MODELLING A TRACEABILITY SYSTEM FOR A FOOD SUPPLY CHAIN: STANDARDS, TECHNOLOGIES AND SOFTWARE TOOLS

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ABSTRACT
The aim of this article is to define the state of the art of the international regulatory framework for the food industry, standards, technologies and software utilized for modelling the food supply chain, analyzing for them the advantages and the disadvantages.
Traceability systems can help to know food origin and monitor means of transport and distribution, create "hallmarks" and improve commercial potential (external o supply chain traceability).
On the other hand, for a single company, there are many advantages in adopting a traceability system such as avoiding food adulteration, improving control systems, guaranteeing high levels of quality, increasing health and safety using transparency during the entire process chain.

Keywords: tracing, tracking, food supply chain, decision support system

1. INTRODUCTION

After the serious incidents that have invested the food sector (BSE, dioxin contamination in food, blue mozzarella, divulgation of the Escherichia Coli mutation, etc..), several institutions have promoted the introduction of control systems able to effectively trace not conforming (good) products and to find the risk factors that led to dangerous conditions for human health by compromising food hygiene. Currently, although important legal regulations have been introduced to define the general principles of food safety, the food sector is continuously exposed to risks and dangers of food fraud. To reduce this exposure is desirable the widespread adoption of efficient traceability systems that take into account the specific features that characterize each type of food supply chain.

The food supply chain is the complex structures that contribute to the production, distribution, marketing and supply of a food product. The food supply chain is typically formed by five basic entities: the raw materials producer, the processing company, the carrier, the distributor and the retailer (Gandino et al. 2009). Each entity plays a specific role. The raw materials producer (first processing company) sows and grows the agricultural products and sells them to the processing company; the processing company transforms the raw materials; the carrier conveys food from a company to another; the distributor handles food commodities; the retailer sells food to the final consumer.

A well organized food supply chain should have the ability to reconstruct the history of each product and follow the food through the various processing steps, identifying and recording the materials used and the operators involved, correctly combining this information to the single product package introduced in the market (Figure 1).

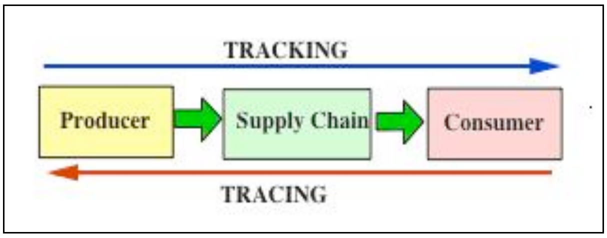

Figure 1: Tracking and tracing system.

This result can be conveniently achieved if each company of the supply chain adopts an internal system for controlling and recording information (internal traceability) and if transitions between the actors are regulated and managed in a coherent and shared form (external traceability). In this way is possible to trace the path followed by a food product that moves from "farm to fork".

Tracking and tracing terms indicate two mirror processes, but they are often used in a interchangeably way even though they have different meanings. Tracking is the process by which the product/food is followed by upstream to downstream in the supply chain by recording date in each production stage. On the other hand, tracing is the reverse process of tracking. Through tracking systems it is possible to trace the global history of the product and the responsibilities at different processing stages. At the end of the production process, a third party or public control authority, processing the stored information, will reconstruct the history of the product and identify the critical control point (Bernardi et al. 2007)„Traceability should not be confused with the obligation to provide consumers with information that characterize the final product, since this information are present in the product label.

The operations required by the traceability management system can be divided into two main activities which refer to internal traceability and supply chain traceability. The *internal traceability* is realized by internal procedures, different for each business, that allow to trace the origin of materials used, the process operations and the food destination. The *food supply chain traceability or external traceability* is guaranteed by the integration and coordination of the tracking procedure adopted by each operator of the chain, and represents the ability to follow the path of a specific unit of product along the production chain.

2. REGULATORY FRAMEWORK

The regulatory framework for food traceability is wide and diversified. The traceability term was first introduced by the Codex Alimentarius Commission (1999) as the "ability to trace the history, application or location of an entity by means of recorded information".

