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Emerging Trends in Traceability Techniques in Food Systems

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1. Introduction

In the entire food supply chain, the major concern of consumers is increasingly focused on safety levels and transparency. At the same time, trade of food is rapidly getting internationalized by food industries. The production, distribution and trade of food products have greatly been influenced during the past decade due to consumer and industrial concerns (Donnelly et al. 2013). Public sectors and concerned policy makers revise the regulations for food safety in response to these changes, based on the resources provided by international regulatory bodies such as World Organization for Animal Health and *Codex Alimentarius* (Trienekens and Zuurbier 2008). In this scenario, traceability is an important tool, because the traceability practices differ among the countries. This can be elaborated by the following example, the trade, production and distribution of food products in Europe need to comply with the "European General Food Law" (European Commission 2002). European General Food Law defines the 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

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food or feed, through all stages of production and distribution", however this law does not specify the methods for keeping and validating the records (Canavari et al. 2010). This fact offers a business opportunity to tailor the methods of traceability based on demands and resources that leads to the development of multiple traceability guidelines and standards (Karlsen et al. 2013). The nature of traceability is determined by food business in practice, particular stage in supply chain and applicable legislation based on the origin (ECR Europe 2004). In an organization dimensions of traceability can be summarized in three steps. First, precision that presents the bulk of a traceable batch that is a unique identity ranging from a single product to whole a batch or lot. This step is named as granularity and serves as a key to traceability (Golan et al. 2004, Karlsen et al. 2013).

The collected information that is linked with the product lot or batch is referred as breadth and is the second dimension in the traceability. Depth is the third dimension that determines how regularly the system traces the information upstream and downstream in a food supply chain.

A detailed level of traceability is not confined to a single firm, but the effective tracking and tracing techniques in a food supply chain relies on the mutual consensus among the group of industries. The lack of transparency at any stage affects the whole food supply chain management system. The automation in data collection and record management elevates the precision level and consistency of identification of the individual product or lot to be traced at any stage of the food supply chain. The devices and technologies are continuously improved to depict the actual traceability. Optical systems (bar code, data matrix, quick response QR code) and radio frequency identification devices (RFID) have been implemented in various food supply chain systems (Costa et al. 2013).

The majority of traceability systems that are currently in practice lack the ability to connect food chain records, inaccuracy and errors in records, resulting in delaying the acquisition of required data, particularly in food-borne disease outbreaks. The recall and withdrawal information of non-consumable products should be addressed by these traceability techniques. The latest traceability techniques such as advanced RFID and DNA sequence analysis raise consumer satisfaction by presenting the actual traceability concepts (Badia-Melis et al. 2015).

2. Framework and Issues Concerning the Implementation of Traceability

The level of traceability capacity, either optimal or adequate, depends on the facilities, objectives and resources of the food processing firm and is mainly associated with cost and benefits (Golan et al. 2003). There might be a deviation from expected cost and benefit analysis in case of uncertainties for implementation of actual traceability capacity. Actual traceability can only be achieved by linking internal and external traceability (Fig. 1).

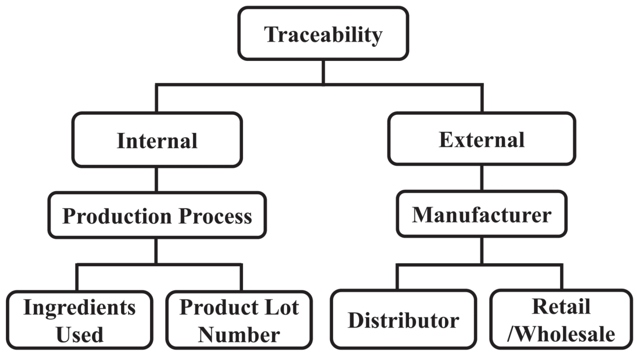

Figure 1. Internal and External Traceability Linked Approach Towards Actual Traceability.

