credibility expresses the level of trust and belief, which the system delivers to customers (Chen *et al.*, 2019). Consumers demand food quality and food safety and therefore ask for the relative guarantees associated with the products before consuming them. Researchers point out the importance of the credibility of the source of information and underline the willingness of consumers to pay more, if they have the chance to trace the origin of a product and the production practices. Zheng *et al.* (2021) claim that the credibility of the traceability system results from the combination of technologies such as big data and IoT.

(5) *Uniqueness and granularity*: The uniqueness of identity is an essential requirement to accomplish traceability. The uniqueness characterises a traceability system, which could ensure the unique product identity across all the FSC (Lawo *et al.*, 2021). The identity is usually described by a code and correlated with the traceable units. The level of granularity refers to the number of products linked with a certain identifier (Olsen and Borit, 2018). Fine granularity implies larger codes and a smaller number of products. In contrast, coarse granularity means shorter codes but a bigger number of products.

3.4 Which are the enabling technologies for food traceability deployment?

The new advanced information and communication technologies (e.g. IoT) and their combination enable companies to face critical issues and provide opportunities for improving traceability systems (Qian *et al.*, 2020). The most common digital technologies used in the traceability systems include: (1) the information technologies, which store data related to track or/and trace products as they move along the supply chain and (2) the technologies, which identify and/or verify that the product is indeed what it is claimed to be (Bai *et al.*, 2017; Regattieri *et al.*, 2007). The implementation of an FTS involves the analysis of requirements in four axes: business requirements, functional requirements, operational requirements and technical requirements (Bougdira *et al.*, 2019). An effective traceability system is the result of the decision-making process for the selection of the most related enabling technologies.

3.4.1 Information technologies for mass storage, computation and communication. The traditional approach for storing traceability information is based on the use of a Database Management System (DBMS) and one or more severs connected through the Internet. However, the following concerns and limitations arise from that scheme (Bougdira *et al.*, 2019): (1) it is an implementation for a specific case, (2) the decline of operating performance as the data volume increases and (3) interoperability and scalability issues. However, the enabling technologies such as cloud computing, fog computing and IoT guided the researchers to examine new approaches for enhanced FTS. For example, the adoption of cloud computing provides storage and processing on a large scale, speedy response time and high availability of resources. The benefits of applying cloud computing in the implementation of traceability systems include (Xu *et al.*, 2015).

(1) Reducing the cost of traceability in terms of hardware, software, maintenance,

(2) Specialists facilitating knowledge discovery and decision support,

(3) Enhancing the value of food products in terms of reliability and safety.

Other common practices and researchers' efforts are based on using IoT technologies to build digital traceability systems. The IoT describes a system with Internet-connected devices, which can interact with each other via the Internet, collect, produce and transfer data to other objects (people or devices). The IoT technology provides various benefits in the field of traceability, such as increased availability of the Internet, enhanced production, enhanced transparency in food production and allows the automation of procedures without human intervention (Astill *et al.*, 2019). Furthermore, traceability systems use various things (objects), such as RFID tags, quick response (QR)-codes, sensors, smartphones and mobile devices, readers, actuators, NFC etc.

3.4.2 Communication technologies. The effective execution of food traceability processes requires the communication of traceability data between system components and functions as well as among all actors of the food supply chain. The lack of communication among traceability tasks and the absence of instructions introduces a degree of ambiguity and uncertainty in the execution process, thus affecting the overall traceability system operation (e.g. degree of accuracy, documentations/recordkeeping, validation/verification) (Mgonja *et al.*, 2013). Another problem arises from the absence of standardised communication between the different systems along the food supply chain (Islam and Cullen, 2021). Successful communication requires common understanding of the transmitted information from all entities involved (Regattieri *et al.*, 2007). Thus, all the data coming from different sources need to obey the rules of common syntax (formatting) and semantics (meaning). Numerous communication solutions are available providing different technologies and protocols with various standards and advantages, which can be used everywhere. Network communications bridge over traceability components and procedures such as data capturing, data storing, data processing, and other similar facilities (Zheng *et al.*, 2021). Li *et al.* (2017) consider technology as one of the three important layers of traceability (data, technology, interaction layer), which includes the network layer. The network layer is the mediator of the infrastructure and the interaction layer, which transmits the data between them. Apart from the network technologies, there is a need for a standard way to exchange digital information following the supply chain between the system's components and/or among other related actors (e.g. Business-to-Business). It involves information structure (formats) and the semantics of data interchange (Regattieri *et al.*, 2007). The most common standards used for information exchange among parts participating in the food production process are the Electronic Data Interchange (EDI), Electronic Product Code (EPC) and XML based languages (Pigini and Conti, 2017).

3.4.3 Identification, verification, and data capture technologies. Tracking and tracing each product, which enters the FTS, requires a unique identity or a traceable code. The identifier has a code type (numeric, alphanumeric), which is made up of one or more different parts for data placement (Olsen and Borit, 2018). Typically, this unique identity is placed on a label once the product enters the system and is accompanied by it throughout the entire life cycle. The label ensures the product identification and facilitates the traceability process in an effective manner. The label contains coded information about the product or part of the product. So, it is necessary for it to be readable and understandable by everyone involved in the supply chain. It is important to determine the level of labelling or granularity (Olsen and Borit, 2018); whether it will be at the level of a part of a product, or whether it will be in a batch of products.