The Regulation (EC) 178/2002 represents the main regulatory reference for the food legislation. The regulation introduces for the first time the traceability concept for all the food products. Regulation EC/178/2002 defines traceability as the ability to trace and follow food, feed, and ingredients through all stages of production, processing and distribution". The Regulation specifies that all operators of the sector must have appropriate systems and procedures that enable the competent authorities to retrieve the necessary information and to select the companies which have been provided. Therefore, each operator can independently choose different tools and methods to achieve this goal. The critical aspect related to the Regulation (EC) 178/2002 is that it obliges each operator to only record the information related to their immediately preceding suppliers and immediately successive client (Charlier et al. 2008). It doesn't introduce any prescription on the internal traceability that enable to trace the path followed by each single unit of raw material and ingredient utilized in the production process in the company.

This information gap can be filled by implementing voluntary internal traceability systems. A voluntary traceability system requires to record additional information that enable companies to effectively monitor each production phase.

In Italy, The Italian National Unification Agency (UNI) has introduced the standards (1) UNI 10939 "Traceability systems in the agricultural chain: general principles for design and development" (April 2001) and (2) UNI 11020 "Traceability System in the agro-food industries: principles and requirements for development" (December 2002). In 2008, this standards where placed by the (3) UNI EN ISO 22005:2008 that defines "General principles and basic requirements for system design and implementation".

Currently, the European regulatory framework requires food and feed labelling and identification documented by recorded information. This goal is achieved by introducing European Directives and specific nation laws. In this context, the European Community has focused is attention to certain foods, such as fresh and processed meets(Reg. CE 1760/2000), milk, eggs (Reg. CE 2295/2003), fish products (Reg. CE 2065/2001), genetically modified foods(Dir. 2001/18/CE) and it has introduced specific regulations for them. Other regulations where introduced for lipids(Re. CE 20.7.98, n. 1638 art. 4 bis), grape and vine transformation(D.M. 29.05.2001), olive oil. In Table 1 the main regulations for the traceability in the food sector are summarized with attached their definition.

Table 1: European and Voluntary standards for the food sector

European Standards	
Directive 93/43/EEC on the hygiene of food	It defines general rules of hygiene for food and the procedures for verification of compliance with these rules.
EC Regulation 1760/2000	It establishes a system of identification and registration of cattle and defines a system of mandatory labeling of beef and beef products.
EC Regulation 2065/2001	It sets out the procedure for implementing Regulation (EC) 104/2000 for informing consumers on the products of the field of fisheries and aquaculture, providing traceability of fish products.
Directive 2001/18/EC on the deliberate release of GMOs	It requires to the Member States to adopt measures to ensure traceability and labeling for GMOs.
EC Regulation 178/2002	It sets out general principles of food law, establishes the European Food Safety Authority and defines procedures in matters of food safety. It introduces for the first time in a horizontal manner, and therefore applicable to all types of food, the instrument of traceability.
EC Regulation 2295/2003	It defines the procedures for implementing Regulation (EEC) 1907/90 to ensure traceability of eggs, the control of their origin and of the production method.
EC Regulation 1830/2003	It defines the rules on traceability and labeling of products containing GMOs or formed by them.
Voluntary standards	
UNI 10939:2001	It provides general principles for the design and development of traceability systems in the agricultural sector.
UNI 11020:2002	It defines principles and specific requirements for the development of a system of traceability in the agro-industries.
ISO 22000:2005	It defines the requirements for the design and implementation of a system of food safety management in any company in the agro-food industry.
UNI EN ISO 22005:2008	It defines the principles and specifies the basic requirements for the design and implementation of a food traceability system.

1. TRACEABILITY STANDARDS AND TECHNOLOGIES

Auto-identification technologies available for food traceability are: bard code, Radio Frequency Identification (RFID) technologies, Near Field Communication (NFC) systems, Real Time Locating Systems (RTLS) systems.

The bar code is the most common and widespread technology for encoding data. In this technology the information are present in form of sequence of vertical bars characterized by different spacing and thickness. (See Figure 2). The decoded data is stored through the use of optical systems (optical scanners) that, reading the sequence of symbols, allow to obtain the desired information.