2.1 Bulk products traceability

Various food industries use raw ingredients to formulate the product such as liquids (juices and oils), powders (coffee, dried milk, salt and sugar) or grains that are stored in large storage tanks that are rarely emptied for fresh lots, so that many lots are contemporaneously kept in same storage tanks. In case of liquid food products processing, cleaning between two lots (even the same product) is of prime importance to differentiate between product batches (Cocucci et al. 2002). The cleaning between the batches ensures cleaning and hygienic standards and is the only way to guarantee that different batches cannot contaminate each other. These cleaning processes present cost elevation for industries and are undesirable under certain conditions such as continuous batch production systems. In continuous batch processing of bulk products any interruption for cleaning would result in extra cost and delay in manufacturing (Skoglund and Dejmek 2007). However, RFID (Radio-frequency identification) markers have been developed for online traceability of continuous flows (Kvarnström and Oghazi 2008). The pills-based food grade tracer for processing units dealing with grains by introducing pill sized food grade tracer labeled with edible materials, such as cellulose or sugar particles are proposed to be put into use in grain harvesting (Lee et al. 2010, Liang et al. 2012 and 2013).

The problems concerning the fluid product traceability in case of continuous batch processing were addressed by a dynamic simulation model to elaborate the issues arising from the leftover portions of lots between different batches (Skoglund and Dejmek 2007). The concept of fuzzy traceability arises from the products developed from subsequent mixing of two different lots. The problem can be addressed by considering "composition distance" that measures the differences of products based on the contents of each supply lot. The product can be considered homogeneous (from a single lot) if the composition distance is within defined limits. This concept correlates with the regulations for the traceability of genetically modified (GM) products (European Commission 2003), that defines, the product can be labelled as GM-free if GM content is less than 0.9%.

2.2 Preservation of quality and identity to ensure traceability capacity

The recent advancements in the development of active RFID tags help in the improvement of the food supply chain system with interesting and novel solutions. These RFID tags are encoded with specific sensors (for example, temperature and humidity) for identifying the specific data along with product identification code. This advancement in the traceability system ensures the availability of automated information about product identity and related data (history, storage, etc.), hence providing the complete description of the current status of the food supply chain. This application leads to a dynamic approach to overcome the "fixed life hypothesis" of perishable items by providing real time measured data of the product (Fig. 2).

The data obtained from this traceability system can be utilized to maintain the lot size and the routing of fresh-food supplies by determining the remaining shelf life. Li et al. (2006) have recommended the dynamic planning method for reducing the loss of the product. This method is based on the linear-in-temperature approximation of the food product

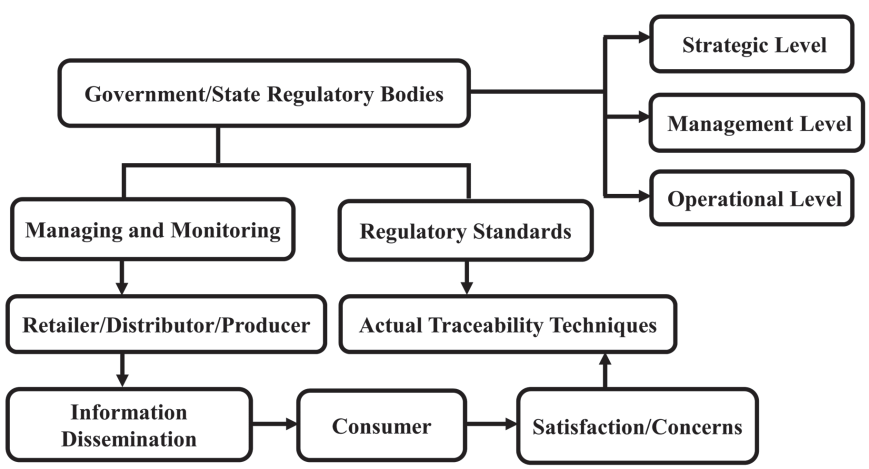

Figure 2. Conceptual Model for Information Dissemination to Achieve Consumer Satisfaction.

deterioration in which temperatures are recorded by the RFID that allows the traceability system to track the product along with its time history. Similarly, an automated traceability system has been established and validated by Abad et al. (2009) which incorporates the online traceability data and monitored cold chain conditions for application to an intercontinental fresh fish logistics chain.

