FOOD TRACEABILITY MODELS: AN OVERVIEW OF THE STATE OF THE ART

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ABSTRACT
The evolution of the information technologies and their impact in the human life promotes an increasing demand of reliable information when security and safety plays a primary role. Nowadays, food traceability represents one of the main concerns in public authorities and industry. Traceability has become a critical part of the agro-food industry. The aim of the agro-food traceability is to allow the full monitoring of a product in the supply chain and trace the history of a good from the producer to the consumer. It is therefore a preventive instrument of quality and safety management. This paper presents an overview about the state of the art of models and systems developed for food traceability. In the first part, a short overview of the regulatory state of the art is presented. Then, the main research works in the area of food traceability are discussed. Finally some considerations are provided.

Keywords: tracking and tracing, food supply chain, information systems,

1. INTRODUCTION
In recent years the traceability of food products has attracted the attention of many researchers for several reasons (Jansen-Vullers, van Dorp, e Beulens 2003): first traceability, according with the Regulation of the European Community N. 178/2002, has become a legal requirement within the European Union from January 1, 2005 (European Commission 2002); secondly, food companies tend to view traceability as a strategic tool needed to increase consumer confidence and improve both the image of the company and of a specific product.

The term traceability refers to the "ability to trace the history, application or location of an entity by means of recorded identifications" (United Nations Food and Agriculture Organization (FAO) 1999). The European Community Regulation N. 178/2002 of the European Commission defines traceability as the "ability to trace a food, feed or producing animal or substance intended to be part of a food or feed, through all stages of production, processing and distribution" (European Commission 2002).

The final scope of a traceability system is generally to ensure the complete monitoring of the Food Supply Chain and to assure the observation of two primary functions, tracking and tracing. Tracking refers to the ability to trace a product through the Supply Chain, from upstream to downstream, recording data in each production stage. Tracing is the reverse process of tracking: through the tracing systems it is possible to identify the source of a food or group of ingredients through the information recorded upstream in the Supply Chain (Schwägele 2005). Kim, Fox, and Gruninger 1995 state that a traceability system must be able to track both products and activities. Therefore, the maintenance of traceability is a complicated and expensive process especially with regard to processed foods. In case of processed foods, in fact, different lots of various raw materials are combined into several production batches typically distributed in various points of sale (Hu et al. 2009). Hence, data to record must include information on products and on processes that operate on products (such as transport, transformation or combination). This goal can be reached through the implementation of an efficient traceability system supported by appropriate architectural solutions (Bechini et al. 2008).

The development of a global and efficient food traceability system faces with the knowledge of the previous research work conducted in this field. The need to analyse and classify the previous works present in the field, led the authors to the definition of a review of the state of the art of the food traceability models.

A general classification of the scientific literature on food traceability has been proposed in the contest of the Trace Project (http://www.trace.eu.org/index.php). Scientific contributions have been classified into two main categories: General Traceability and Chain Traceability. The General Traceability category includes general articles on traceability system, such as papers about general frameworks, analysis of benefits, advantages and disadvantages. Under the category of Chain Traceability have been classified the scientific works which refer to a particular supply chain, such as meat/agro or seafood, those devoted to the analysis of particular technologies, the articles that define which benefits can be obtained through the implementation of a traceability systems in the supply chain, the papers that analyze the impacts in logistics, the articles which defines the regulatory framework in the European

Union. Moreover, there is no a clear definition of how these sub-categories have been obtained.
In this paper the authors propose a new classification of the previous works on traceability system for food products. Two different parts have been analysed:

- Regulation, recommendation, and guides of Governments;
- Scientific literature.

Scientific literature has been classified into two main categories: Mathematical models and Information models.

The category of Mathematical models includes a review of the works oriented to the definition of some mathematical models containing mixing and risk transmission problems. During the development of a traceability system the definition of the rules for the identification of product units and their complete monitoring plays an important role for reducing batch dispersion and optimizing products recall. To this end, particular attention has been devoted to the analysis of those papers focused on the analysis and modelling of the lot behaviour.