3.5 Evaluation of the existing food traceability technologies

In the following section, we evaluate contemporary technologies using a list of criteria (or abilities) defined in a way that is independent of any technology type or application domain. The selection of the evaluation criteria is based on the collective knowledge presented in the previous research (Bhatt *et al.*, 2016; Mgonja *et al.*, 2013; Fricke and Schulz, 2005). The criteria are named as follows: adaptability, interoperability and performance. The criterion of performance contributes to choosing technologies for a digital traceability system whereas adaptability and interoperability are critical issues of digital traceability.

Adaptability: Adaptability is defined as "a system's ability to adapt itself towards changing environments" (Fricke and Schulz, 2005). Practically, it means that the technological system could be adapted to individual companies' needs. Here we consider "adaptability" in two directions: (1) the ability of existing technologies to be quickly integrated into all supply chain processes in order to support traceability requirements and (2) the ability to quickly familiarise with technology and allow successful integration in business.

Interoperability: Interoperability is the ability of seamless communication and data exchange among various information technology systems (Bhatt *et al.*, 2016) or a metric of the ability of "systems, organisations, and/or individuals to work together to achieve a common goal" (Ide and Pustejovsky, 2010). Interoperability is achieved through a common data format (syntactic interoperability) and shared definitions to interpret data (semantic interoperability). The ability to exchange product information and interpret the shared data is a crucial factor in building effective traceability systems (Bougdira *et al.*, 2019).

Performance: As far as the traceability systems are concerned, performance is evaluated through criteria, such as the degree of detail of information and the degree of automation. The performance indicator may also be the ability of a traceability system to minimise product recall and the relevant cost (Dabbene and Gay, 2011). According to Mgonja *et al.* (2013), system performance depends on the deployment and practical implementation, which are associated with (1) rapidity, (2) reliability, (3) capability and (4) precision/accuracy. Rapidity expresses the speed of obtaining information. Capability is the skill of retrieving the desired information without errors. Reliability can be determined as the probability that a system will be capable of retrieving information correctly, which depends on the procedures, tools and information sources used as well as the links among them. The terms "precision" and/or "accuracy" describe the ability to trace the product movement throughout the steps of its life cycle. Table 1 presents the comparison between the identification technologies mostly used according to the above-mentioned criteria.

Concerning the IoT technology, its adoption on a large scale in FTSs involves important issues, such as the cost of sensors (e.g. in case of use of RFID tags), the huge amount of data produced by IoT devices, information security and the lack of standardisation for interconnections between different systems, platforms and standards. Nevertheless, FTSs may take advantage of IoT technology, as it significantly contributes to reshaping the supply chain at the level of communication and in terms of visibility, agility and adaptability (Ben-Daya *et al.*, 2021). IoT provides opportunities to work with other technologies, such as cloud computing, fog computing and blockchain, while the FSC reaps the benefits (Lawo *et al.*, 2021). The integration of all these technologies and their absorption into traceability systems promise to improve food quality and food safety, enhance consumers' confidence, add more effectiveness and reliability to food production and rapidly share the information.

3.6 What do we need to further explore in the future about food traceability?

As the food industry is seeking new and emerging technologies in the food traceability process, special attention shall be given to adopting open innovation. Open innovation is the new imperative for creating and profiting from technology and is defined as "the implementation of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006). Open innovation paves the way to advanced technology as companies collectively exploit both external and internal ideas, along with the internal and external market path. Any open innovation process consists at least of the stages of research and development. The research phase includes inputs from the outside boundaries of the company. Many companies have already provided successful examples of implementing the

Table 1. Evaluation of identification traceability technologies

Technology	Adaptability Successful integration	Learn technology quickly	Interoperability Common data format	Shared definitions	Performance Rapidity (access)	Reliability	Capability	Precision/ accuracy	Cost
RFID	Complex	Very simple	Partial	Yes	High	High	Medium	High	High
NFC	Simple	Simple	Yes	Yes	High	High	High	High	Low
WSN (WiFi, Bluetooth and Zigbee.)	Simple	Simple	Yes	Yes	High	High	High	High	Low-
Barcode (1D)	Complex	Very simple	Yes	Yes	High	Medium	Medium	Medium	Low
QR code	Complex	Simple	Yes	Yes	High	Low	Medium	High	Low
Smart Cameras	Simple	Simple	Yes	Yes	High	High	High	High	High

Source(s): authors

open innovation model to solve problems and adopt innovative solutions. Food traceability could be achieved by adopting Industry 4.0 technologies. Digital traceability initiatives would be based on technological infrastructure, open-source software standards, fast Internet, 5G solutions, data and cloud-computing networks.

Open data is the backbone of food traceability and currently comprises an applied open innovation practice. When the public accesses open data, it creates added value for industry, governments and society. Open data adopts and applies open innovation initiatives fostering the collaboration among the public sector, policymakers, organisations, and companies to valorise and exploit the vast amount of produced data in order to propose solutions for the food producers and the end-users in terms of quality and health benefits. Open data has a vital role in decreasing the lack of sharing information among the food value chain actors.

