Traceability in a food supply chain: Safety and quality perspectives

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ABSTRACT

The food industry is becoming more customer-oriented and needs faster response times to deal with food scandals and incidents. Good traceability systems help to minimize the production and distribution of unsafe or poor quality products, thereby minimizing the potential for bad publicity, liability, and recalls. The current food labelling system cannot guarantee that the food is authentic, good quality and safe. Therefore, traceability is applied as a tool to assist in the assurance of food safety and quality as well as to achieve consumer confidence. This paper presents comprehensive information about traceability with regards to safety and quality in the food supply chain.

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1. Introduction

Nowadays, the distance that food travels from producer to consumer has increased as a result of globalization in food trade. Therefore, keeping safety and quality along the food supply chain has become a significant challenge. During the last couple of decades, the credibility of the food industry was heavily challenged after a number of food crises, such as Bovine Spongiform Encephalopathy (BSE) or mad cow disease, Dioxin in chicken feed, Food-and-Mouth Disease (FMD) and issues such as the use of Genetically Modified (GM) crops in foods. The outbreak of foodborne illnesses such as salmonella, campylobacter and *Escherichia coli* has also further increase consumer concerns over the safety and quality of food. As a consequence of food scandals and incidents, customers call for high quality food with integrity, safety guarantees and transparency (Bertolini et al., 2006; Beulens, Broens, Folstar, & Hofstede, 2005; Regattieri, Gamberti, & Manzini, 2007; Trienekens & Zuurbier, 2008). Traceability has gained considerable importance with regard to food, particularly following a number of food safety incidents during which traceability systems have been shown to be weak or absent (FSA, 2002).

In response to growing food safety issues, the laws, policies and standards regarding food safety and quality management have been developed for the food industry. Quality assurance has become a cornerstone of food safety policy in the food industry that started to implement integrated quality and food safety management systems (Pinto, Castro, & Vicente, 2006; Trienekens & Zuurbier, 2008). Traceability is found to be a tool to comply with legislation and to meet the food safety and quality requirements. It is considered to be an effective safety- and quality-monitoring system with the potential to improve safety within food chains, as well as to increase consumer confidence (Kher et al., 2010) and to connect producers and consumers (Regattieri et al., 2007).

Due to globalization in food trade, food chain integrity not only includes safety concerns but also origin fraud and quality concern. Consumers also demand verifiable evidence of traceability as an important criterion of food quality and safety. To tackle these re- traceability is de- fined as: “the ability to trace the history, application or location of an entity by means of recorded identification”. In ISO 9000 (2005) standards, the definition is extended into “the ability to trace the history, application or location of that which is under consideration”. ISO guidelines further specify that traceability may refer to the origin of materials and parts, the processing history, and the distribution and location of the product after delivery.

The European Union (EU) regulation 178/2002 (EU, 2002) narrows the definition to the food industry by defining traceability as the ability to trace and follow a food, feed, food-producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution. The Codex Alimentarius Commission (CAC, 2005) defines a more concise definition of traceability as the ability to follow the movement of a food through specified stage(s) of production, processing and distribution.

The definition of food traceability is found different depending on the sector of the food industry. For the agro-based food chain, Wilson and Clarke (1998) defined food traceability as the information necessary to describe the production history of a food crop, and any subsequent transformations or processes that the crop might be subject to on its journey from the grower to the consumer’s plate. In contrast, traceability is defined as a system able to maintain a credible custody of identification for animals or animal products through various steps within the food chain, from the farm to the retailer (Dhillon, Marchi, & Cassandro, 2007; McKeen, 2001).

Olsen and Borit (2013) redefined traceability based on the definitions of ISO as the ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications. Karlsen, Olsen, and Donnelly (2010) highlighted that traceability is not the product and process information itself, but a tool that makes it possible to find this information again at a later date. However, these definitions do not reflect the specific characteristics of food traceability.

The revised definition of Bosona and Gebresenbet (2013) is very informative and comprehensive definition to food traceability. Food traceability is defined as a part of logistics management that captures, store, and transmit adequate information about a food, feed, food-producing animal or substance at all stages in the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time. A chart that classifies the short phrases of selected definitions on traceability is shown in Table 1 to compare the differences among the definitions. The definitions of ISO are found to define generic traceability and not specific to food commodity. But the rest of the definitions tried to define food traceability more specifically based on a product to trace. Traceability is found to be defined as “a tool to trace and follow”, “a tool for information retrieval”, “a record keeping system” and “a part of logistics management”. Some definitions failed to mention that traceability can work bi-directionally along supply chains. The phrase “by means of recorded identification” is found to be appropriate to combine with other definitions as well since identification is mandatory to traceability.

2. The context of traceability

2.1. Defining traceability

Golan et al. (2004) mentioned that the definition of traceability is necessarily broad because traceability is a tool for achieving a number of different objectives and food is a complex product. Accordingly, several definitions of traceability and its classifications which come from organizations, legislations and research literature can be found. According to ISO 8402 (1994) quality standards, traceability is defined as: “the ability to trace the history, application or location of an entity by means of recorded identification”. In ISO 9000 (2005) standards, the definition is extended into “the ability to trace the history, application or location of that which is under consideration”. ISO guidelines further specify that traceability may refer to the origin of materials and parts, the processing history, and the distribution and location of the product after delivery.

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2.2. Principle of traceability

An independent food safety watchdog, Food Standard Agency (FSA, 2002) identified three basic characteristics for traceability systems: i) identification of units/batches of all ingredients and products, ii) information on when and where they are moved and transformed, and iii) a system linking these data. To enable traceability, an entity to trace has to be a Traceable Resource Unit (TRU). There are three types of traceable units: batch, trade unit and logistic unit. A batch is defined as a quantity going through the same processes. A trade unit is a unit which is sent from one company to the next company in a supply chain (e.g. a box, a bottle or pack of bottles). The logistic unit is a type of trade unit, and it designates the grouping that a business creates before transportation or storage (e.g. pallet, container, etc.)
Keeping historical records by means of recorded identification and between the different links of the supply chain in addition to their disposition. But in an active sense, the on-line tracking traceability provides the visibility to where items are at all times.

Types of traceability, as the effectiveness for one type does not assure to pinpoint a particular movement of a food product) to tracks the relevant information) and precision (i.e. degree of assurance to balance cost and benefits.