Traceability along with other quality parameters like physical, chemical, microbiological, bio-molecular and organoleptic analysis can be used to achieve the product information of each lot (Fig. 3). Therefore, quality attributes should also be considered while assigning and managing the lot that will allow in variation of price based on quality characteristics (Jang and Olson 2010).

Nature of the product is another parameter that has to be taken into account in the supply chain. So, the design cannot be executed in the supply chain without considering the perishability and variability in different stages of the chain for the fresh food products (Dabbene et al. 2008a, 2008b). During the sizing and preparation of a lot, the quality and residual shelf life should be considered as they are continuously varying. This dynamic nature of the product quality should be embedded in a logistics optimization framework (Rong et al. 2011).

For facilitating the differentiation of product, a concept of identity preservation (IP) has been introduced. IP can preserve the particular traits and/or attributes and enhance the economic value to the product (Bennet 2009). There are some process or credence attributes that contribute to the product value for the consumer/buyer but are tough to be recognized and detected by them for example GMO, halal, country of origin, microbial and allergen contamination, "free-range" livestock, animal welfare, dolphin free, low carbon footprint, etc.

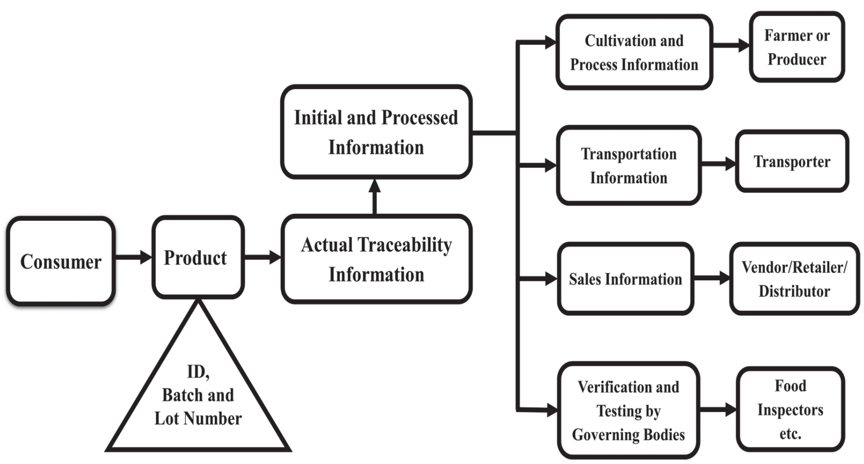

Figure 3. Actual Traceability Model with Stage Specific Essential Information.

These attributes may or may not affect the quality parameters of the product, but they are related with the enhancement of product value as perceived by the consumer (Niederhauser et al. 2008). These attributes should be guaranteed by the producers through the certification along the whole supply chain. The cost analysis and benefits from IP at supply chain level are evaluated by constructing models (Desquilbet and Bullock 2009).

Identity preservation (IP) technique is used to differentiate the genetically modified maize and soybeans varieties (*Bacillus thuringiensis* (BT) maize or Roundup-ready soybean) from that of non-genetically modified (Sobolevsky et al. 2005). Spatial is based on separation of grains in different driers and silos whereas temporal does time scheduling of the grain collection and utilization of the facilities (Coléno 2008). IP can also be implemented for separating different product lots according to their specific traits or known compositions of the ingredients in the mixture for enhancing the properties of the resulting mix. Some of the related cases are balancing protein content in flour, acidity and ethanol content in wine, quantity of lysine, oil, amylose, and extractable starch in maize (Wilson and Dahl 2008).

2.3 Prevention of fraud and anti-counterfeit concerns in the traceability system

There is an increasing trend in the cases of fraud and cheating in the field of food mostly on high value products like wine, ham, cheese, extra virgin oil, etc. These types of activities cause economic loss, unhealthy competition and negative impact on brand reputation. In such cases, a traceability system can be used to avoid and eliminate illegal, unreported and unregulated (IUU) food productions. As the traceability system can trace the history and location of the particular food entity with the help of recorded data and unique identity, it can help in preventing the fraud in food supply chain.

