Traceability in the Food Supply Chain: Review of the literature from a technological perspective.

Trazabilidad en la Cadena de Suministro Alimentaría: Revisión de la literatura desde una perspectiva tecnológica.

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Abstract: An increasingly customer-oriented food industry needs faster response times to address dynamic and collaborative supply chains. Good traceability systems help to minimize the production and distribution of unsafe or poor quality products. Therefore, traceability is applied as a tool to help ensure the safety and quality of food, as well as to achieve consumer confidence. New technologies are being used and new proposals are being tested in this field. Industry 4.0 includes a variety of technologies that enable the development of a digital and automated manufacturing environment. These new technologies are implying a drastic change in the way companies operates. These tech-nologies are having a high impact in different areas of the company, and naturally, the traceability processes are included in this new wave of changes. The terms "tracing" and "tracking" are generally discussed in traceability. Tracing is defined as a retroactive process in which the origin is identified by the history or the records in the supply chain and tracking is the direct process in which the end users and the trading partners are identified by the location in the supply chain, both terms provide visibility in supply chains. In the present work a literature review is realized on the implementation of in-dustry 4.0 in the traceability of the food supply chain. As a result of this literature re-view have been possible to note that the interest is growing and is concentrated in the last five years. Furthermore, the temporal evolution of technologies applied in the trace-ability of food supply chain is becoming increasingly complex due to the inclusion of new proposals (RFID, QR, NFC, Barcode, …). Finally, an analysis of the technologies applied to different areas of the food sector is presented, thus proposals for fruit, vege-tables, meat or fish have been analyzed and the Industry 4.0 technologies have been identified for each area. This study makes it possible to reveal clearly those sectors that have not yet been approached by these new proposals, as well as technologies that are been applied in Industry 4.0 proposals but have not been used for traceability. Thus, the present work enables the identification of research gaps in this field.

Keywords: Food Supply Chain, Traceability, Industry 4.0, Internet of things

Resumen: Una industria alimentaria, cada vez más orientada al cliente, necesita tiempos de respuesta más rápidos para conseguir cadenas de suministro dinámicas y colaborativas. Los sistemas de trazabilidad ayudan a minimizar problemas por la producción y distribución de productos inseguros o de baja calidad. Por lo tanto, la trazabilidad se presenta como una herramienta para ayudar a garantizar la seguridad y la calidad de los alimentos, así como para lograr la confianza del consumidor. En el presente trabajo se realiza una revisión bibliográfica sobre la implementación de la industria 4.0 en la tra-zabilidad de la cadena de suministro alimentaria.

Palabras clave: Cadena de suministro alimentaria , Trazabilidad, Industria 4.0, Internet de las cosas

1. Introduction

In recent years, the concept of industry 4.0 has taken shape. This trend is transform-ing the manufacturing industry and supply chain (SC) to the next generation where ma-chines and products work in a collaborative network, sharing information in a more ef-ficient way.

The term Industry 4.0 includes a variety of technologies that enable the development of a digital and automat-ed manufacturing environment. This translates into im-prove-ments in product quality and a decrease in time to market, as well as improvements in the performance of the company.

A recent trend of application of the concept of industry 4.0 deals with SC traceability for the food industry. Ad-vanced food traceability systems help minimize unsafe or poor quality products (Chen, 2017).

Traceability is defined in (Dandage et al., 2017) as "The ability to access all or any information related to what is under consideration, throughout its entire life cycle, through registered identifications". The terms "tracing" and "tracking" are generally dis-cussed in traceability. Tracing is defined as a retroactive process in which the origin is identified by the history or the records in the SC and tracking is the direct process in which the end users and the trading partners are identified by the lo-cation in the SC, both terms provide visibility in SC. The tracing and tracking system must be connected to the physical transport system and the information system.

2. Review of the literature

The emergence of traceable food SC is the result of a long series of advances in the im-provement of food quality and safety management. For example the pur-pose of agri-food traceability is to enable the complete tracking back and forth of a product and its life history (activities) in the SC, from the farm to the table. The following section pre-sents an analysis of the literature on traceability in food SC.