According to Jansen-Vullers, Van Pramatari, & Doukidis, 2007). Moe (1998) explained that traceability can be seen in two types: internal traceability that tracks internally in one of the steps of the chain or chain traceability that tracks a product batch and its history through the whole, or part, of a production chain from harvest through transport, storage, processing, distribution and sales. Opara (2003) classified traceability into six important elements: product traceability, process traceability, genetic traceability, input traceability, disease and pest traceability, and measurement traceability focusing on agricultural and the food supply chain.

Depending on the direction in which information is recalled in the chain, backward traceability or tracing is the ability, at every point of the supply chain, to find the origin and characteristics of a product based on one or several given criteria. In contrast, forward traceability, or tracking, is the ability, at every point of the supply chain, to find the locality of products from one or several given criteria. It is important for an information system to support both types of traceability, as the effectiveness for one type does not necessarily imply the effectiveness for the other (Karlsen et al., 2010). Golan et al. (2004) suggested that an efficient traceability system should be characterized by breadth (i.e. the amount of information collected), depth (i.e. how far back or forward the system tracks the relevant information) and precision (i.e. degree of assurance to pinpoint a particular movement of a food product) to be able to balance cost and benefits.

2.3. Traceability objectives

Firms have three primary objectives in using traceability systems: improve supply management; facilitate traceback for food safety and quality; and differentiate and market foods with subtle or undetectable quality attributes. The benefits associated with these objectives include lower cost distribution systems, reduced recall expenses, and expanded sales of products with attributes that are difficult to discern (Golan et al., 2004). Not only just a way to improve food safety systems, traceability can also be seen as a strategic tool to improve the quality of raw materials (Galvão, Margeirsson, Garate, Viðarsson & Oetterer, 2010), to improve inventory management and as a source of competitive advantages (Alfaro & Rábade, 2009).

From a consumer perspective, traceability helps to build trust, peace of mind, and increase confidence in the food system. For the growers, traceability is part of an overall cost-effective quality management system that can also assist in continuous improvement and minimization of the impact of safety hazards. It also facilitates in the rapid and effective recall of products, and the determination and settlement of liabilities (Opara, 2003).

The control of food-related risks involves consideration of every step in the chain, from raw material to food consumption as hazards can enter at any point in the chain until the food reaches the consumer. Therefore, a good traceability management system allows for trace-back and trace-forward capabilities to any step in the supply chain, for the effective identification of products and management of recall when quality and safety standards are breached (Opara, 2003). This end to end supply chain approach has been defined in many terms such as "Seed to Shelf (Morris & Young, 2000)”, “Field to Plate (Opara & Mazaud, 2001)”, “Farm to Plate (Mousavi, Sarhadi, Lenk, & Fawcett, 2002)”, “Farm to Fork (Opara, 2003; Ruiz-Garcia, Steinberger, & Rothmund, 2010)” and “Farm to Table (FAO, 2003; Raspor, 2008) “ etc.

There is a number of motivating factors or drivers for traceability in the food supply chain. These drivers enforce traceability as a tool to answer the questions of “who (i.e., actor/product), what (i.e., actor/product’s information), when (i.e., time), where (i.e., location) and why (i.e. cause/reasons)” with regard to food safety, quality and visibility (Fig. 1).

3. Safety and quality, concerns for food industry

Food quality, including safety, is a major concern facing the food industry today. The production and consumption of food is central

<table>
<thead>
<tr>
<th>Define in</th>
<th>Traceability?</th>
<th>Trace what</th>
<th>Trace how</th>
<th>Trace where</th>
<th>Trace why</th>
<th>Trace when</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 8402</td>
<td>Ability to trace</td>
<td>An entity (origin/history/location)</td>
<td>By means of recorded identification</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>ISO 9000</td>
<td>Ability to trace</td>
<td>An entity under consideration (origin/history/location)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>EU Regulation (178/2002)</td>
<td>The ability to trace and follow</td>
<td>A food or ingredients of food</td>
<td>All stages of supply chain</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>CAC</td>
<td>The ability to follow information necessary about a product</td>
<td>A food (i.e. Agri-food)</td>
<td>From the grower to the consumer's plate</td>
<td>–</td>
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<td>–</td>
</tr>
<tr>
<td>Wilson and Clarke (1998)</td>
<td>The ability to access any records about products</td>
<td>Animal or animal products</td>
<td>From farm to retailer</td>
<td>–</td>
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</tr>
<tr>
<td>Dalvit et al. (2007).</td>
<td>A system able to maintain</td>
<td>Entire life cycle of food</td>
<td>–</td>
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<tr>
<td>McKean (2001)</td>
<td>The ability to access any or all information</td>
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<tr>
<td>Olsen and Borit (2013)</td>
<td>The ability to access any or all information</td>
<td>–</td>
<td>Entire life cycle of food</td>
<td>–</td>
<td>–</td>
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</tr>
<tr>
<td>Bosona and Gebresenbet (2013)</td>
<td>Part of logistics management that capture, store, and transmit adequate information</td>
<td>A food, feed, food-producing animal or substance</td>
<td>At all stages in the food supply chain, traced upward, and tracked downward</td>
<td>For safety and quality control</td>
<td>At any time required.</td>
<td>–</td>
</tr>
</tbody>
</table>
to any society and has a wide range of social, economic and in many cases environmental consequences.

3.1. Social

Food safety is an increasingly important public health issue. Outbreaks of foodborne illness can damage trade and tourism, and lead to a loss of earnings, unemployment and litigation (CAC, 2003). Globally, the incidence of foodborne diseases is increasing and international food trade is disrupted by frequent disputes over food safety and quality requirements (FAO, 2003). Unsafe food causes many acute and life-long diseases, ranging from diarrhoeal diseases to various forms of cancer.

The World Health Organization (WHO, 2002) estimated that foodborne and waterborne diarrhoeal diseases taken together kill about 2.2 million people annually, 1.9 million of them children. In industrialized countries, the percentage of the population suffering from foodborne diseases each year has been reported to be up to 30%. In the United States (US), for example, around 76 million cases of foodborne diseases, resulting in 325,000 hospitalizations and 5000 deaths, are estimated to occur each year. The high prevalence of diarrhoeal diseases in many developing countries highlights many acute and life-long diseases, ranging from diarrhoeal diseases to various forms of cancer.