Figure 2: Typical linear bar codes

Recently, the linear bar codes have been joined by the two-dimensional bar codes. The latter adopt a matrix representation and encode information in ordered sequences of white and black modules. (See Figure 3). Such codes can contain much more information than that encoded in a linear bar code, in a more compact and with redundancy. This latter feature allows the system to read the complete information even if a piece of code is illegible or is damaged (torn) through the passing from one point in the chain to another. In fact, even if the image is damaged or irregular due to the effects of light or reflection, it is possible to reconstruct and decode the code through the use of appropriate algorithms. The reading of the two-dimensional code is possible through the use of imager or camera-based scanner that capture an image of two-dimensional using the same principle of industrial vision systems. The disadvantages in the use of two-dimensional codes are related to the shortcomings of the technologies used to capture images that are seriously affected by dirt and/or inadequate lighting conditions. The most common formats for the two-dimensional bar codes are: the standard QRCode, (especially prevalent in Japan and Asian); Datamatrix standard used in Europe, and the EZCode standards that are "proprietary solutions" present in various forms (Spain, Italy, USA, Mexico).

Figure 3: Typical two-dimensional bar codes

Currently, the market is characterized by a significant growth of two-dimensional barcode and a progressive development of self identification systems based on RFID. The radio frequency identification technology, called "RFID System", uses some electronic components called reader and transponder. The reader is the device installed at the control center and has the ability to interrogate the transponder, send and receive data, interfacing with the corporate information systems. The transponder is an intelligent electronic device that is applied to the object that must be tracked and/or monitored. It consists of a tag, an antenna and a support that includes the other components. The tag is the electronic component used to store the information, the antenna allows the tag to receive and transmit information, while the packaging ensure their adequate protection from bumps and weather. The antenna enable the communication between the reader and the tag and allow the tag to receive the energy necessary for its operation. The information exchange takes place via a radio signal generated by and reflected from the tag reader.

Depending on the type of power required, the tags can be classified as active or passive. The first are characterized by autonomous internal power, or battery, and enable greater power transmission and greater working distance. Passive tags do not have instead internal energy sources and are characterized by a smaller overall size. The transmission frequency is the most important technology parameter for the correct application of RFID technology. There are four different frequency bands for transmission:

- LF (Low Frequency) 125 kHz - 131 kHz;
- HF (High Frequency) 13.56 MHz;
- UHF (Ultra High Frequency) 433 MHz and 866 MHz - 915 MHz;
- MW (MicroWave) 2.45 GHz and 5.8 GHz.

The last frequency band is not really used because of the low number of applications and the high costs of employment.

The use of different frequency bands affects the ability of communication, and the construction and environmental conditions in which the tag is able to work. In fact, the higher is the operating frequency the higher is the distance of employment, the amount of information that can be transferred per unit time, the moving speed of the object to be traced and the manufacturing cost, while the operational sensitivity is significantly conditioned by the presence of metals, liquids and electromagnetic activity. Table 2 shows, for different operating frequencies, the spectra, the reading distance, the type of power, the bit rate and areas of application (Puddu et al. 2011)

Table 2 - Operating frequencies of RFID

Operating frequency	125-135 kHz	13,6 MHz	860-960 MHz	2,4 GHz
Spectrum	low frequency (LF)	high frequency (HF)	ultra-high frequency (UHF)	microwave
Magnitude order of the operating distance	0,5 m	1 m	3 m	1 m
Power	passive	passive	passive, active	passive, active
Bit rate	up to 1 kbit/s	25 kbit/s	100 kbit/s	250 kbit/s
Application examples	animal tracking, access control, containers, vehicles identification	smart card, logistics, ticketing, baggage handling	logistics: pallet and objects, control	supply chain and logistics

A recent evolution of RFID systems is represented by the Near Field Communication (NFC). NFC technology provides wireless connectivity (RF) two-way short-range. NFC operates on a frequency of 13.56 MHz and can achieve very high transmission rate with up to 424 kbit/s. The basic elements involved in transmission are the initiator (or the first device to interrogate) and the target. Initiator and Target have symmetrical roles, and, once the communication has been initiated, they are alternate equally in the transmission. Unlike traditional RFID systems, NFC technology allows therefore a two-way communication in which initiators and targets create a peer-to-peer network in which they can both send and receive information.