As a rapidly evolving field, traceability has attracted the massive interest of researchers of several fields (agriculture, industrial management and technology, food science, food industries, etc.). Nevertheless, the research underlines constraints and open issues, which make room for improvements. Thus, there are many open challenging issues for possible future study. In Table 2 we summarise the challenges for future research on FTSs based on recent studies and their authors' suggestions. We can separate them into six broad categories:

Functional technological challenges: The adoption of enabling technologies in developing FTSs aims to improve traceability in the food domain in terms of transparency, security, information management, performance and scalability (Feng *et al.*, 2020; Astill *et al.*, 2019). Due to the absence of wide application of such technologies (blockchain, IoT, big data) in FTSs, numerous aspects shall be covered by future studies, such as blockchain issues, IoT issues and RFID issues (Feng *et al.*, 2020; Hao *et al.*, 2020; Astill *et al.*, 2019).

Non-functional technological challenges: Enabling technologies are a useful tool in the FSC, in particular in the areas of supply planning, building knowledge, data analysis, predictive analysis, standardisation and complexity handling (Zheng *et al.*, 2021; Annosi *et al.*, 2021; Feng *et al.*, 2020; Yiying *et al.*, 2019). However, a deep understanding of which, when and how exactly digital tools will be used is missing. The effective integration of digital technologies

Research area	Research fields	References
Non-functional technological challenges	Food safety, IoT managing, standardisation, predictive analysis, managing complexity, safety issues, blockchain, FTS transparency, decision support system, smart food traceability, FTS data analysis	Annosi *et al.* (2021), Zheng *et al.* (2021), Kennedy *et al.* (2020), Panetto *et al.* (2020), Yu *et al.* (2020), Feng *et al.* (2020), Yiying *et al.* (2019) and Dasaklis *et al.* (2019)
Functional technological challenges	Data acquisition, using available technologies, blockchain issues, RFID issues, visualisation technologies	Haji *et al.* (2020), Hao *et al.* (2020) and Astill *et al.* (2019)
Consumer perspective challenges	Consumer centricity, consumer confidence, consumer perception, consumer behaviour	Anastasiadis *et al.* (2021) and Yuan *et al.* (2020)
Optimisation/ improvement challenges	Blockchain, fog computing, privacy, optimising traceability using digital technologies, quality optimization	Ben-Daya *et al.* (2021), Qu *et al.* (2020)
Application challenges	Traceability apps	Lawo *et al.* (2021)
General challenges	Conceptual frameworks, granularity, model guidance, interoperability, diffusion traceability, modeling traceability, translate traceability to quality	Islam and Cullen (2021), Sharma *et al.* (2021), Corallo *et al.* (2020), Bougdira *et al.* (2019)

Table 2.
Summary of future research trends

into FTSs requires addressing specific challenges and difficulties related to food quality systems, information sharing, the effective combination of technologies, missing links, performance, efficiency and interconnection (Qian *et al.*, 2020). Apart from the above challenges, it is vital to study aspects of the decision-making process, such as coordination, integration, planning, and path selection for identifying, evaluating and providing directions for the improvement of the agri-food value-chain (Panetto *et al.*, 2020).

Optimisation/improvement challenges: The most important challenges for the improvement of FTSs include quality optimisation, data storage optimisation (Ben-Daya *et al.*, 2021) and the enhancement of the system's characteristics (e.g. efficiency, reliability, robustness, scalability, access control and data isolation). Digital technologies introduce new ways for trade and traceability, yet research is required for the optimisation of the cooperation and coordination between regulators, businesses, support institutions and consumers. Moreover, future studies should identify the optimal conditions in terms of computation and communication costs, removing the uncertainty in the quality of measurements and data transmission, involving customers in the traceability process (Ben-Daya *et al.*, 2021; Qu *et al.*, 2020).

Application challenges: Applications are the communication channels between consumers and products. Consumers use apps to retrieve product related information and make decisions, while suppliers use apps to communicate product safety and quality guarantees. All of them are considered as drivers for developing a wide range of solutions drawn from open standards and aligned by consumers' requirements. Applications may inform, recommend, communicate and bring information directly to the consumers (Lawo *et al.*, 2021).

Consumer perspective challenges: Many researchers have underlined the relation between consumers and FTSs. However, a defined food traceability framework, involving and engaging the consumer, is still lacking. This opens up several future research paths including cross-regional and cross-cultural comparative studies, the analysis of the consumer perspective and behaviour, the improvement of customers' satisfaction, the extent to which consumer trust is affected by credibility and the effectiveness of risks identification (Yuan *et al.*, 2020; Chen *et al.*, 2019).

Other (general) challenges (theoretical and conceptual framework): In the absence of a conceptual or contextual framework, issues, such as the factors driving the FTS, their importance, the relationships among various drivers, the methodological framework for interoperability and granularity, need further research. However, all the above will be drawn from further analysis and comparison of traceability systems considering the reusability of components and their replacement with the intention of improving an FTS (Islam and Cullen, 2021; Sharma *et al.*, 2021; Bougdira *et al.*, 2019).