The Waste Resources and Action Programme (WRAP, 2008) estimated that about 300 million tonnes of produce are wasted annually through deficient refrigeration worldwide. In the US, the food industry annually discards USD 35 billion worth of spoiled goods. The wastage of food and resources used for growing unused products are also a big issue for the environment (Flores & Tanner, 2008).

3.2. Economic

The WHO (2002) stated that foodborne diseases not only significantly affect people’s health and well-being, but they also have economic consequences for individuals, families, communities, businesses and countries. These diseases impose a substantial burden on health-care systems and markedly reduce economic productivity. There is only limited data on the economic consequences of food contamination and foodborne disease. In 1995, studies in the US reported that the annual cost of the 3.3–12 million cases of foodborne illness caused by seven pathogens was approximately USD $6.5–35 billion. Recently, former U.S. Food and Drug Administration (FDA) economist Robert L. Scharff estimated the total economic impact of foodborne illness across the nation to be a combined $152 billion annually (Scharff, 2010, pp. 1–28).

The U.S. Department of Agriculture (USDA) estimates the cost of illness associated with medical expenses and losses in productivity from five major types of foodborne illnesses at $ 6.9 billion annually (Vogt, 2005). In the European Union, annual costs levelled on the health care system as a consequence of salmonella infections are estimated to be around 3 billion euros (Asian Productivity Organisation, 2009). The medical costs and the value of the lives lost during just five foodborne outbreaks in England and Wales in 1996 were estimated at UK£ 300–700 million. The cost of the estimated 11,500 daily cases of food poisoning in Australia was calculated at AUS 2.6 billion annually. The increased incidence of foodborne disease due to microbiological hazards is the result of a multiplicity of factors, all associated with our fast-changing world (WHO, 2002).

3.3. Environmental

With the growth of international food trade, the environmental impact of the food supply chain has become a growing concern. The distance that food travels from the farm where it is produced to the kitchen in which it is consumed is longer than ever before. Therefore, the use of energy, resources and the emission of Green House Gases (GHG) in the entire food cycle, including production, consumption, and transportation is unavoidable. The initiatives to use carbon labelling (i.e., carbon footprints of the products) and conception of food miles (the distance that food is transported as it travels from producer to consumer) indicate that the food chain needs more environmentally friendly solutions to reduce the environmental impacts such as pollution and global warming.

In many countries, one of the problems concerning food safety and quality is food spoilage. Food spoilage is wasteful, costly and can adversely affect trade and consumer confidence. Naturally, all foods have a limited life time and most foods are perishable. Safe and high quality chilled foods require minimal contamination during manufacture, rapid chilling and temperature control along the chain (Martin & Ronan, 2000, pp. 5–33). Temperature abuse in the cold chain can make microbial growth and spoilage of food and are factors in causing foodborne illness. The International Institute of Refrigeration (IIIR) indicates that about 300 million tonnes of produce are wasted annually through deficient refrigeration worldwide. In the US, the food industry annually discards USD 35 billion worth of spoiled goods. The wastage of food and resources used for growing unused products are also a big issue for the environment (Flores & Tanner, 2008).

UK households waste 6.7 million tonnes of food every year. The Waste Resources and Action Programme (WRAP) estimates that a third of the food bought is thrown out. If that food waste was eradicated, it would be equivalent to taking one in five cars off the road. Every tonne of food waste is responsible for 4.5 tonnes of carbon dioxide. The food waste which are thrown as landfill where it is liable to create methane, a powerful greenhouse gas which is over 20 times more potent than carbon dioxide make a significant environmental impact (WRAP, 2008). Research by the Australia Institute indicates that Australians throw away about $5.2 billion worth of food every year. Wasting food also wastes the water that went into its production (Baker, Fear, & Denniss, 2009).

4. Requirements of traceability regarding safety and quality

Currently, to build customer confidence and to achieve safety and quality, participants in food supply rely on two methodologies. One manages food supply chains via regulations/standards or certifications. The second records logistics operations and production processes via a food traceability system that provides transparent trace back and track forward information (Hong et al., 2011).
4.1. Regulations and standards for traceability

Because of globalization in food trade, effective food control systems are essential to protect the health and safety of consumers. The foremost responsibility of food control is to enforce the food law(s) protecting the consumer against unsafe, impure and fraudulently presented food (FAO & WHO, 2003). The global concern for food safety and quality; and the need for traceability are being addressed by the development of legislation, new international standards and industry guidelines (Petersen, 2004). Two principal players leading legislative efforts to require traceability of foods are the EU and US.

In Europe, EU directive 178/2002 went into effect on 1 January 2005 and requires mandatory traceability for all food and feed products sold within European Union countries (Folinias, Manikas, & Manos, 2006). The directive enforces strict legislation on labelling systems for food products. In the US, the Bioterrorism Act of 2002 mentioned the person who manufactures, processes, packs, transports, distributes, receives, holds, or imports food has the responsibility to establish and maintain records. It also allows the FDA to inspect those records if there is a reasonable belief that an article of food presents a serious health threat (Levinson, 2009). The FDA’s Food Safety Modernization Act (FSMA), which became law on January 4, 2011, requires registered food facilities to evaluate the food safety hazards that could affect the food and feed they manufacture, process, pack, or hold and to identify and implement preventive controls to address those hazards. This is to ensure the safety of both imported and domestic food supply by focusing on preventing contamination rather than responding to contamination (FDA, 2011).

Other organizations such as the CAC established by the FAO and WHO; and the International Standardization Organization (ISO) play an important role in the development of international standards and industry guidelines for food traceability (Petersen, 2004). In 1993, The CAC recommended Hazard Analysis Critical Control Point (HACCP) as the most effective system to maintain the assurance of a safe food supply (Reulens et al., 2005). Traditional food control procedures such as Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) are accepted as prerequisites or the foundation for HACCP in an overall food safety management programme (Huss, Ababouch, & Gram, 2004, pp. 10–11). In 2003, the Codex Alimentarius standard was published to serve as a guideline for food safety and to support balanced trade relationships in food. Codex standard issues range from specific raw and processed materials characteristics; to food hygiene, pesticides residues, contaminants and labelling; to analysis and sampling methods (Trienekens & Zuurbier, 2008).