The category of Information models includes works on the definition and development of innovative traceability information systems. In this area, important considerations have been done on the evaluation of the different technologies that can be used for recording, managing and transferring information. This technologies, known as auto-identification technologies are: bard code, Radio Frequency Identification (RFID) technologies, Near Field Communication (NFC) systems, Real Time Locating Systems (RTLS). The awareness of benefits and costs related to the introduction of these technologies is fundamental in the development of a traceability information system. In addition, new tendencies show that ontologies can be used to set up innovative traceability semantic models.

This paper is structured as follows. Section 2 presents a brief review of the regulatory state of the art on traceability. Section 3 presents an overview of the scientific literature.
The analysis of the state of the art is a requirement of any step previous at the development of a traceability system.

2. REGULATORY OVERVIEW

The increasing concern on food safety matter has promoted that many governments have begun thinking the adequacy of the private traceability system and the possibility of adopting mandatory traceability systems to improve the social food safety level. Some of the nations and regions have required mandatory food traceability systems or encouraged voluntary traceability programmes (F. Wang et al. 2011). In many developing countries, traceability initiatives have been started in the last decade. They mainly refer to perishable and high-risk food export products like beef and fish, fruits and vegetables, but also coffee or wine.

In Europe, Regulation (EC) 178/2002 of the European Parliament and of the Council lays down the general principles and requirements of a food law. The principal aim of this Regulation is to protect human health and consumer interests in relation to food. It applies to all stages of production, processing and distribution of food and feed, but there is an exemption for primary production for private domestic use, and the domestic preparation, handling, or storage of food for private domestic consumption. The traceability requested is known as "one step back-one step forward", which means to identify the immediate supplier of the product in question and the immediate subsequent recipient. In fact traceability is a requirement limited to ensure the ability for businesses to identify at least the direct supplier of a product as well as the immediate client, with the exemption for retailers (European Commission, 2002, European Commission 2004). Each food business operator must record and preserve information such as (1) name, address of supplier, and type of products supplied, (2) name, address of customer, nature of the products delivered to the customer, and (3) date of the transaction/delivery (European Commission, 2002).

In Japan, the Government has supported the development of traceability systems from 2003 with the establishment of the Food Safety and Consumer Affairs Bureau within the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF). The MAFF policy is to encourage food business operators to voluntary establish traceability systems (MAFF 2004, 2007). The government has taken decisions to support the development of traceability systems. In 2003, the Food Safety and Consumer Affairs Bureau was established within the (MAFF). Although traceability systems are not legally required except for domestic beef, MAFF policy is to encourage food business operators to voluntarily establish traceability systems (MAFF 2004, 2007). Supporting this policy, MAFF has provided funds for projects such as developing traceability systems utilizing advanced ICT and formulating a handbook to guide the establishment of traceability systems. The handbook for the introduction of food traceability systems was created for food business operators and aims to facilitate cooperation between the various operators throughout the food chain (Revision Committee on the Handbook for Introduction of Food Traceability Systems 2007). The handbook covers definitions, basic objectives of traceability, the role that each operator should play to establish traceability, and how to proceed with the introduction of a traceability system. It outlines examples of general traceability systems as well as guidelines for specific food items. An English translation has been produced for overseas suppliers. In June 2003 the Japanese Govern introduced the Beef Traceability Law and in October 2010 enacted the Act on Recording Source Data and Other Information Relate to the Trade of Rice and Other Gains. In this act is reported that "The government has drafted a plan calling for a new law to establish the traceability of all food products" (Summary of FY2010, 2008).

In China the first Food Safety Law becomes effective in July 2009, and it requests the food company to keep the account book of procurement and sale for at least two years to be reviewed by food safety authorities once needed. No mandatory regulation was in effect till that the General Administration of Quality Supervision, Inspection and Quarantine of the P. R. C. released a new regulatory to ask diary industry to adopt IT system to record critical information (AQSIQ of PRC, 2010). The Announcement No.119, 2010 might be treat as a trend on the food traceability system adoption.

In Canada, traceability initiatives were mostly oriented to animal identification and tracking, through the creation of the Canadian Cattle Identification Agency (CCIA).

In 2001, Québec was the first province implementing a traceability procedure for cattle, sheep, and pigs under Agri-Traçabilité Québec, which provides a framework for identification of animals and premises, as well as animal transportation tracking.