Scientific databases, such as Scopus, ScienceDirect and Web of Science, have been consulted to carry out the review, and the following terms: "food supply chain", "trace-ability", "traceability in agriculture" were used in combination with "industry 4.0", "in-ternet of things",. It was decided to look into the last 7 years to limit the search range and include some previous referenced papers. The result was a total of 73 articles ob-tained. Although the concept traceability has sever-al years of study, its combination with subjects related to Industry 4.0 are recent and do not exceed 10 years research of both concepts.

Subsequently, a second filter was made based on the analysis of summaries and conclu-sions to discard pa-pers not addressed with the subject matter. Finally, 36 articles were used for the analysis and classification. Table 1 presents the authors and their respective con-tributions.

Table 1 - Summary of articles investigated and their respective contributions

Proposals	Authors
Application Analysis	(Badia-Melis et al., 2015)
Application reviews	(Wang and Li, 2013)
Architecture	(Mahalik and Kim, 2016; Ver-douw et al., 2016; Wang and Yue, 2017)
Computer systems for whole-chain traceability	(Adam et al., 2015)
EPCIS Traceability System	(Thakur and Forås, 2015)
Framework	(Badia-Melis et al., 2015; Chen, 2017; Mao et al., 2015; Pizzuti and Mirabelli, 2015; Thakur and Hurburgh, 2009; Yang et al., 2016)
Information Model	(Grunow and Piramuthu, 2013)
Mathematical Model	(Aiello et al., 2015) (Gautam et al., 2017)
Mobile Farming Information System	(Liu and Gao, 2016)
Ontology	(Geerts and O'Leary, 2014; Pizzuti et al., 2017)
Review	(Lee et al., 2010)
RFID applications	(Ruiz-Garcia and Lunadei, 2011)
RFSM System Architecture	(Ngai et al., 2008)
Robotic traceability systems	(Kondo, 2010)
Sensor System	(Xiao et al., 2017)

Simulation of a real-time traceability system	(Accorsi et al., 2016)
Smart Cold Chain System	(Chen et al., 2014)
Traceability system	(Abad et al., 2009; Barge et al., 2014; Qian et al., 2012; Regattieri et al., 2007; Tarjan et al., 2014)
Traceability System Architecture	(Parreño-Marchante et al., 2014; Scholten et al., 2016)
Traceability System Model	(Liang et al., 2012; Qian et al., 2017)
UML Models	(Hu et al., 2013)

2.1. Analysis

The following section presents a set of graphs and tables that summarize the results of the research. Figure 1 shows the trend of the topic addressed:

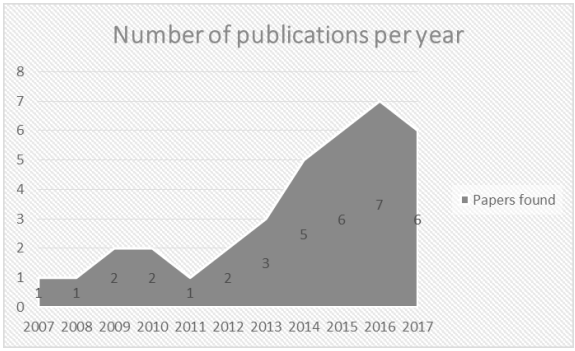

Fig. 1 – Temporal evolution of food traceability and IoT research.

The Figure 1 shows a growing evolution in the last years. A point for the analysis re-garding the traceability in food supply chains is the technology applied to carry out the tracing or the obtaining of information of the product.