The tracking, tracing and identification of the product through the supply chain can be done to prevent fraud and counterfeiting by both overt and covert technologies (Li 2013, Sun et al. 2014). The data from machine-readable devices such as QR codes, barcodes, datamatrix, etc. permit the enhanced number of checks and also let the data be shared on secured networks. RFID system is one of the most reliable methods in "actual traceability system" due to unique features like automation, object tracking method and non-line-of sight identification. The authentication in RFID can be accomplished by three different ways.

2.3.1 Centralized database checking

Here the authentication of online product in real-time is done by a plausibility check of the unique identity code that is performed over internet. Although this method has higher efficiency but back-end database maintaining cost is expensive and it is tough to keep privacy levels.

2.3.2 Offline object authentication

This system is based on the encrypted tags and cryptographic algorithms carry out the authentication. For few cases, memory cards are also used to store the product information and are transported along with the entity so that the information can be retrieved on-site. Currently this type of system is being used in meat supply chains where weight-by-mass-balance control is accomplished through intelligent selling scales that will release sales receipts along with traceability information only when the carcass weight is reached to desirable value.

2.3.3 Track and trace

Track and trace method is a recent one and has more advantages for authentication of product. For any suspicious activity in the supply chain, the monitoring actions can be increased and extended so that anti-counterfeit system based on the traceability could be shared with different partners along with the customers. Jie et al. (2012) introduced this approach to Chinese authorities to utilize such a system for wine and suggested it for application to other food commodities. Similarly, Borit and Olsen (2012), proposed a traceability system for the prevention of IUU (Illegal, Unreported, and Unregulated) fishing in the supply chain of Nordic fish. While handling any anti-counterfeit case, the information used are mostly collected during the food supply chain. So, the tracking and tracing of anti-counterfeit systems will reduce the cost of methods for protection of fake and fraud activities without losing competitiveness.

3. Trends and Perspectives for Actual Traceability

For the optimized traceability system, there is a need for formulating models based on both operational and financial point of view that will help in evaluation and comparison of procedures in an integrated framework. During the optimization process, the financial gap between the investment cost for establishing and implementation of a traceability system, and the savings from the product recall should be taken into account while designing a strategic operational plan (Wang et al. 2009). Therefore, these different components of cost should be highly considered while developing optimization model so that the solution obtained will be optimal for all the cases. According to Regulation (EC) No. 178/2002 proposed by the European Commission, the main principle of traceability is based on "one-step-back-one-step-forward traceability" in which every actor in the supply chain only handles the information or data that is coming from his supplier and sent to his customer (European Commission 2002). However, to make the traceability system more effective and efficient, it should be considered and implemented at the whole supply chain level. Several companies face problems at the supply chain level in sharing of the data/information due to the lack of widely accepted standards. Maximum benefit from the system can be attained by involving all the stakeholders and by improving traceability in the entire supply chain. Similarly, data exchange can be made faster and efficient by building an inter-organizational communication and information sharing system between all the organizations across the food supply chain (Anica-Popa 2012, Karlsen and Olsen 2011). This will result in:

- the time reduction for identifying all the activities and the food processors that are involved in the food supply chain,
- the identification and elimination of potential critical points of the traceability system, and
- the implementation of more sophisticated management rules that consider the detail history and information of food product.

Extension of optimal lot size and integration of the policies from production to distribution section help in achieving these benefits. This integrated approach of combining production and distribution is a new and promising way that not only characterizes the traceability but also modern management strategies in the food production system (Amorim et al. 2012) (Fig. 4).