4. Discussion

Food traceability has become a progressively interesting topic within the quality management and technological field. It is defined by business, consumers, technical, operational and functional requirements, which have to comply with the government's regulations, policies and laws. As such, it could be considered as a complex system, in which the demands for data communication among its entities, security, interoperability, management and sustainability extend the degree of complexity. This study organises the fundamental aspects and components, which are interconnected and interacted to enable a total FTS. In fact, this study presents a framework, which will enable companies and traceability mechanics to move forward within this topic. It contributes to management, information and food safety literature by synthesising published food traceability research findings and identifying the mechanisms for effective implementation. The development of traceability-related literature over the last decade indicates that more research is needed in order for the topic itself to be understood. To our knowledge, the present study offers the first systematic and transparent review of extant research, followed by a synthesis on FTSs, which underlines the main concepts, makes criticism, and supports theories, maps extant literature and evaluates findings. Thus, in contrast with Siddh *et al.* (2017), who conclude that it was not entirely clear how technology bridges the separate entities of FSC, this study exhibits the traceability technology as a powerful tool for consumer access to information and extends our knowledge on how traceability technologies can exert positive influences not only on food companies but on the consumers' satisfaction, as well. Thus, a holistic picture of what existing empirical studies have found, has been developed.

First and foremost, this study contributes to organising the extant literature, thus offering an understanding of the meaning of traceability, the existing technology, the practices and processes it involves as well as the main results, providing a clear picture of the recent trends. In line with other studies (Li *et al.*, 2017; Bosona and Gebresenbet, 2013), we define traceability and underline its significance in terms of legislation and certification, management, safety and quality, customers' satisfaction, sustainability, product value, timely assessment of information, low cost, effectiveness and efficiency. Secondly, this study contributes to the identification and presentation of the success factors and key attributes of the FTSs. We identify the essential attributes, such as visibility, transparency, credibility, uniqueness and granularity for their importance in building trust, increasing gains and determining the degree of openness in FTSs. Moreover, we found that the consumers' perceptions, high-quality information (Yuan *et al.*, 2020) and timely access to information (Wang *et al.*, 2017) contribute to developing a successful FTS. As the diversity of attributes is exceptionally large, the lack of a common framework mentioning the key elements is highlighted.

Furthermore, the study contributes to the evaluation of the technology, which is suitable for each part of the FTS. Nowadays, there are advanced technologies available providing a number of possible solutions, acting either individually or in combination. Technologies contribute to system integration. For example, cloud computing provides storage and computational resources and access to various services. IoT is the best solution for real-time data capturing and transferring, while fog computing enhances security and privacy based on blockchains. In practice, technology should be used as a linkage between FTS components, processes and tools. Our approach regarding the selection of the most suitable technology was based on the needs. In addition, the study contributes to the evaluation of the information technologies used for mass storage, computation and communication, which were analysed through defined criteria revealing their benefits and disadvantages. Furthermore, this study is in line with Dima *et al.* (2022), who support the view that traceability is becoming an essential tool for both the industry and consumers. Consumers are very interested in the information provided to them and therefore, traceability may affect their buying habits to a high degree. This high interest showed that a traceability system would benefit a company by giving it an edge in the market. Finally, we identified theoretical inconsistencies and research gaps, which future research should resolve regarding many topics of FTSs.

4.1 Implications

In the context of FSC and traceability, this study has stimulating implications for the entire community involved: practitioners, managers, researchers and policymakers. First of all, this study provides important practical implications for managers, decision-makers of food organisations as well as for academics and traceability researchers. It provides an insight and a common theoretical framework, which could affect the implementation process of traceability in the food industry within the context of an FTS. By creating awareness of the existing traceability system, this study helps practitioners exploit the full potential of their FTSs and enhance their effectiveness. It may assist food companies to take better into account the various factors, which may facilitate or hinder the effectiveness of an FTS in practice. The present review highlights the utilisation of up-to-date technologies in building FTSs from various perspectives and a critical point of view. Furthermore, the main challenge is to check whether their company needs devices to track food products from their origin to end-users using a simple or more complicated traceability technology.

Secondly, this study enables managerial authorities to understand in depth the procedures, techniques and technologies influencing and supplying the chain quality and enhance their efficiency by providing knowledge on traceability as well as the framework to identify, elect and evaluate potential solutions. Astill *et al.* (2019) consider that the integration of technology into the FCS may transparently address the challenges posed by the volume of data and the complexity of the production process. If managers and traceability researchers understand the role of traceability within the FSC, the framework, the main principles of development (interoperability, transparency, credibility), the possibilities and the limitations of the implementation using enabling technologies, they will be able to create a traceability system, which will meet users' requirements and be cost-efficient, transparent and secure, thus creating more value for products and food companies.

The level of success of the FTS will depend on the combination of the emerging technologies and the management of the interrelated parts of that system. According to Sharma *et al.* (2021), the development of an FTS is a collaborative effort based on a methodological framework and a record keeping system. Under this direction, managers have to take into consideration all these issues that need to be investigated and improved. Managers and decision-makers should pay attention to the consumers' demand for food product traceability by adopting the most suitable traceability technology in order to achieve the greatest potential gains. Kumar *et al.* (2020) point out that the total understanding of the needs and challenges and their relationships in the FSC allows us to define the priorities, the better management and to consider the sustainability. Ben-Daya *et al.* (2021) stated that technologies, such as blockchain and IoT, could provide visibility and quality regarding FTS processes, while they are needed to support the decision-making process within a reasonable period.

Thirdly, our findings reveal new pathways for the research community as the adoption of new, open innovations entails not only drawbacks, limitations and interoperability issues but drivers, as well. In addition, the conceptual framework needs to be further tested and empirically verified. Last but not least, our findings could be the input of rational and intended models, which should be developed and deployed by policy makers and regulators.