ISO is the world’s largest developer and publisher of international standards. ISO standards are used in order to achieve uniformity and to prevent technical barriers to trade throughout the world. The most used of all ISO standards is the ISO 9000 series for Quality Management Systems (QMS) in production environments which are independent of any specific industry. The 2000 version ISO 9001 (2000) addressed the standard model for quality management and quality assurance but did not address food safety. The requirement for food safety and traceability is added in the new ISO standards with more focus on traceability. ISO 22000 (2005) specified requirements for a food safety management system where an organization in the food chain needs to demonstrate its ability to control food safety hazards in order to ensure that food is safe at the time of human consumption. This standard includes analysing methods of food hazards from HACCP and the approach of the management system from ISO 9001 (PMBC, 2008). Furthermore, ISO 22005 (2007) defined the principles and objectives of traceability and also specified the basic requirements for the design and implementation of a feed and food traceability system. It can be applied by an organization operating at any step in the feed and food chain.

The important approach, “one-step-up-one-step-down” traceability enables actors in the food chain to identify the immediate supplier of a product as well as immediate subsequent recipient. This approach is the basic requirements for the design and implementation of a feed and food traceability system which is mentioned in EU regulation, ISO/DIS 22005 and the Bioterrorism Act 2002 of US (Ruiz-Garcia et al., 2010).

Traceability can only be achieved successfully if it is built upon global standards that enable interoperability between traceability systems across the whole supply chain. The GS1 global traceability standard is a voluntary business process standard describing the traceability process independently from the choice of enabling technologies. It meets the core legislative and business need to cost-effectively trace back and track forward at any point along the whole length of the supply chain. Because of its ability to provide globally unique identification of trade items, assets, logistic units, parties and locations, the GS1 system is particularly well suited to be used for traceability purposes (GS1, 2009). EPCglobal Inc., a subsidiary of GS1 supports the global adoption of Electronic Product Code (EPC) Information Services (EPCIS) which is a standard designed to enable EPC related data sharing within and across enterprises (EPCglobal, 2009).

Moreover, there are other private food quality and safety standards such as Eurep-GAP, International Standard for Auditing Food Suppliers (IFS), the British Retail Consortium (BRC) and Safe Quality Food (SQF) etc. Fig. 2 below shows the scope of vertical and horizontal private industry and trade standards in the food supply chain.

4.2. Food safety versus food quality

Food safety and food quality are two important terms which describe aspects of food products and the reputations of the processors who produce food. The CAC (2003) defines food safety as an assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Food safety refers to all hazards, whether chronic or acute, that may make food injurious to the health of the consumer. It is not negotiable and a global issue affecting billions of people who suffer from diseases caused by contaminated food. Both developed and developing countries share concerns over food safety as international food trade and cross-border movements of people and live animals increase (Asian Productivity Organisation, 2009). In industries such as telecommunications, software development and airlines, security is the principal driver for traceability in contrast to the food industry where the safety is a really important issue (Opara, 2003).

Food safety hazards may occur at a variety of points in the food chain. Therefore, food safety is a responsibility that is shared by producers, processors, distributors, retailers, and consumers. An important preventative approach that may be applied at all stages in the food chain involves the HACCP system (FAO & WHO, 2003). The traceability of food products and the ability of food facilities to provide information about their sources, recipients, and transporters are essential to ensure the safety of food supply (Levinson, 2009).

Quality is defined by ISO as “the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs” (Van Reeuwijk, 1998). Also, quality can be defined as “conformance to requirement”, “fitness for use” or, more appropriately for foodstuffs, “fitness for consumption”. Thus, quality can be described as the requirements necessary to satisfy the needs and expectations of the consumer (Ho, 1994; Peri, 2006). However, food quality is very general, implying many expectations which can be different from consumer to consumer. Quality includes attributes that influence a product’s value to the consumer. Quality does not
refer solely to the properties of the food itself, but also to the ways in which those properties have been achieved (Morris & Young, 2000). The classes of quality attributes are listed in Table 2.

Many experts have argued that safety is the most important component of quality since a lack of safety can result in serious injury and even death for the consumer. Safety differs from many other quality attributes since it is a quality attribute that is difficult to observe. A product can appear to be of high quality (i.e. well coloured, appetizing and flavourful, etc.), but it can be unsafe because it might be contaminated with undetected pathogenic organisms, toxic chemicals, or physical hazards (UN, 2007). Rohr, Luddecke, Drusch, Muller, and Alvensleben (2005), Grunert (2005) and Pinto et al. (2006) agreed that food safety has become an important food quality attribute.

Defects and improper food quality may result in consumer rejection and lower sales, while food safety hazards may be hidden and go undetected until the product has been consumed. If detected, serious food safety hazards may result in market access exclusion and major economic loss and costs. Since food safety hazards directly affect public health and economies, achieving proper food safety must always take precedence over achieving high levels of other quality attributes (UN, 2007). These two have obvious links, but food quality is primarily an economical issue decided by the consumer, while food safety is a governmental commitment to ensure that the food supply is safe for consumers and meets regulatory requirements (Sarig, 2003). Quality is seen to lead to taste, health, safety and pleasure. Similarly, safety is seen to be the consequence of control, origin, best before date and quality, while resulting in health and a feeling of calm. Both quality and safety are interrelated and linked to trust/confidence (Rijswijk & Frewer, 2006).

4.3. The link between traceability & quality and safety

Consumer perceptions show an increasing concern about food safety and properties of the food they buy and eat. The information available from labelling conventions does not always translate into more confidence. It has been recognized that there is an increasing need for transparent information on the quality of the entire food chain, supported by modern tracking and tracing methods. Essentially, food quality is associated with a proactive policy and the creation of requirements to maintain a safe food supply (Beulens et al., 2005). Product-tracing systems are essential for food safety and quality control. Traceability systems help firms isolate the source and extent of safety or quality control problems. The more precise the tracing system, the faster a producer can identify and resolve food safety or quality problems (Golan et al., 2004). In themselves, traceability systems neither produce safer/high-quality products nor determine liability. But they act as an element of any supply-management or quality/safety control system so that they can provide information about whether control points in the production or supply chain are operating correctly or not. So early detection and faster response to these problems is possible.