- In the Health of Animals Act, cattle, bison and sheep identification became federally regulated by 2004.
- In 2003, Agriculture and Agri-Foods Canada consulted with federal, provincial and territorial governments, where a consensus "that traceability is necessary in a safe food supply" was established; this was incorporated into the Agricultural Policy Framework (APF).
- Can-Trace, created in 2003, released the 2nd version of the Canadian Food Traceability Data Standard in 2006, based on the EAN.UCC system. Can-Trace is a collaborative, multi-commodity effort to establish traceability standards for all food products in Canada.

Participation in the Can-Trace is currently on a voluntary basis.

In the United States, after the Bioterrorism Act program regulation of 2002, local and foreign food businesses that produce food products for sale in the United States must be registered with the U.S. Food and Drug Administration (FDA). Importers and processors are required to keep records of their immediate suppliers and buyers for 2 years after transaction, and must be able to reproduce these records upon request for inspection by the FDA. In 2007, the FDA issued the Food Protection Plan (FPP), which objective is improving the food safety and defense for all domestic and imported products in the United States. A component of the FPP is the emergency response development, under which traceability practices are in the process of being defined, in collaboration with the food industry and other stakeholders. Recently, the FDA Food Safety Modernization Act (FSMA) signed as law on January 4th, 2011establishes within the FDA a tracing system able to receive information that improves the capacity to effectively and rapidly track and trace food in United States, or offered for importation into the United States.

In Australia, under the Legislative Instrument Act, the Australian New Zealand Food Standards Code was stipulated in 2003. Through this standard code the food businesses must be able to identify where their products come from (Diogo et al. 2004).

South Korea and Taiwan have included a definition of traceability in their food legislation and they have also implemented traceability programmes for some categories of domestic products, where participation of food operators in most of these programmes is voluntary.

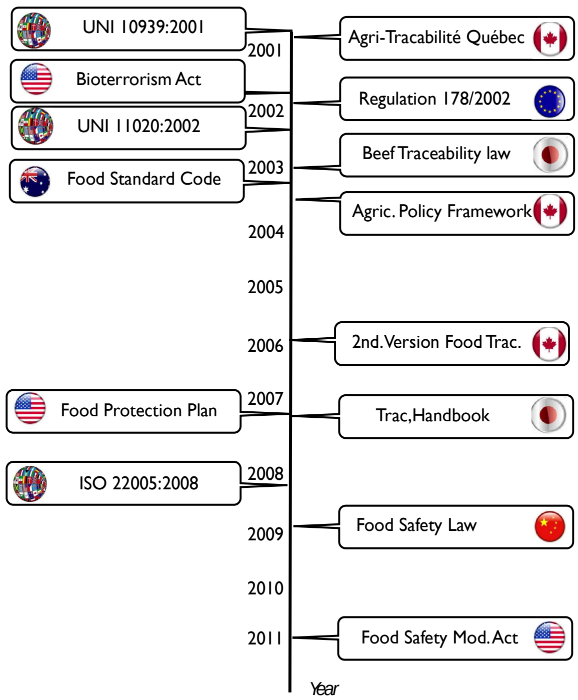

Figure 1- Food Traceability Regulatory Framework

An interesting finding by reviewing the history of food traceability regulations is that not only the approaches to establish the systems are different, but also the breadth, depth and precisions of these systems are different. While most chains allow only one step forward and one-back trace, a deeper traceability system back to the producer of raw materials is required e.g. for ensuring that products have not been genetically modified (Golan, Krissoff, and Kuchler 2004). Additional requirements should be satisfied to ensure food security and to improve food quality (Food Standards Agency 2002). Additional information should be collected in each stage of the supply chain in order to ensure the availability of data for the production analysis and optimization (Thompson, Sylvia, and Morrissey 2005). All trading partners in the supply chain must guarantee both the internal and external, or well-know supply chain, traceability.

Therefore, the no existence of a global standard for food traceability hinters the communication between the different actors of the supply chain and hence the traceability chain. An important bottleneck for traceability is, in fact, the lack of a global standardization. Companies positioned in different geographical contexts (America, EU, Asia, Africa) have to deals with different implementation for the products responsibility and liability, and different standards for labeling. A global traceability system can be conveniently achieved if each company in the supply chain follows a common system for information encoding, registration and control, and the transactions between actors involved are regulated in a coherent and shared form (De Cindio et al. 2011).