Increasingly complex supply chains, with more players involved and requiring prod-ucts that involve more processing stages, also increase the complexity of the hardware and software systems required to track them throughout the chain. This is why the need arises to combine technologies that support each of the stages by which the product is acquiring value. Thus, several authors present in their proposals more than one technique to achieve the goal of traceability. Authors such as (Kemény and Ilie-Zudor, 2016) (Pizzuti and Mirabelli, 2016) (Zhou et al., 2015) (Bosona and Gebresenbet, 2013) detail a set of technologies that support traceability. As the principal and leader in traceability systems is RFID, it is applied at a greater rate over the years either individually or integrated into other technology. Another technology that stands out for its usefulness in the agri-food sector and in the cold chains are the electronic sensors, allowing the control of the agricultural foods from their cultivation, transport and arrival to the con-sumer. They are characterized by providing the necessary data on soil properties and nu-trients, crop nutrients, volume, water content and pest conditions, as well as their ap-plicability in monitoring food requiring temperature control since its production until the arrival at the table of the consumer (Lee et al., 2010). Other techniques will contribute to the adequate monitoring, such as the Internet of Things, the concept of intelligent traceability, and the temperature estimation methods (Badia-Melis and Ruiz-Garcia, 2016).

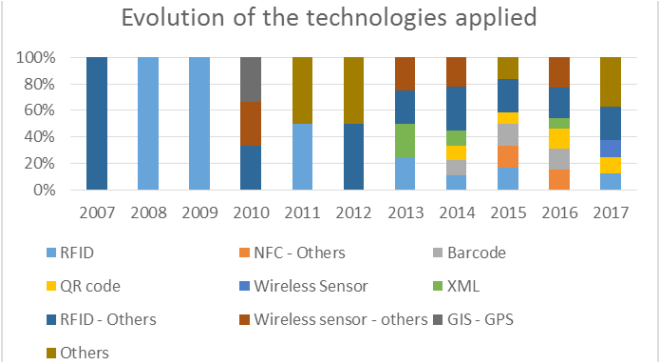

Fig. 2 - Temporal evolution of the technologies applied in the traceability of food SC.

Figure 2 shows the temporal evolution of a set of technologies applied in the different systems or models proposed in each article. Some of them are considered individually and others as a combination with other technologies. It can be clearly seen how the new technologies are incorporated every year, always maintaining the combination with RFID, thus improving the traceability in SC.

2.1.1 Gaps in literature

Table 2 presents an analysis of the technologies applied to different areas of the food sector. This study makes it possible to reveal clearly those sectors that have not yet been approached by research, as well as technologies that can be exploited in combination with those already applied. An example of this is QR codes, wireless sensors and NFC technology have been under rapid development during the last 10 years, however the re-search does not reflect its application in the food industry. Another widely used nowa-days but that is not reflected use in food traceability technology are GIS-GPS systems.

Table 2 - Application of each technology in different food SC

Technology –Area	Barcode	RFID	QR code	Wireless Sensor	NFC	XML	GIS - GPS	Others
Agri-Food	x	x	x	x	x			x
Aquaculture		x		x				x
Cereals	x	x	x			x		x
Cold chains		x						
Dairy		x		x				x
Fish	x	x		x	x	x		x
Fruits		x		x				
Highly perishable food		x						
Meat	x	x	x					
Sushi		x						
Vegetables and fruits		x				x	x	
Others	x	x		x	x	x		x

3. Conclusion

As can be observed in the present work, the traceability in the SC of food is an area where there are still several Gaps, either because it has not yet been investigated or be-cause no system was applied in any sector. In addition to this there are several aspects to consider as they are the applicability to collaborative SC where it is necessary to inte-grate different technologies and systems throughout the process of a product, the added value for both companies and final consumers, performance of the SC through the effec-tive exchange of information, as well as its applicability to SC working with sensitive information. Another aspect that is interesting for the investigation is the applicability of the Internet of Things in the traceability, a subject that at the moment is in full devel-opment but in the subject addressed in this work only are conceptual advances. A chal-lenge highlighted by (Badia-Melis and Ruiz-Garcia, 2016) is the real-time tracking. Us-ing real-time tracking and monitoring technologies, it is possible to reduce risks of no desired situations, the freight becomes a more controlled environment, and because the cargo is under surveillance, less people will be touching or opening up goods until the final destination.

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