Quality and safety are both linked to traceability whereas safety is implicated by traceability more often. They are two very important elements of people’s conceptions of food and associated decision making (i.e. food choice). Traceability is primarily viewed as a tool for the food safety by providing a means for recall as well as proof for the authenticity of food, but it is also related to food quality. Since both quality and safety were shown to be related to confidence, traceability may indeed boost consumer confidence through quality and safety assessments (Rijswijk & Frewer, 2006). Moe (1998) mentioned that traceability is an essential subsystem of quality management. Thus, a well developed internal traceability system is necessary for quality management. It would efficiently improve data collection, production flow control, and quality assurance.

To foster continuous improvement in the quality of products and processes, firms use Total Quality Management (TQM) system. Ho (1994) stated that ISO 9000 can be seen as a route to implementing TQM. Fig. 3 below shows the relationship of food safety, quality and traceability systems from the management point of view. In addition, a brief summary of requirements to be managed in a food supply chain is shown in Table 3.

### Table 2

<table>
<thead>
<tr>
<th>Classes of food quality attributes (UN, 2007)</th>
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<tbody>
<tr>
<td><strong>External</strong></td>
</tr>
<tr>
<td>Appearance (Sight)</td>
</tr>
<tr>
<td>Odour</td>
</tr>
<tr>
<td>Feel (touch)</td>
</tr>
<tr>
<td>Taste</td>
</tr>
<tr>
<td>Texture</td>
</tr>
<tr>
<td>Defects</td>
</tr>
<tr>
<td>Nutritive Value</td>
</tr>
<tr>
<td>Wholesomeness</td>
</tr>
<tr>
<td>Safety</td>
</tr>
<tr>
<td><strong>Hidden</strong></td>
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Fig. 2. Scope of selected private industry and trade standards (Will & Guenther, 2007).
5. Food contamination and traceability

Foodborne disease outbreaks and incidents, including those arising from natural, accidental, and deliberate contamination of food, have been identified by the World Health Organization (WHO) as major global public health threats of the 21st century (WHO, 2007b). Many outbreaks are the consequence of a failed process, or inappropriate storage conditions (usually temperature abuse) during distribution, food service or by the consumer. The vast majority of these problems have been caused by the unintentional contamination of food but, there is growing concern for the threat of intentional contamination such as bioterrorism. Food contaminants are substances that may be present in certain foodstuffs due to environmental contamination, cultivation practices or production processes. Food may be accidentally or deliberately contaminated by microbiological, chemical or physical hazards. In addition, there are other hazards/factors which cause contamination to food such as Genetically Modified Organisms (GMOs) and radioactive substances.

In the event of food outbreaks and incidents, a traceback investigation is the method used to determine and document the distribution and production chain, and the source(s) of a product that has been implicated in a foodborne illness investigation. Public health agencies conduct traceback activities to determine the source and distribution of the implicated product associated with the outbreak and to subsequently identify potential points where contamination could have occurred. This action helps prevent additional illnesses by providing a foundation for recalls of contaminated food remaining in the marketplace and identifying hazardous practices or violations. A traceback investigation may result in a recall of product (i.e. traceforward), other regulatory actions such as detention of an imported product, an injunction against a processor or grower, informing the public via press releases, closer monitoring of the product in general, domestic and foreign outreach, and “on-the-farm” investigations. Some of the challenges found in fresh produce traceback include the absence of labelling and distribution records, complex distribution systems, and multiple sources of product at the point of service. Another challenge is that traceback investigations are very resource-intensive and may implicate but not confirm the cause of the contamination. These challenges include the fact that the epidemiology of foodborne disease is changing and new pathogens have emerged, some spreading worldwide (Guzewich & Salbary, 2001).

The WHO is promoting the use of all food technologies which may contribute to public health, such as pasteurization, food irradiation and fermentation (WHO, 2007b). Also, the implementation of HACCP system is recommended to prevent food contamination by identifying potentially unsafe links in the food processing chain. The system manages the risk associated with food safety aspects of production (Kumar & Budin, 2006). By having a crisis management program that defines the action to be taken in the event of recall, the impact can be reduced. For food companies, reducing processing batch size and batch mixing is an approach to reduce the cost of recalls, in term of product quantity and media impact. However, it was also found that reducing batch size leads to losses in production efficiency, due to increased production set up times, setup costs, cleaning efforts, etc (Depuy, Botta-Genoulaz, & Guinet, 2005; Saltini & Akkerman, 2012).

Especially, monitoring and surveillance for high-value and high-risk food is important and inspection should be done at the port of entry, the best place to control food safety for imported foods. For preventative purposes, the analyses and interpretation of foodborne disease surveillance data requires an associated and similar approach for data from food monitoring. The most modern and scientific way to perform that is to use the risk assessment process that evaluates potential health risks to humans and animals. The integration of both foodborne disease surveillance and food monitoring could provide the data which are crucial for risk assessment (Schlundt, 2002). Actually, traceability’s strength lies in preventing the incidence of food safety hazards, and reducing the enormity and impact of such incidents by facilitating the identification of product(s) and/or batches affected, specifying what occurred, when and where it occurred in the supply chain, and identifying who is responsible (Opara, 2003).

6. The need for real time traceability

The main fact that differentiates food supply chains from other chains is that there is a continuous change in the quality from the time the raw materials leave the grower to the time the product reaches the consumer (Apaiyah, Hendrix, Meerdink, & Linnemann, 2005). Perishables such as produce, meat, fish, milk and more can change hands many times before reaching the consumer. Keeping food safe and in good quality is a significant challenge as it moves through the

Table 3
Key issues to be managed for a food supply chain traceability.

<table>
<thead>
<tr>
<th>Technical</th>
<th>Internet &amp; Web technologies (online tracking, monitoring, information exchange and retrieval over web etc.)</th>
<th>Location based technologies (e.g., GPS, RS, RTLS etc.)</th>
<th>Sensing technologies (e.g., WSN, TTI, Electronic Nose etc.)</th>
<th>Identification technologies (e.g., Bar code, RFID etc.)</th>
<th>Information and Communication technologies (e.g. Information systems, computers and mobile networks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managerial</td>
<td>Product, time, location and quality traceability, Monitoring, surveillance, recording and control, Inspections</td>
<td>Identify risks and apply safety &amp; quality assurance schemes (i.e., ISO, HACCP, TQM, etc.)</td>
<td>Follow regulations, Standards and Standard Operating Procedures (SOPs)</td>
<td>Routing decisions and recall strategies</td>
<td>Traceability data management (to collect, to keep and to share) Implement coordination among supply chain actors Transparency, authenticity and access of information</td>
</tr>
<tr>
<td>Environmental</td>
<td>Evaluation on carbon footprint of food and labelling</td>
<td>Use of eco-friendly packaging materials and processing methods</td>
<td>Waste and water management</td>
<td>Recycling food and food related materials</td>
<td>Protect odours, pollutants, contamination</td>
</tr>
</tbody>
</table>
frequency identification (RFID) to trace cheese products and to achieve efficient recall on the chain level when necessary and support early warnings in case of a possible emerging problem through a pro-active quality monitoring system to optimize the supply chain. 