3. SCIENTIFIC LITERATURE

In this section is presented a review of the scientific literature on food traceability, with a particular focus on the fruit and vegetable field.

The increased interest of the scientific world in the research area of the supply chain traceability is the result of a long series of developments aimed at improving food quality and safety management (Opara 2003).

3.1 Mathematical Models

The implementation of an effective shop floor traceability system does not only consist of recording, manually or using computers, the various supply chain batches. Indeed, it implies a deep modification of the organization and, sometimes, of the company fabrication processes. A traceability system must ensure the linkage between products and information, and must guarantee this connection through the supply chain. Moreover, as mentioned before, the maintenance of traceability is a complicated and expensive process especially with regard to processed foods. In case of processed foods different lots of various raw materials are combined into several production batches typically distributed through various points of sale (Hu et al. 2009). Some mathematical models have been proposed in order to solve this problem and to model the lot behavior.

Dupuy, Botta-Genoulaz, e Guinet (2005) propose a mathematical model to reduce batch dispersion, for controlling the mixing of production bathes in order to limit the size, and consequently the cost and the media impact of batches recalled in case of problem. The problem studied aims to minimize the quantity of products recalled in case of a problem that occurs in a particular situation with a 3-level ‘‘disassembling and assembling’’ bill of material. For the development of the mathematical model they implemented a model proposed in Dupuy, Botta-Genoulaz, e Guinet (2002), a method based on the concepts of Traceability Resource Unit (TRU) and batch dispersion.

Bollen, Riden, and Cox (2007) and Riden and Bollen (2007), studied and analyzed the traceability in fruit supply chains in order to improve the traceability control of the batches. They proposed a mixing model that was able to assign the probabilities of bin origin to individual fruit at the point that they are packed into their final packs. The model can significantly reduce fruit mixing and improve the traceability. They introduced concepts for quantify aspects of processing transformations, implementing a model based on enable simulations that examine the effect of splitting throughput into multiple output lines. They stated that there is a potential to implement high precision and fine granularity traceability in agricultural supply systems, which can also meet a number of other purposes such as improvement feedback to producers and benefits to supply system efficiency, as well as being acceptable for compliance purposes.

Hu et al. (2009) studied the traceable information flow and risk transmission throughout food supply which contains raw material, process and distribution. They propose a mathematical model based on dynamic programming in order to solve the risk transmission problem in a China dumpling factory, using Radio Frequency Identification (RFID) to identify and transfer traceable information. The purpose of the study in the factory is to minimize the cost due to a food safety crisis. If a food safety problem comes from a raw material batch, the factory will trace and identify all products. This model takes into consideration the previous research work of Dupuy, Botta-Genoulaz, e Guinet (2002). They propose a graphical model to describe the risk transference problem, according to the Gozinto graphs proposed by van Dorp 2003.

Tamayo et al. (2009) used the traceability information in order to reduce the size of products recalls. Three principal subjects are defined as follows: dispersion evaluation and optimization, criticality determination and final product delivery optimization. To achieve the final purpose of reducing the recall size and cost they stated that it is important to perform an intelligent delivery allocation. The developed expert system uses the information produced by a genetic algorithm and an artificial neural network to optimize product dispatches.

X. Wang et al. (2010) developed an integrated optimization model in which the product safety related traceability factor is incorporated with operations factors to develop an optimal production plan. The model aims to improve traceability and manufacturing performance by simultaneously optimizing the production batch size and batch dispersion with risk factors.

3.2 Information Models

In recent years, many works have been conducted on the development of traceability systems in food supply chain.

Jansen-Vullers, van Dorp, e Beulens (2003) proposed a reference-data model for tracking and tracing of food based on the Gozinto Graph, a tree-like graphical representation of raw materials parts, intermediates and subassemblies, in which a particular production process transforms an end-product through a sequence of operations. In the paper the tracking and tracing requirements from three business cases situated in a production network (breeder, grower and egg producer) are discussed. A concise overview of the main requirements is identified for each business case and a data model is constructed. The development of the reference data model is described by explaining the model-part of the bill of lots and/or batches, the model-part of operations and variables and the integration of these two model-parts. The reference data model supports the registration of historic relations between lots and batches (where-from and where-used relations), the registration of operations on lots and batches in production, the registration of associated variables and values, on operation control, and the registration of capacity units on which operations are executed. The reference data model includes tracing of generating properties, which have been identified as an overlaying requirement.