A further RFID evolution is represented by the RTLS systems. This systems, using the same technology used by RFID, can identify a product, locate its position, track their movements over time. A typical active RTLS uses active tags placed on the good you want to locate, reader devices that detect the information sent by the tag and, finally, hardware and software devices that, processing the received information, are able to determine the position of the product under observation. (See Figure 4). RTLS systems may use different communication standards, the most common are: GPS Protocol, WiFi, ZiBee, RFID and Ultra Wide Band (UWB). The choice of this standards depends on the type of application: for this purpose ZiBee technologies, RFID, WiFi, and the Ultra Wide Band can be classified as indoor localization systems, while the GPS and active RFID are outdoor localization systems.

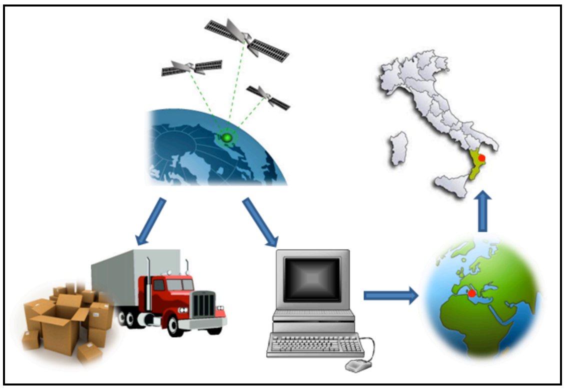

Figure 4 - Structure of a traceability system using RTLS systems

The most commonly used systems are bar codes and RFID; the use of RTLS is limited to those products of high value or particularly dangerous. The choice of the appropriate technology depends on many factors such as the value of assets, the size of objects, the nature of the products, the type of packaging, the amount of data to be stored, the supply chain characteristics, construction and operating costs. It is clear that the choice of RFID is the most appropriate for valuable and critical products, while bar codes are preferred for products characterized by low value, small size and low hazard of perishability.

Therefore, the possibility to use radiofrequency identification is connected with the adoption of the same frequency band for the data transmission common to all the operators of the supply chain. As a consequence, for the large adoption of RFID systems in the food supply chain is indispensable to identify a free band at global level. Finally, some privacy problems occurs during the phase of information exchange between different operators, even if some researches are trying to avoid security and privacy risks (Sanchez et al. 2001; Juels A. 2006).

The choice of the technology depends on the specific application that can ensure the lowest total cost of ownership (TCO) and faster return on investment (ROI). Of course, bar codes are more convenient for individual packages of product (consumer units) even if the adoption of RFID systems are preferable for multi-packs (packaging unit and pallets).

3. SOFTWARE TOOLS FOR THE DESIGN, IMPLEMENTATION AND MANAGEMENT OF TRACEABILITY SYSTEMS FOR THE FOOD INDUSTRY

The use of software for modeling and managing processes either directly or through web services is a valuable tool for implementing a traceability system. A system for storing and disseminating data concerning the traceability must include a software for modeling the food supply chain, a data server to store information and an access via the web that make the data accessible simultaneously from multiple locations.

The processes and actors involved in the supply chain and the relations existing between them can be modeled through different techniques including Petri nets, the Structured Analysis and Design Technique (SADT), techniques for Integration Definition (IDEF) and Event-driven process chain (EPC). These techniques, along with other methodologies for process modeling (UML Activity Diagram, UML EDOC Business Processes, IDEF, ebXML BPSS, Activity-Decision Flow (ADF) Diagram, RosettaNet, Loveme, and Event-Process Chains (EPCs)), were revised in 2001 by the Business Process Management Initiative (BPMI), which defined a new standard notation, the Business Process Model and Notation (BPMN).

The BPMN allows to reconstruct the process diagrams (BPD - Business Process Diagram) by means of graphs or networks of "objects". These objects represent the activities of the process and are linked by control flows that define the logical relationships, dependencies and order of execution. In general, BPMN is used for two different operating configurations. The first refers to processes that take entirely place in a company. In this case, processes are private and the internal activities are not directly visible from the outside (internal tracking).The latter refers to "collaborative" processes between two or more business entities (companies, organizations, units, etc..). Each entity develops its own process, which will exchange information with other industry players. These exchanges take place especially when a product moves from one operator of the supply chain to another and it is necessary to keep track of this transition.