4.2 Conclusion and future work

The main findings of this study include the various descriptions of the architecture of the FTS, and the different sources enabling the practice of traceability, namely the company, the technologies and the receiver, that is the consumer. Moreover, the study underlines the common desirable attributes of a traceability system (visibility, transparency, functional attributes, credibility, uniqueness and granularity) and reveals the great number of enabling technologies, which may be used for the deployment and implementation of a traceability system. Finally, it presents several technological solutions, which are currently available for traceability systems, and points out the need for reshaping and redefining in the name of optimisation, improvement, regulation, guarantee and technology integration with the cooperation of all actors.

However, as review-based research, this study has certain limitations providing opportunities for future research. Its methodology process should be extended to investigate more relevant studies on food traceability, which are not covered in the present article. Moreover, the proposed framework does not include other additional advanced theories regarding FTS performance, costs, benefits, barriers or risks. There is a pressing need to investigate the cost issues stemming from the development and maintenance of an FTS (Islam and Cullen, 2021). The absence of FTS modelling for an entire scheme was also observed. FTS modelling can be described with mathematical expressions and symbols or can be represented as a formation of components (Dede *et al.*, 2017). This kind of modelling is needed to alleviate the complexity and assist in the understanding of the real system behaviour. Our study may further serve as a basis, on which a discourse may begin, on how traceability is understood from a technological and a strategic management perspective.

References

Anastasiadis, F., Apostolidou, I. and Michailidis, A. (2021), "Food traceability: a consumer-centric supply chain approach on sustainable tomato", *Foods*, Vol. 10 No 3, pp. 543-553.

Annosi, M.C., Brunetta, F., Bimbo, F. and Kostoula, M. (2021), "Digitalization within FSCs to prevent food waste. Drivers, barriers, and collaboration practices", *Industrial Marketing Management*, Vol. 93 No. 1, pp. 208-220.

Astill, J., Dara, R.A., Campbell, M., Farber, J.M., Fraser, E.D., Sharif, S. and Yada, R.Y. (2019), "Transparency in food supply chains: a review of enabling technology solutions", *Trends in Food Science and Technology*, Vol. 91 No. 3, pp. 240-247.

Aung, M.M. and Chang, Y.S. (2014), "Traceability in a food supply chain: safety and quality perspectives", *Food Control*, Vol. 39 No. 2, pp. 172-184.

Bai, H., Zhou, G., Hu, Y., Sun, A., Xu, X., Liu, X. and Lu, C. (2017), "Traceability technologies for farm animals and their products in China", *Food Control*, Vol. 79 No. 1, pp. 35-43.

Ben-Daya, M., Hassini, E., Bahroun, Z. and Banimfreg, B. (2021), "The role of internet of things in food supply chain quality management: a review", *Quality Management Journal*, Vol. 28 No. 1, pp. 17-40.

Bhatt, T., Cusack, C., Dent, B., Gooch, M., Jones, D., Newsome, R., Stitzinger, J., Sylvia, G. and Zhang, J. (2016), "Project to develop an interoperable seafood traceability technology architecture: issues brief", *Comprehensive Reviews in Food Science and Food Safety*, Vol. 15 No. 2, pp. 392-429.

Bobinis, J., Garrison, C., Haimowitz, J., Klingberg, J., Mitchell, T. and Tuttle, P. (2013), "Affordability considerations: cost effective capability", *INCOSE International Symposium*, Vol. 23, pp. 287-303.

Bosona, T. and Gebresenbet, G. (2013), "Food traceability as an integral part of logistics management in food and agricultural supply chain", *Food Control*, Vol. 33 No. 1, pp. 32-48.

Bougdira, A., Ahaitouf, A. and Akharraz, I. (2019), "Conceptual framework for general traceability solution: description and bases", *Journal of Modelling in Management*, Vol. 15 No. 2, pp. 509-530.

Bresciani, S. (2017), "Open, networked and dynamic innovation in the food and beverage industry", *British Food Journal*, Vol. 119 No. 11, pp. 2290-2293.

Centobelli, P., Cerchione, R., Espositoa, E. and Shashi, K. (2019), "Exploration and exploitation in the development of more entrepreneurial universities: a twisting learning path model of ambidexterity", *Technological Forecasting and Social Change*, Vol. 141, pp. 172-194.

Chen, R.Y. (2017), "An intelligent value stream-based approach to collaboration of food traceability cyber physical system by fog computing", *Food Control*, Vol. 71 No. 2, pp. 124-136.

Chen, K.H., Chang, F.H., Chen, Y.L. and Chen, P.M. (2019), "The relationships between corporate credibility, service convenience, and consumers' use intentions: toward ticketing apps for low-cost carriers", *Sustainability*, Vol. 11 No. 3, pp. 810-830.

Chesbrough, H. (2006), "New puzzles and new findings", in Chesbrough, H., Vanhaverbeke, W. and West, J. (Eds), *Open Innovation: Researching a New Paradigm*, Oxford University Press, Oxford.

Christofi, M., Vrontis, D. and Cadogan, J. (2021), "Micro-foundational ambidexterity and multinational enterprises: a systematic review and a conceptual framework", *International Business Review*, Vol. 30 No. 1, pp. 1-17.