Lo Bello et al. (2005) proposed a general approach based on distributed collaborative information systems where every company exchanges traceability data with the others over a network. XML was used as the format to represent data, for its ability to cope with data structures of different size. Web Services based technology has been adopted to interface different suppliers which communicate through HTTP protocol.

Regattieri, Gamberi, e Manzini (2007) develop a traceability system for Parmigiano Reggiano (the famous Italian cheese) introducing a general framework based on the integration of alphanumeric codes and RFID. The characteristics of a product are identified in its different aspects along the entire supply chain, from the bovine farm, the dairy, the seasoning warehouse, and lastly to the packaging factory. The complete supply chain of Parmigiano Reggiano is traced by an RFID system integrated with an alphanumerical code. Technically the system developed is based on a central database that collects data from bovine farms and from dairies. Manufacturers can check the progress made in production at any time and, if problems occur in the market place, they can re-trace the development of the portion of infected products and introduce effective re-call strategies.

Bechini et al. (2008) introduce a data model for identifying assets and actors and show a formal description of the lot behavior throughout the Supply Chain. The lot behaviour has been modelled by six activity patterns (integration, division, alteration, movement, acquisition and providing) using a UML activity diagram. The standard Unified Modelling Language (UML) notation is adopted to formally describe the different aspects of the modelled system. The model of a simply cheese supply chain with a UML communication diagram is presented. An independent, private data-sharing networks (PDSNs) is proposed as proper infrastructure for business process integration and Enterprise Service Bus (ESB) as architectural scheme for connecting third party applications. The ebXML Message Service (ebMS) is used for transporting business documents in a secure, reliable, and recoverable way in the inter-enterprise business collaboration scenario. In case that one of the business partners cannot manage ebMS messages (for instance, in the case of legacy systems), the communication is handled via ESB.

Thakur e Hurburgh (2009) developed a model for implementing internal traceability systems for a grain elevator that handles specialty grain and a model for information exchange among the supply chain actors. A UML sequence diagram shows the information exchange in the grain supply chain when a user requests additional information about a suspected product. The usage requirements of the traceability system are defined by the UML Use Case diagram technique. One of the most important goals of defining system requirements is to synchronize the requirements of all the actors. Integrated Definition Modeling (IDEF0) is used to develop the system for the internal traceability that they use and all the information is recorded in a RDBMS (Relational Database Management System) form by each actor. Finally some suitable technologies to enable this information exchange, such as the XML documents, are discussed. A relational database model to facilitate internal traceability at grain elevator is presented in Thakur el al. 2011. In this reference the entity-relationship modeling technique is used to develop the internal traceability grain handling a RDBMS for constructing and implementing the Entity Relationship model. The main purpose of the database is to connect the incoming grain lots with the outgoing grain lots. Once the data is stored in the database, the manipulation is accomplished through the use of queries written using the Structured Query Language (SQL).

Thakur and Donnelly (2010) presented a model for information capturing in the soybean supply chain. Actors involved in the supply chain are responsible for production, handling and processing. The soybean value chain and the main inputs and outputs of each stage are modeled using a simple flowchart. Conceptual process flow diagrams are created for farming, handling and processing sectors in the soybean value chain. Information capture points are identified for each sector and the corresponding products, processes and quality information to be captured are determined. A UML class diagram is developed for modeling products, processes, quality and transformed information. Finally some technologies available for transferring the information, such as the XML, are presented.

Maitri Thakur et al. (2011) presented a new methodology for modeling traceability information using the EPCIS framework and UML statecharts. EPCIS is an EPCglobal standard designed to enable EPC-related data sharing within and across enterprises. The model presented is used for mapping of food production processes in order to provide improved description and integration of traceability information. The method follows the approach of defining states and transitions in food production. A generic statecharts for food production is presented and applied to two supply chains: pelagic fish and grain. A state-transition model with emphasis on identifying both traceability transitions and food safety and quality data are developed. The application of current EPCIS framework for managing food traceability information is presented by mapping the transitions identified in two product chains to the EPCIS events: Object Event and Aggregation Event. The corresponding states where the quality parameters are recorded are also identified and linked to these EPCIS events.