For traceability information it is possible to create a computer-based system that integrates the database of the business processes and creates a "front end" displayed in a Web browser that enables the retrieval of information via internet. There are different software for modeling processes according to the BPMN standard that directly create a user interface for displaying the flow of information. The most commonly used are:

1. Aris (IDS Scheer GmbH Prof.)
2. Tibco Business Studio 2.0
3. Intalio
4. WebRatio.

The ARIS Platform has been mainly used in the past for modeling processes according to the scheme EPC scheme (Event-Driven Process Chain) (Bevilacqua et al. 2009). It is a web based application that allows to design in a "user friendly" way the business processes. The information captured by the Aris tool set is stored in a database according with the Entity-relationship (ER) model. Aris allows to different servers to immediately visualize the processes. Moreover it allows to quickly access to the information, simplifying data management.

In accordance with the BPMN 1.0 standard, Tibco Business Studio supports multiple processes in separated pools that represent the environment within the process is developed, even if the are only connected by streams of messages. It does not support the execution environment created in some constructs such as Tibco Process Modeler such as intermediate posts, intermediate events and error message, solutions multi pool connected with streams of messages.

Intalio is software based on the BPMS standard (Business Process Management System) which, starting from business process, generates executable platform independent processes that can be directly managed by users. Intalio is built on the Eclipse platform and it is characterized by a modular architecture. It is able to translate any BPMN diagram in a executable model using the Business Process Execution Language (BPEL). In particular, Intalio | BPMS AJAX tool represents an integrated environment used for the real-time development of user interfaces. It is based on open source version of TIBCO General Interface TM that allows to communicate using XML, SOAP, Java Script and other accessible http services. Moreover this tool offers the possibility to directly create user-maintainable web interface.

Web Ratio is an useful tool for supporting the modeling and design of a traceability system. It allows to model the food supply chain according to the BPMN standard, create the Entity Relationship model and visualize the Web interface without the necessity to write code. Starting from a BPMN diagram, it is able to generate a complete web application according to the WebML standard. In fact, using Web Ratio is possible to create a working system without the need to master the WebML standard. The WebML model represents the basic structure for a web application and uses a unique and fixed data model for any web project. The data model is shown in the form of ER. Web Ratio allows a parallelism between the BPMN elements and the entity/relationship data model. Moreover this tool allows to save information about the status of the elements and actors of the workflow system. The use of such software, which allow process modeling and management of information flows along the supply chain can efficiently implement a system of traceability and management of a typical food chain.

4. CONCLUSIONS

The development of efficient traceability systems in food chains has assumed considerable importance in recent years. The ability to trace and track every single unit of product depends on the supply chain traceability system which in turn depends on the internal data management system and the information exchanged between the actors. The technological tools, such as bar code and RFID, available for guaranteeing the traceability of product can be advantageously used in a comprehensive traceability system that includes an internal software infrastructure for modeling the supply chain, defining the points for data capture and generating of a front end for the retrieval of information both locally and directly on a web browser.

Of course, to ensure traceability and implement an effective traceability system is necessary to model the supply chain using a notation or a language understandable by analysts and computer experts. A notation that can be advantageously used for processes modeling is the BPMN standard, that allows the reconstruction of processes through basic graphics elements.

The software infrastructure for the storage and dissemination of data on traceability should also include a data server to store information that can be retrieved by simple queries.

Currently, there are different software tools that enable the supply chain modeling and the creation of complete web applications; however, to ensure system interoperability and communication between the different actors, it is necessary to identify a standard for encoding information not only for common companies operating in the single chain, but for all reference operators.

Finally seems trivial to note that managing a system of traceability after the definition of the reference context (food chain), technology and software infrastructure usable, as well as organizational and management issues, led to the definition of the realization costs and of the costs of exercise that necessarily have to be compared with the benefits expected in order to verify the actual economic sustainability.

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