Practically, the quality assurance manager of the company conducts the risk analysis and determines the corresponding risk exposure. Risk may come from raw material or during processing steps. The risk exposure in raw materials can be assessed on the basis of the trust worthiness of the ingredient supplier and the possible criticality of the material. Some of the researches that are associated with the risk analysis and risk exposure are stated further. Cassin et al. (1998) developed the process risk model for the quantitative risk assessment for *E. coli* O175:H7 in beef hamburgers. Same model was also revealed by Resende-Filho and Buhr (2010) for estimating the probability of recall in a hamburger supply chain due to *E. coli* O157:H7 contamination of ground meat. The effects of both the traceability system and probable intervention on the quality control system for reduction in the costs of recall were also revealed. A risk rating parameter was proposed by Wang et al. (2009) that accounts for the probability of product recall, which is estimated on the basis of hazard analysis and critical control point (HACCP)-inspired criteria. Similarly, Tamayo et al. (2009) recommended to measure the criticality of product for projecting its current state of risk. Three different parameters: dispersion rate, trust worthiness of supplier and the residual shelf life of product are used for calculating this index.

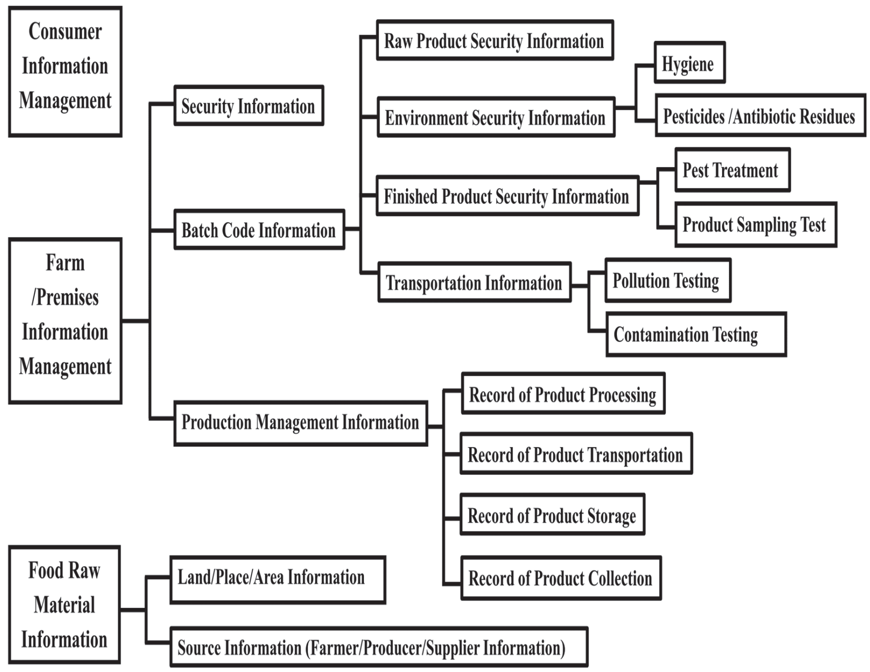

Figure 4. Critical Product Information for Strategic Planning to Maintain Actual Traceability.

Another point that needs to be discussed is the expected nature of the information/data obtained from a traceability system. It is always expected that the information from a traceability system is exact and correct. But in reality, most of the processes in the supply chain are affected by underlying stochastic phenomena that result in deviation from the exact information (Riden and Bollen 2007). The better performance can only be achieved by reducing the absolute certainty constraint and admitting tolerances expressed in probabilistic terms. This will provide a small tolerance (very fine) to the composition of an output lot. Hence, this will follow the same direction as the tolerance-based definition of GM and non-GM products as stated in EC Regulation 1829/2003 (European Commission 2003).

Till now most of the traceability optimization has been carried out as being considered static framework but it is necessary to understand that the production is a dynamic system with continuous change with time. Generally, production is always considered for a fixed time interval (hours, days or weeks) and the batch analysis determines the route of the product. Similar concept was adapted during batch processing of meat for sausage production with different compositions (Dupuy et al. 2005) and productions of cheese (Barge et al. 2014). In both cases, the production manager is the one who plans for daily production and can decide the route of the food supply chain in advance. Nevertheless this may not be applicable in all the cases. In some production lines, there may be continuous introduction of a new ingredient at a specific time after each batch. So each batch must be distinguished appropriately in order to have a better traceability system. In the supply chain, the quantity of products that can be traced at any point and at any time is influenced by the production rate, shelf life and consumption rate of the product. Hence, these variable times should be considered for establishing an optimization and planning framework. The main aim is to track the changes involved in the production line, update and adjust the planning strategies according to the alterations.