7. Traceability in the food industry

The term ‘traceability’ has become so useful in recent times in various industries not only in the food industry but also in software (Lago, Muccini, & Vanvliet, 2009), automotive (Robson, Watanabe, & Numao, 2007; Sohal, 1997) and aerospace industries (Harun, Cheng, & Wibbelmann, 2008). Many researchers proposed frameworks and models in order to deal with the increasing complexity of food chain traceability.

Regattieri et al. (2007) analysed legal and regulatory aspects of food traceability and proposed a general framework based on product identification, data to trace, product routing, and traceability tools for traceability of food products. They presented a traceability system which uses an alphanumeric code and Radio Frequency Identification (RFID) to trace cheese products and to apply possible recall strategies very rapidly. The system also allows customers to access product history of cheese they bought by inputting a code via a web site. For traceability tools, two fundamental points are highlighted, the need for standardization and the cost of the tag. Another RFID based framework is suggested by Shanahan et al. (2009) for beef traceability from farm to slaughter using global standards. The integrated system which applies RFID for the identification of individual cattle, and biometric identifiers (e.g., Retinal Scan) for the verification of cattle’s identity is proposed as a solution to the loss of ear tags, the inaccessibility of traceability records and the fraudulent activities that have occurred in some situations. The framework also mentioned the use of RFID in ISO compliant format (ISO 11784, 2006) which can be converted into an EPC data structure in order to facilitate the use of the EPCGlobal Network (EPCglobal, 2009) for the exchange of traceability data.

Obviously, exchange of traceability data is an important issue to achieve transparency and the smooth transfer of information among the food supply chain actors. Folinas et al. (2006) introduced a framework for the management of traceability data, in fresh, non-processed food products supply chains. The framework was based upon Physical Markup Language (PML), which is a standard technology of Extensible Markup Language (XML), a simple and flexible information exchange format that is well suited to support web-enabled business applications. Furthermore, Thakur and Hurburgh (2009) suggested a framework which uses a relational database management system to record information (i.e., for internal traceability) and XML for the exchange of information (i.e., for chain traceability) between different parties of the grain supply chain. All grain lot information should be recorded in a centralized database system and only relevant lot/batch information should be passed on to the next link in the supply chain.

In the agro-based food chain, Ruiz-Garcia et al. (2010) proposed a model and prototype implementation for tracking and tracing agricultural batch products along the food chain. The proposed model suggests using web-based systems for data processing, storage and transfer which makes a flexible way of information access, networking and usability to achieve full traceability. Alfaro and Rábade (2009) presented a case study of one firm in the Spanish vegetable industry and found that the firm has had significant qualitative and quantitative improvements in supply, warehousing, inventory, Zebra products, after implementing an enhanced traceability system. For the wine logistics chain, Mattoli, Mazzolai, Mondini, Zampolli, and Dario (2010) developed a Flexible Tag Data-logger (FTD) which is attached to the bottles to collect environmental data (light, humidity and temperature) in order to trace the wine bottles that leave the producer cellar for transport to a shop. The history data stored in the FTD can be read by smart phone or Personal Digital Assistant (PDA) with integrated infrared port to evaluate the safety of wine bottles. Another PDA-based record-keeping and decision-support system is suggested for cucumber production traceability to achieve real-time and portable record-keeping in the field for farmers (Li, Qian, Yang, Sun, & Ji, 2010).

For the meat-processing industry, Mousavi et al. (2002) proposed a solution which integrates a material handling system and RFID to track meat products and provide information about them throughout the production process until they become retail packs. Hsu, Chen, and Wang (2008) proposed an RFID-enabled traceability system for the live fish supply chain. A chain consists of aquaculture farms, inspectors, logistic center, and the restaurants. The RFID tag is put on each live fish and it links to all stages of the live fish supply chain. To achieve the safety of live fish and customers’ confidence, the traceability information is designed to be exchanged on a web-based system for farmers and consumers to use. One of the challenges is how to attach the RFID to the live fish. Abad et al. (2009) tried to validate an RFID smart tag (with integrated temperature and relative humidity sensors) developed for real-time traceability and cold chain monitoring of food under the case study of an intercontinental fresh fish logistics chain. The aim is to build an automated system that integrates online traceability data and chill chain condition monitoring.

Recent developments in technology make new features achievable. These include: advanced data handling systems based on RFID and a Wireless Sensor Network (WSN), a location tracking system like Global Positioning System (GPS) and decision support system using intelligent software agents etc. Jedermann, Behrens, Westphal, and Lang (2006) proposed an intelligent container system using a combination of RFID, sensor networks, and software agents to trace fruit transports, demonstrating an effective use of RFID technology in fruit logistics. Zhang, Liu, Mu, Moga, and Zhang (2009) developed a temperature-managed traceability system for frozen and chilled food during storage and transportation. The system integrated RFID with GPS, mobile communication with Time Temperature Tolerance (TTT) theory can automate the tasks, like daily work routines, and cross-
communicate information flow between the manager, the driver, the stakeholders and insecurities about arrival time. Wang, Kwok, and Ip (2010) developed a real-time monitoring and decision support system, with a combination of existing technologies such as RFID, WSN, GPS and rule-based decisions to improve the delivery system for perishable products. Based on the mathematical models, and data from the RFID and sensor network, the quality of the goods can be predicted by the forecast module.