Corallo, A., Latino, M.E., Menegoli, M. and Striani, F. (2020), "What factors impact on technological traceability systems diffusion in the agrifood industry? An Italian survey", *Journal of Rural Studies*, Vol. 75 No. 1, pp. 30-47.

Dabbene, F. and Gay, P. (2011), "Food traceability systems: performance evaluation and optimization", *Computers and Electronics in Agriculture*, Vol. 75 No. 1, pp. 139-146.

Dabbene, F., Paolo, G. and Tortia, C. (2014), "Traceability issues in food supply chain, management: a review", *Biosystems Engineering*, Vol. 120 No. 1, pp. 65-80.

Dandage, K., Badia-Melis, R. and Ruiz-García, C. (2017), "Indian perspective in food traceability: a review", *Food Control*, Vol. 71 No. 2, pp. 217-227.

Dasaklis, T.K., Casino, F. and Patsakis, C. (2019), "Defining granularity levels for supply chain traceability based on IoT and blockchain", in *Proceedings of the International Conference on Omni-layer Intelligent Systems*, pp. 184-190.

Dede, J., Förster, A., Hernández-Orallo, E., Herrera-Tapia, J., Kuladinithi, K., Kuppusamy, V., Manzoni, P., Muslim, A., Udugama, A. and Vatandas, Z. (2017), "Simulating opportunistic networks: survey and future directions", *IEEE Communications Surveys and Tutor*, Vol. 20 No. 2, pp. 1547-1573.

Denyer, D. and Neely, A. (2004), "Introduction to special issue: innovation and productivity performance in the UK", *International Journal of Management Reviews*, Vols 5/6, pp. 131-135.

Dima, A., Arvaniti, E., Stylios, C., Kafetzopoulos, D. and Skalkos, D. (2022), "Adapting open innovation practices for the creation of a traceability system in a meat producing industry in Northwest Greece", *Sustainability*, Vol. 14, p. 5111.

Feng, H., Wang, X., Duan, Y., Zhang, J. and Zhang, X. (2020), "Applying blockchain technology to improve agri-food traceability: a review of development methods, benefits, and challenges", *Journal of Cleaner Production*, Vol. 260, pp. 121-131.

Fricke, E. and Schulz, A.P. (2005), "Design for changeability (DfC): principles to enable changes in systems throughout their entire lifecycle", *Systems Engineering*, Vol. 8 No. 4, pp. 342-360.

Gallo, A., Accorsi, R., Goh, A., Hsiao, H. and Manzini, R. (2021), "A traceability-support system to control safety and sustainability indicators in food distribution", *Food Control*, Vol. 124, 107866.

Haji, M., Kerbache, L., Muhammad, M. and Al-Ansari, T. (2020), "Roles of technology in improving perishable food supply chains", *Logistics*, Vol. 4 No 4, pp. 33-57.

Hao, Z., Mao, D., Zhang, B., Zuo, M. and Zhao, Z. (2020), "A novel visual analysis method of food safety risk traceability based on blockchain", *International Journal of Environmental Research and Public Health*, Vol. 17 No. 7, p. 2300.

Heft-Neal, S., Otte, J., Roaring-Arunsuwannakorn, V., Jayme, K.L., Thein, M.T., Chantola, N. and Lattanavong, S. (2016), *Roadmap on the Prospects for GMS National Scaling and GMS Regional Coordination of Agrifood Traceability Schemes*, Asian Development Bank, Manila.

Ide, N. and Pustejovsky, J. (2010), "What does interoperability mean, anyway? Toward an operational definition of interoperability for language technology", *Proceedings of the Second International Conference on Global Interoperability for Language Resources, Hong Kong, China*.

Islam, S. and Cullen, J.M. (2021), "Food traceability: a generic theoretical framework", *Food Control*, Vol. 23, 107848.

Karlsen, K.M., Dreyer, B., Olsen, P. and Elvevoll, E.O. (2013), "Literature review: does a common theoretical framework to implement food traceability exist?", *Food Control*, Vol. 32 No. 2, pp. 409-417.

Kennedy, A., Stitzinger, J. and Burke, T. (2020), *Food traceability", in Food Safety Engineering*, Springer, Cham, pp. 227-245.

Keupp, M.M., Palmie, M. and Gassmann, O. (2012), "The strategic management of innovation: a systematic review and paths for future research", *International Journal of Management Reviews*, Vol. 14 No. 4, pp. 367-390.

Khosravi, Newton, C. and Rezvani, A. (2019), "Management innovation: a systematic review and meta-analysis of past decades of research", *European Management Journal*, Vol. 37 No. 5, pp. 694-707.

Kumar, S., Heustis, D. and Graham, J.M. (2015), "The future of traceability within the U.S. food industry supply chain: a business case", *International Journal of Productivity and Performance Management*, Vol. 64 No. 1, pp. 129-146.

Kumar, A., Mangla, S.K., Kumar, P. and Karamperidis, S. (2020), "Challenges in perishable food supply chains for sustainability management: a developing economy perspective", *Business Strategy and the Environment*, Vol. 29 No. 5, pp. 1809-1831.

Lawo, D., Neifer, T., Esau, M., Vonholdt, S. and Stevens, G. (2021), "From farms to fridges: a consumer-oriented design approach to sustainable food traceability", *Sustainable Production and Consumption*, Vol. 27 No. 3, pp. 282-297.