In many cases, after getting the initial signal of potential risk in the supply chain, even the modern industries with the best traceability systems are not fully ready to immediately start the recall process and trace back the product. Therefore, the concept of rapidity has been presented by Mgonja et al. (2013) that can assess the speed of a traceability system in response to the primary information of traded injured products. The recalling time should be as minimum as possible because the rise in recall time may increase the possibility of more product injuries/defects. The consumer will also assume it as negligence by the company. However, it cannot be denied that some time is required for the process of product recall. Thus, the relation between the speed of the recalling process and the measure of the product dispersion is also considered as a function of time. Faster the removal of defected product from the production chain, lesser will be the dispersion.

4. Technological Advancements for Traceability Techniques

Any risk associated with the food in the supply chain should be handled seriously due to consciousness among the consumers. Food traceability has become an integral part of the supply chain for controlling the injured products. With globalization, traditional traceability techniques are not adequate and advancements in these methods are desirable for effective an traceability system. Some of the recent technological advancements in the actual traceability techniques are discussed. Figure 5 illustrates the overall strategies of the traceability techniques in food supply chain systems.

4.1 Radio-frequency identification (RFID)

RFID is the wireless traceability technology in which radio waves are used for collecting the data/information that are stored in an electronic tag connected to the product in the supply chain. RFID has been a promising tool for monitoring traceability in food supply chains for more than a decade and its application is becoming more popular day by day (Costa et al. 2013). As compared to the traditional traceability system (barcodes), RFID provides

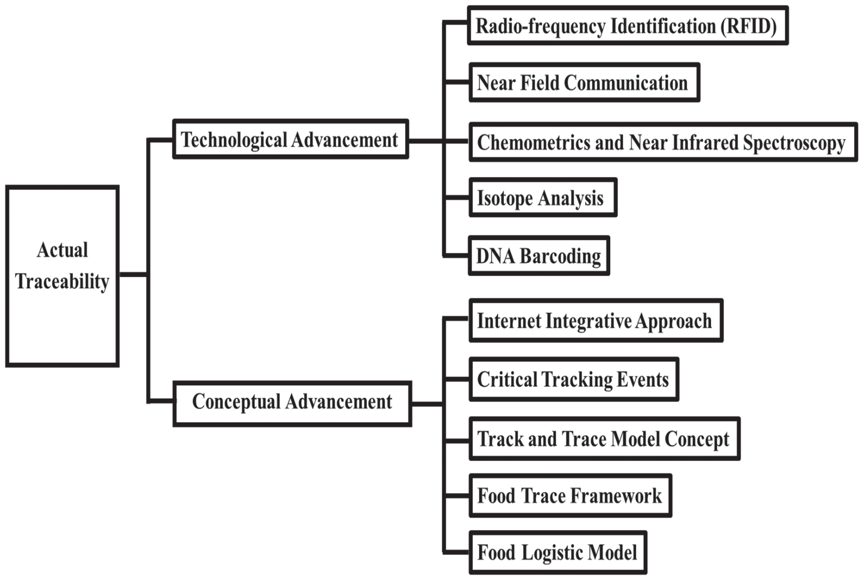

Figure 5. Technological and Conceptual Advancements in Actual Traceability Practice.

higher reading rate, therefore, it is one of the most efficient and reliable methods for food traceability systems (Hong et al. 2011). RFID technology can track and identify the product without any physical connection and offers effective sharing of the information with efficient customization and handling (Zhang and Li 2012).

In the food traceability system, the application of RFID technology is extensive for various purposes due to the recent innovations in its technology and integration of vital tools like sensors and data loggers (Ruiz-Garcia and Lunadei 2011). A framework was developed by Kelepouris et al. (2007) using RFID for comparison of this system with conventional lot sizing and the information collecting method. They have mentioned that RFID possess benefits over traditional system like low investment cost, easy information gathering, automatic identification of the product and identical electronic product code (EPC) for all the participating organizations. RFID traceability system have been used for long time in numerous agro-food logistics and supply chain management processes which is also stated by several authors (Attaran 2007, Ngai et al. 2007, Sugahara 2008).