The important area with regard to traceability is food product recall, a growing concern for food companies. Kumar and Budin (2006) presented the prevention and management of product recalls in the processed food industry. Findings from analysis suggested potential reduction of product recalls through recommended preventive measures including the use of the HACCP and RFID systems. Doukidis (2009) reported a work that was undertaken for a company that deals with frozen food regarding the requirements analysis, development and pilot implementation of a RFID-enabled traceability system within the central warehouse. The cost reduction is achieved as a consequence of identifying the number of possible locations that a defective product is located. In summary, an effective traceability system can reduce recall cost since it is possible to have a prospective product recall (for safety), and to identify what caused the problems (Regattieri et al., 2007).

Based on the requirements of traceability in the food chain, a conceptual framework is considered in this paper (Fig. 4). In this framework, all supply chain actors are considered to have internal and external traceability in order to achieve the whole supply chain traceability. The safety and quality regulations enforce all actors to apply safety and quality assurance systems that comply with regulations and to manage all their operations in an efficient and standard manner. For supply chain operation and performance, enabling technologies can be seen as facilitators which serve as a medium for all actors to enable access to food traceability information systems.

8. Technologies applied

Opara (2003) mentioned the need of technologies for product identification, information capture, analysis, storage and transmission, as well as overall system integration. These technologies include hardware (such as measuring equipment, identification tags and labels) and software (information systems). Advances in information and computer technology for information systems management; scanning and other digital technology for product identification, image capture, storage and display; nondestructive testing and biosensors for quality and safety assessment; and geo-spatial technologies (Geographic Information System (GIS), Global Positioning System (GPS), Remote Sensing (RS)) for mobile assets tracking and site-specific operations, are technological innovations that can be applied in a traceability system. Basically, a product traceability system requires the identification of all the physical entities (and locations) from which the product originates, that is to say, where it is processed, packaged, and stocked, including every agent in the supply chain (Regattieri et al., 2007). A summary of the fundamental technical instruments available is shown in Table 4.

Several technologies which complement identification for verification already exist, particularly in the livestock industry, for implementing traceable supply chains. Future innovations in DNA fingerprinting, nanotechnology for miniature-machines, iris scanning, nose-print matching, facial recognition and retinal imaging and their integration into plant and livestock industries have considerable potential for improving the speed and precision of traceability in the food industry (Opara, 2003; Smith, Pendell, Tatum, Belk, & Sofos, 2008). Aarnisalo, Heiskanen, Jaakkola, Landor, and Raaska (2007) mentioned that there is a growing need for the use of real-time sensors for quality and safety assurance in the food industry especially for perishable food products.

In traceability, the traceback investigation for food is found necessary in order to verify counterfeit, authenticity and provenance of food in the event of fraud or commercial disputes. In Europe, food legislation is particularly strict and traceability systems, based on product labelling, have become mandatory in all European countries. In the US, the US Congress mandated Country-of-Origin Labeling (COOL) for many food crops/products as a requirement (Smith et al., 2005). However, the implementation of these systems does not ensure consumers against fraud. Paper documents can be counterfeit so alternative methods for genetic traceability systems based on product identification are needed (Dalvit et al., 2007).

It is found that modern analytical techniques, in particular molecular biology techniques, can determine the plant or animal

![Fig. 4. Conceptual framework of food traceability system.](Image)
species present in a foodstuff. These techniques can be categorized into two types: the physicochemical techniques, which use either the variation of the radioactive isotope content of the product, spectroscopy, pyrolysis or electronic nose, and the biological techniques which use the analysis of total bacterial flora or DNA chips. Using the above techniques will help in differentiating milk produced on a mountain from that produced on the plains, of determining the origin of various cheeses or various wines, or of identifying the geographical origin of other foods like oysters, meats, fish, olive oils, teas or fruit juices (Peres et al., 2007). Indication of origin may only become a signal of enhanced quality if the source-of-origin is associated with higher food safety or quality (Loureiro & Umberger, 2006).

The study on the application of these techniques to improve food traceability can be seen in the TRACE project (2005–2009) which is sponsored by the European Commission. In this project, cost effective analytical methods integrated within sector-specific and generic traceability systems were developed to enable the determination and the objective verification of the origin of food. Mineral water, meat, honey and cereal samples were analysed in order to develop methods for the determination of the origin of food labelled with Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI). To verify the food origin, the applicability of using different methods such as trace elements and isotopes methods, rapid and profiling methods, molecular biology methods and Chemometrics are studied. The project also addressed the issues of European consumer perceptions, attitudes, and expectations regarding food production systems and their ability-to-trace food products, together with consumer attitudes to designated origin products, food authenticity and food fraud (Rijswijk, Frewer, Menozzi, & Päioi, 2008; TRACE, 2009). Also, a joint IAEA/FAO programme proposed the implementation of nuclear techniques such as isotope ratio analysis along with multi-element analysis and other complementary methods, for the verification of food traceability systems and claims related to food origin, production, and authenticity (IAEA, 2011).

The main problem found with all of these techniques is the need for the construction of data banks which are very necessary for them. Therefore, the TRACE project explored a mapping process that reduces the need for commodity specific databases by finding the correlation between the tracers in food and the local environment (i.e. geology and groundwater). TRACE also exploits geological and climatic maps that are available and maintained annually. Under the joint IAEA/FAO project, a database that enables linking with other databases is preferably hosted to facilitate its sustain-ability in the longer term for partners to use in provenance studies.

9. Problems and implementation hurdles in food traceability

The growing importance of food safety and quality in the food industry enforces all actors in the supply chain to adopt traceability from farm to fork although there are some problems to handle regarding traceability. First, the costs associated with putting traceability systems into place are seen as barriers for supply chain actors especially for small-scale producers from less developed countries. However, the benefits gained from traceability for high-risk and high-valued food far outweigh the cost of traceability.

Many developing countries lag in developing and implementing food safety and traceability standards thus limit exports of food products from developing countries, where poor regulation of chemical use, pollutants, and a steep learning curve in traceability capacity restrict growers’ and processors’ participation. One of the biggest challenges with supply chain traceability is the exchange of information in a standardized format between various links in the chain. This information needs to be exchanged in a precise, effective and electronic manner (FSA, 2002; Moe, 1998).

Traceability systems are critically reliant on the recording of information. Robust mechanisms are needed to facilitate the collection and authentication of any information, to enable it to be updated and shared through the chain. Paper is still used as a cheaper option for traceability, although it limits the ability to record data accurately, store it, and query it to identify and trace products. Digital databases for traceability are seen as more expensive to implement, operate, and maintain, requiring investments in hardware and software, skilled human resources, training, and certification (Karippacheril, Rios, & Srivastava, 2011).