Li, Z., Liu, G., Liu, L., Lai, X. and Xu, G. (2017), "IoT-based tracking and tracing platform for pre-packaged food supply chain", *Industrial Management and Data Systems*, Vol. 117 No. 9, pp. 1906-1916.

Liu, X., Xu, L., Zhu, D. and Wu, L. (2015), "Consumers' WTP for certified traceable tea in China", *British Food Journal*, Vol. 117 No. 5, pp. 1440-1452.

Mäder, P. and Gotel, O. (2012), "Towards automated traceability maintenance", *Journal of Systems and Software*, Vol. 85 No. 10, pp. 2205-2227.

Mahroof, K., Omar, A. and Kucukaltan, B. (2022), "Sustainable food supply chains: overcoming key challenges through digital technologies", *International Journal of Productivity and Performance Management*, Vol. 71 No. 3, pp. 981-1003.

Mgonja, J.T., Luning, P. and Van der Vorst, J.G. (2013), "Diagnostic model for assessing traceability system performance in fish processing plants", *Journal of Food Engineering*, Vol. 118 No. 2, pp. 188-197.

Nandankar, S. and Sachan, A. (2020), "Electronic procurement adoption, usage and performance a literature review", *Journal of Science and Technology Policy Management*, Vol. 11 No. 4, pp. 515-535.

Olsen, P. and Borit, M. (2018), "The components of a food traceability system", *Trends in Food Science and Technology*, Vol. 77 No. 2, pp. 143-149.

Panetto, H., Lezoche, M., Hormazabal, J.E.H., Diaz, M. and Kacprzyk, J. (2020), "Special issue on Agri-Food 4.0 and digitalization in agriculture supply chains-New directions, challenges and applications", *Computers in Industry*, Vol. 116, 103188.

Paré, G., Trudel, M.-C., Jaana, M. and Kitsiou, S. (2015), "Synthesizing information systems knowledge: a typology of literature reviews", *Information and Management*, Vol. 52 No. 2, pp. 183-199.

Peng, Y., Zhang, L., Song, Z., Yan, J., Li, X. and Li, Z. (2018), "A QR code-based tracing method for fresh pork quality in cold chain", *Journal of Food Process Engineering*, Vol. 41 No. 4, 12685.

Pigini, D. and Conti, M. (2017), "NFC-based traceability in the food chain", *Sustainability*, Vol. 9 No. 9, p. 1910.

Qian, J., Fan, B., Wu, X., Han, S., Liu, S. and Yang, X. (2017), "Comprehensive and quantifiable granularity: a novel model to measure agro-food traceability", *Food Control*, Vol. 31 No. 2, pp. 314-325.

Qian, J., Ruiz-Garcia, L., Fan, B., Villalba, J.I.R., McCarthy, U., Zhang, B., Yu, Q. and Wu, W. (2020), "Food traceability system from governmental, corporate, and consumer perspectives in the European Union and China: a comparative review", *Trends in Food Science and Technology*, Vol. 99 No. 5, pp. 402-412.

Qu, Y., Gao, L., Luan, T.H., Xiang, Y., Yu, S., Li, B. and Zheng, G. (2020), "Decentralized privacy using blockchain-enabled federated learning in fog computing", *IEEE Internet of Things Journal*, Vol. 7 No. 6, pp. 5171-5183.

Rainero, C. and Modarelli, G. (2021), "Food tracking and blockchain induced knowledge: a corporate social responsibility tool for sustainable decision-making", *British Food Journal*, Vol. 123 No. 12, pp. 4284-4308.

Regattieri, A., Gamberi, M. and Manzini, R. (2007), “Traceability of food products: general framework and experimental evidence”, *Journal of Food Engineering*, Vol. 81 No. 2, pp. 347-356.

Sharma, M.G. (2023), “Supply chain, geographical indicator and blockchain: provenance model for commodity”, *International Journal of Productivity and Performance Management*, Vol. 72 No. 1, pp. 92-108.

Sharma, R., Hurburgh, C. and Mosher, G.A. (2021), “Developing guidance templates and terminology to support multiple traceability objectives in the grain supply chain”, *Cereal Chemistry*, Vol. 98 No. 1, pp. 52-69.

Siddh, M., Kumar, S., Soni, G., Jain, V., Chandra, C., Jain, R., Sharma, M.K. and Kazancoglu, Y. (2022), “Impact of agri-fresh food supply chain quality practices on organizational sustainability”, *Operations Management Research*, Vol. 15 Nos 3-4, pp. 136-165.

Siddh, M.M., Soni, G., Jain, R. and Sharma, M.K. (2018), “Structural model of perishable food supply chain quality (PFSCQ) to improve sustainable organizational performance”, *Benchmarking: An International Journal*, Vol. 25 No. 7, pp. 2272-2317.

Siddh, M.M., Soni, G., Jain, R., Sharma, M.K. and Yadav, V. (2017), “Agri-fresh food supply chain quality (AFSCQ): a literature review”, *Industrial Management and Data Systems*, Vol. 117 No. 9, pp. 2015-2044.

Siddh, M.M., Soni, G., Jain, R., Sharma, M.K. and Yadav, V. (2021a), “A framework for managing the agri-fresh food supply chain quality in Indian industry”, *Management of Environmental Quality: An International Journal*, Vol. 32 No. 2, pp. 436-451.