Bevilacqua, Ciarapica, e Giacchetta (2009) used the business process reengineering (BPR) approach to create a computer-based system for the management of the supply chain traceability information flows. They present a computer-based system for the traceability of fourth range of vegetables. They used an Event-Driven Process Chains (EPCs) technique to model the business processes. In order to ensure the traceability, each single unit or lot of the food products has been uniquely identified combining GTIN and the lot code. The business processes database follows the Entity Relationship Model (ERM). In the paper, moreover, the data model is not presented, and the front-and generated, based on the software ARIS, is only discussed.

Ruiz-Garcia, Steinberger, e Rothmund (2010) presented a web-based system to process, save and transfer data for tracking and tracing agricultural batch products along the SC. The development of the prototype involved the integration of several information technologies and protocols. The tracking system is based on a service-oriented architecture (SOA) and the communication is through messages in XML. Moreover, the work not deals with the problem of process and data modeling. In addition, there are only few authors using the BPMN standard for process modeling.

In the area of information modeling, several research works have been conducted on the analysis and evaluation of the different tools that can be used for recording, managing and transferring information such as barcode and Radio Frequency Identification (RFID) technologies. RFID systems have found applications in the agri-food sector especially in fresh-produce companies (Amador, Emond, and Nunes 2009; Gandino et al. 2009; Jedermann, Ruiz-Garcia, and Lang 2009; Martinez-Sala et al. 2009) and meat processing companies (Abad et al. 2009; LiWei, DongPing, and ChunHui 2009; Hsu, Chen, and Wang 2008; Reiners et al. 2009; Shanahan et al. 2009; Bo, Haiyan, and Caijiang 2008).

3.3 Future of Traceability Systems: Ontological Models

Currently there is a large variety of traceability mechanisms used in food supply chains. Some older traceability schemes are paper based while more recent are IT based. Notwithstanding, the information technologies can only be used to track information which were generated by product, management processes, manipulation operations. In fact, the information resources cannot be shared and reused in the process of tracing. A new research area is currently investigating how ontologies can be used to set up a traceability semantic model in order to reuse the information resources in the process of tracing and promote the accuracy and efficiency of information management. An ontology is an explicit specification of a conceptualization" (Gruber, T. R. 1993). The aim of ontology is to capture knowledge in related field, provide shared understanding to conceptual knowledge, definite common vocabulary in this field and give clear definition to the mutual relationship between these jargons and words from different levels of formal model (Heijst et al. 1995). Several ontologies have been proposed in the area of agriculture (Shoaib and Basharat 2010; Bansal and Malik 2011) and in particular in the vegetable supply chain domain (Yue et al. 2005) (Yue et al. 2005). Food ontologies are emerging related to nutritional concepts, such as the FOODS ontology (Snae and Bruckner 2008). The development process for a food ontology related to a specific health problem is shown in Cantais et al. (2005). This ontology is part of PIPS (Personalized Information Platform for Health and Life Sciences).

Kim, Fox, e Gruninger (1995) proposed the first quality ontology for products traceability and introduced two fundamental concepts, Traceable Resource Unit (TRU) and primitive activity. The data model presented by Kim et al. (1995) describes the main elements of the traceable ontology and underlines the relationships between terms. These concepts where revised by Moe (1998) which defined for each core entity a set of essential descriptors that must be included in order to secure ideal traceability of products and activities.

Yue et al. (2005) analysed the situation of China agricultural supply chain Informationization and discussed the use of Ontology in vegetable supply chain knowledge expressing. They put forward a process to build vegetable supply chain Ontology and gave a vegetable supply chain knowledge expressing frame. The frame can be used to express concepts and their relationships of vegetable supply chain as well as build vegetable supply chain knowledge base.

Salampasis et al. (2008) suggest a traceability solution which considers food traceability as a complex integration of business process problem which demands information sharing. To enable information sharing, data and the way they are organized should be standardized and their meaning and carrying semantics should be commonly agreed by the different operators along the food supply chain. To this end, they propose a generic framework for traceability applications which consists of three basic components: (i) an ontology management component based on OWL; (ii) an annotation component for "connecting" a traceable unit with traceability information using RDF; (iii) Traceability core services & applications.