Traceability concerns many products in the food industry. Bulk produce is found more challenging to trace than fresh produce.
Products such as grain, coffee, olive oil, rice, and milk from multiple farms are combined in silos and storage tanks, making it difficult to trace them back to their sources (IFT, 2009). A number of proposed frameworks and models for traceability are found in research literature; however, there is no common theoretical framework with respect to implementation of food traceability (Karlsen, Dreyer, Olsen, & Elvevoll, 2013).

Also, there are hurdles to overcome in the implementation of traceability. The hurdles can be seen in two categories: organizational and technological. In supply chain networks, transparency among the supply chain actors is important to exchange data. Each actor is responsible for maintaining and communicating their own product, process and transformation information. There is an ongoing concern to maintain a balance between useful transparency and the confidentiality of information of each entity in the chain (Thakur & Donnelly, 2010). Furthermore, internal traceability systems are a prerequisite to achieve full traceability (Senneset, Foras, & Fremme, 2007).

One of the biggest challenges of food chain traceability is the extensive use of the manual exchange of information between companies. Bechini, Cimino, Lazzarini, Marcelloni, and Tomasi (2005) reported that only a few links in a supply chain are using software for internal traceability in existing traceability systems. The diversity of the systems also makes the integration difficult. Not only the smooth exchange and integration of information but also the aspects of grower’s perception and customers’ willingness in traceability should be better studied. In addition, company motivation is an important factor in creating the conditions for a successful tracing event (Donnelly, Karlsen, & Dreyer, 2011).

The adequate knowledge on diverse characteristics of food is important in the food industry. For example, in the fresh produce industry, the development of traceability systems has been greatly influenced by the characteristics of the product. Perishability and quality variation in fresh fruits and vegetables necessitate proper storage conditions and the identification of quality attributes (Golan et al., 2004). But for the livestock industry, it has a long history of implementing animal identification and traceability systems to control disease and ensure the safety of meat and dairy products. Mixing transformations create challenges for traceability that are more severe than other types of transformations.

From a technological point of view, a DNA-based technique such as DNA barcoding is effective in certifying both origin and quality of raw materials, and to detect adulterations occurring in the industrial food chain. But it relies on the availability of an international platform repository BOLD (Barcode of life database). Also, seeds, fruit, and different plant and animal parts are transformed in food with a definite shape, taste and smell through physical (i.e. heating, boiling, UV radiation) or chemical (i.e. addition of food preservatives, artificial sweeteners) treatments, which could alter DNA structure (Galimberti et al., 2013). These techniques are too expensive to apply in routine tests but they could be a trusted tool for verification of suspected fraud (Dalvit et al., 2007).

Paper-based systems are still widely used for traceability systems in both large and small companies, and even within systems operating across the whole food chain. Implementation of electronic traceability may involve changes both in work processes and software systems. RFID is found as the most cutting edge technology for supply chain integrity and traceability. But the problem is still the high cost of tags used in these systems, even though the prices have decreased significantly in recent years (Aarnisalo et al., 2007). Moreover, it is difficult to achieve 100% readability of RFID tags through metal, glass and liquid (Petersen, 2004). Tight profit margins and inadequate knowledge on potential benefits of traceability systems are reported as some of the main factors that hinder investments on sophisticated traceability schemes (Manos & Mnikas, 2010).

10. Conclusions

Moe (1998) estimated that demand for information along the food chain will increase and it will set higher requirements for well-structured traceability systems. Therefore, traceability will emerge as a new index of quality and a basis for trade in the future. Customer demand for real time information about the products they buy and eat will also grow and it will be one of the competitive advantages of food industry marketing.

The use of mobile phones accelerates the age of ubiquity. The ability to check food safety in the hands of the consumer has become a reality by tagging products with RFID or bar codes that can be read with a mobile phone. Smart phones today could be the future handheld device for traceability because of its portability, mobility, accessibility to Internet and application software support. Consumers can scan the code in the store using a mobile phone camera or embedded mobile RFID reader so they can find out the product history at their finger tips and make purchases for safe and quality foods. They can even offer feedback to the farmer.

In the near future, RFID and sensor based systems will be widely used, not only for tracking the goods but also for monitoring the quality of the products and the supply chain itself. This will enable the detection of the spoilage of food products and enhance the continuity of the food supply chain. Biosensors will most probably be used for various uses such as detection of mycotoxins, bacteriocides, allergens and contaminating microbes (Aarnisalo et al., 2007). The advanced techniques like gas chromatography and electronic noses (i.e., a machine which can detect and discriminate among complex odours using a sensor array) will be increasingly used in the field of food quality management (Peris & Escuder-Gilabert, 2009).

The Internet promises to be an important tool for food traceability. Web based traceability systems will enable traceability chains for products to personal computers and smart phones of consumers based on the access control level of the consumer identification system. This will deliver real-time information to consumers on the quality and safety status of products and also permit speedy recalls when quality and safety standards are breached. The larger trend in the future is the convergence of smart phones with the Internet of Things (i.e. Internet-connected real world objects). Devices such as smart phones essentially become sensors and RFID readers, which allow consumers to interact with real world objects in a much more detailed manner.

To minimize foodborne hazards and incidents, the sustainable agriculture which can produce good crop yields using natural methods to feed the soil and reduce pests (e.g. organic farming) should be maintained in order to balance economic, environmental, and quality of life benefits not only for farmers but also for consumers as well. As a consequence of incidents that have happened in the livestock food industry (e.g. BSE, FMD, Bird flu and Swine flu etc.), monitoring and inspection of feeding diet and health of animals will become a mandatory task to do as human and animals share one health and the cost of impact on the food industry and consumer confidence is intangible. As since the environmental concerns in the food supply chain grow, to design and implement an eco-friendly supply chain will be a new challenge.

Most of the previous research is found to focus on traceability until the retail point of the food chain thereby missing to trace the consumer part of the food chain. In terms of food safety, the consumer segment is also important therefore traceability should be extended to consumers. It is clear that traceability comes at a cost.
But the costs of not having it or having inefficient systems in place may be severe both for governments, consumers, individual companies and the food industry as a whole. In conclusion, food traceability from “farm to fork” is going to become a reality if market forces, consumer demand and government regulations all are converging to push a new level of supply chain visibility.

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