Snyder, H. (2019), “Literature review as a research methodology: an overview and guidelines”, *Journal of Business Research*, Vol. 104, pp. 333-339.

Tranfield, D., Denyer, D. and Smart, P. (2003), “Towards a methodology for developing evidence-informed management knowledge by means of systematic review”, *British Journal of Management*, Vol. 14 No. 2, pp. 207-222.

Turner, N., Swart, J. and Maylor, H. (2013), “Mechanisms for managing ambidexterity: a review and research agenda”, *International Journal of Management Reviews*, Vol. 15 No. 3, pp. 317-332.

Wang, J., Yue, H. and Zhou, Z. (2017), “An improved traceability system for food quality assurance and evaluation based on fuzzy classification and neural network”, *Food Control*, Vol. 79 No. 4, pp. 363-370.

Xu, M., Siraj, S. and Qi, L. (2015), “A Hadoop-based data processing platform for fresh agro-products traceability”, *Proceedings of the IADIS International Conference Intelligent Systems and Agents: Las Palmas de Gran Canaria, Spain 22-24 July*, IADIS Press.

Yi, Y., Bremer, P., Mather, D. and Mirosa, M. (2021), “Factors affecting the diffusion of traceability practices in an imported fresh produce supply chain in China”, *British Food Journal*, Vol. 124 No. 4, pp. 1350-1364.

Yiying, Z., Yuanlong, R., Fei, L., Jing, S. and Song, L. (2019), “Research on meat food traceability system based on RFID technology”, *2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference*, pp. 2172-2175.

Yu, Z., Jung, D., Park, S., Hu, Y., Huang, K., Rasco, B.A., Wang, S., Ronholm, J., Lu, X. and Chen, J. (2020), “Smart traceability for food safety”, *Critical Reviews in Food Science and Nutrition*, Vol. 10 No. 1, pp. 1-12.

Yuan, C., Wang, S. and Yu, X. (2020), “The impact of food traceability system on consumer perceived value and purchase intention in China”, *Industrial Management and Data Systems*, Vol. 120 No. 4, pp. 810-824.

Zheng, M., Zhang, S., Zhang, Y. and Hu, B. (2021), “Construct food safety traceability system for people’s health under the internet of things and big data”, *IEEE Access*, Vol. 9, pp. 70571-70583.

Further reading

Dimara, E. and Skuras, D. (2003), "Consumer evaluations of product certification, geographic association and traceability in Greece", *European Journal of Marketing*, Vol. 37 Nos 5-6, pp. 690-705.

About the authors

Dimitrios Kafetzopoulos is Assistant Professor of Management in the Department of Business Administration in the University of Macedonia. He received a PhD in Management at the University of Ioannina, Greece. He was a postdoc researcher in the Department of Food Science and Nutrition in the University of the Aegean and also in the Department of Business Administration in the University of Macedonia. He has published over 80 journal and conference papers. He has dealt with issues of management and his research interests include leadership, ambidexterity, quality management, innovation management, organisational change, human resource management and production and operational management. Dimitrios Kafetzopoulos is the corresponding author and can be contacted at: dimkafe@uom.edu.gr

Spiridoula Margariti received her BSc in Electronics from the Technological Educational Institute of Lamia, Greece. She received her MSc and BSc in Computer Science from the Department of Computer Science and Engineering, University of Ioannina, Greece. She also holds a PhD from the same Department. She is a member of Laboratory Teaching Staff of the Department of Informatics and Telecommunication of University of Ioannina and she teaches in both undergraduate and postgraduate study programs of the Department. Her research interests include distributed systems, data networks, complex networks, network performance, fog and cloud computing, modeling and simulation.

Chrysostomos Stylios is Director of the Laboratory of Knowledge and Intelligent Computing, Department of Informatics and Telecommunication, University of Ioannina, Greece. Based on his pioneering research on fuzzy cognitive maps (FCMs) a new field opened and nowadays FCMs are applied in discipline research areas. He has published over 200 journal and conference papers and book chapters. His main scientific interests include fuzzy cognitive maps, artificial intelligence, big data, data mining, soft computing, biosignal processing and analysis; modeling and decision support systems, knowledge-based systems; simulation and modeling complex systems; intelligent systems; hierarchical systems and supervisory control; intelligent manufacturing systems, innovation, technology transfer, educational methodologies and tools, virtual and augmentative reality. Prof. Stylios is scientific coordinator of more than 30 R&D projects funded by EC and national funds with more than 5MEuros budget. Prof. Stylios is senior member of IEEE and member of the TC 8.2 and TC 5.4 of IFAC.

Eleni Arvaniti holds a bachelor degree in business administration and an MBA (University of Patras). She is a PhD student in the Dept. of Environmental Engineering (University of Patras) and the title of her thesis is "Open Social Innovation for regional sustainable development". She has more than 12 years of experience in the design and implementation of National and EU funded developmental/research projects.

Panagiotis Kafetzopoulos holds a bachelor degree in food technology and an MBA in food enterprises at the University of Patras, Greece. He is a PhD candidate in the Department of Business Administration of Food and Agricultural Enterprises in the University of Patras. He has extensive knowledge and practical experience in the food industry and food traceability as he has been working in this sector for over 5 years. His research interests include management, ambidexterity, innovation and food quality and safety. His current research projects are in advancing quality management and ambidexterity strategies and their application to manufacturing organisations.