Chifi, Salomie, and Chifu (2007) proposed an ontological model approach which allows semantic annotation of Web Services aiming at automatic Web Services composition for food chain traceability. The model has been implemented in the framework of the Food-Trace project (Food Trace) for traceability in the domain of meat industry. The developed ontology is for the Romanian language. The model consists of core ontology and two categories of taxonomic trees: Business Service Description (BSD) tree and Business Product Description (BPD) trees. The core ontology defines six generic concepts: Business Actor, Service, Service Input, Service Output, Product and Feature.

Wang et al. (2012) proposed a quality and safety traceability system of fruit and vegetable products based on ontology. This work analyzed the whole process of fruit and vegetable products from farm to sale terminal, determined the collection scope of quality and safety traceability information of fruit and vegetables products, and established the traceability information ontology of the fruit and vegetables products. Through the definition of the traceability information ontology the authors introduced an example of traceability semantic net of control elements in the planting sub-system to explain the practical application process.

Bansal and Malik (2011) used the AGROVOC thesaurus as base vocabulary to develop the CROPont ontology. AGROVOC vocabulary developed by Food and Agriculture Organization is used for indexing and retrieving data in agricultural information systems. The idea is to develop ontology for crop production cycle that serves as a building block to an ontology driven Agriculture Information System Framework.

Yang et al. (2011) used the ontology theory and established an ontology knowledge base of food safety in emergencies domain which can provides semantic support for information retrieval in food safety domain. On the basis of this ontology knowledge base they developed an experimental semantic retrieval system FSSRS (Food Safety Semantic Retrieval System), trying to improve the retrieval performance and make up for the defect of traditional search methods.

4. DISCUSSION AND CONCLUSIONS

The main objective of this paper was to present a literature review on traceability models. Over the last decades, the development of traceability systems has received growing attention and several models have been developed. The authors have reviewed these models as they run through the literature by classifying them into mathematical and information models. The initial search identified a huge number of technical papers which were reduced according to content and quality.

The analysis of the state of the art highlights that several countries have developed traceability programs in the many sectors. However, more than often these programs do not provide information to the consumer about raw material management, processing**,** storage and distribution practices. Rather, traceability is viewed as a mechanism for improving food safety control by ensuring rapid product recall ability when a food safety incident occurs.

The scientific literature about the potential of traceability systems and the numerous advantages that can be obtained through its implementation is diverse (Moe 1998; Golan, Krissoff, and Kuchler 2004; Lo Bello, Mirabella, and Torrisi 2004; X. Wang and Li 2006; Pouliot and Sumner 2009; Nishantha, Wanniarachchige, and Jehan 2010).

Advantages of chain traceability and advantages of internal traceability in the production step are well discussed by Moe (1998). A traceability system can be used in order to guarantee food quality and safety and to improve the consumer trust (Lo Bello, Mirabella, and Torrisi 2004). Traceability, in fact, is becoming popular as a tool for winning consumer trust and managing complex supply chain while complying with ever increasing legal standards notwithstanding the nature of the industry (Nishantha, Wanniarachchige, and Jehan 2010). An efficient food traceability system can address information asymmetry in the supply chain, increase the speed of response to safety failures, and strengthen market and liability for precaution (Pouliot and Sumner 2009).

Tracing and tracking capabilities are crucial to confine the reaction to possible hazards and reduce the recovery cost (Bechini et al. 2005). Nevertheless, the recent food safety incidents (e.g. dioxins in animal feedstuffs in Belgium, E. Coli in Germany) have demonstrated that traceability is a “buzz word” with regard to food. Traceability systems have been shown to be weak or absent and hence slow or unable to assure consumers of food safety. In such case, food recalls or warnings have been applied to all suppliers, even to the supplier of products that do not contribute to the contamination

In addition, even if today a variety of lot code markings and systems exists for products identification and these have merit, they do not link across the life cycle of the world’s food supply.

The analysis of the discussed model highlight that the degree of coordination between the different actors of the supply chain is fundamental in the implementation of a traceability system. Also Álvarez et al. (2006) state that particular importance must be devoted to the degree of coordination between buyers and suppliers.

New traceability systems can be developed integrating the advantages of the previous works, in order to obtain a better solution at lower cost.

ACKNOWLEDGMENTS

This paper is co-funded with the support of the European Commission, European Social Fund and Regione Calabria (Italy).

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