A RFID system was developed for tracing the temperature for combating the logistics related to feeding by Amador and Emond (2010). A concept of cold traceability was put forward to track the set of products that are temperature sensitive using the different sensors during the transportation in different atmospheric conditions (Ruiz-Garcia et al. 2010). Qian et al. (2012) established a Wheat Flour Milling Traceability System (WFMTS) in

China which is the combination of RFID and 2D barcode technology for validating the wheat flour mill system. In this system, the small packages of wheat flour were identified by the QR Code labels and tags from RFID were used for identifying wheat flour bins and for automatic recording of all the logistics data. The cost analysis indicated that there is an increase in the total cost of the system by 17.2% but in return it is giving 32.5% more sales income. Therefore, this WFMTS has higher scope to be used in both medium and large wheatmill industries for traceability of product. Similarly, a cattle/beef traceability system has been designed and tested for the application and management of traceability in the production line. This system has combined RFID technology along with bar code printer and personal digital assistant (PDA) to achieve the acquisition and transmission of real-time and accurate data. And the result indicated that the efficiency of the traceability system was improved in the supply chain (Feng et al. 2013). Barge et al. (2014) fixed the RFID tags to the cheese wheels by various methods to track the movement of cheese wheels during production, handling, storage, delivery, packaging and distribution process. RFID was combined with wireless sensor network (WSN) for improving the traceability system in the whole supply chain of white wine starting from the vineyard to consumer (Catarinucci et al. 2011). WSN is a similar wireless technology as RFID that has been used to enhance the effectiveness of traceability system in food and aquaculture industries (Qi et al. 2014).

Besides having so many advantages, RFID technology also has some drawbacks. There are more interferences in some of the Ultra High Frequency tags (bands 860 MHz Europe, 915 MHz USA) that are used in controlling the traceability and monitoring of the cold chain as compared to other frequencies. Also there is a problem in the availability of the bands, as Japan and China restrict these transmissions and only USA and Europe provide these bands (Ruiz-Garcia and Lunadei 2011). In the application of RFID technology in the traceability system, other major barriers are the difficulty in entering data, disorganized sequence of data input and mode of communication with the RFID reader (Feng et al. 2013). RFID technologies have more advantages than disadvantages but still the companies do not prefer to adopt this technology because of its extra cost of investment. But, if the company conducts detail analysis on the overall benefit and gives importance to the safety of product, they will definitely adopt traceability technologies like RFID (Zhang and Li 2012).

4.2 Near field communication (NFC)

Near Field Communication can be considered as part or subgroup or modified version of RFID technology which has similar features as other wireless technologies used at the consumer level (the existing standards for contactless card technologies ISO/IEC 14443 A and B and JIS-X 6319-4). NFC technology offers two better ways of communications between electronic devices for sharing the information in the very short distance of less than 4 cm (Badia-Melis et al. 2015). This technology operates at the frequency of 13.56 MHz and data rates of 106, 212, 424 or 848 Kbit/s are supported by this (Mainetti et al. 2013). For the purpose of specific identity, security and anti-theft of the information, very small sized tags are prepared which can be inserted in the products. The advantage of this technology over the traditional barcode and QR codes is that a laser beam does not have to travel in a solid path in order to travel between two different devices.

The implementation of an integrated system of RFID and NFC in the supply chain can provide the full history of purchased product to the consumer. Mainetti et al. (2013) mentioned that NFC is linked with mobile applications so that the traceability information can be correlated with the products directly. In the recent future, with the use of the mobile, a consumer can get information about the product prior to buying and decide whether to buy or not (Chen et al. 2014). A chemiresistor-based NFC tag has the potential of detecting certain gases. The electronic circuit is disconnected by creating a hole and then reconnected with the carbon nanotube linker. In presence of specific gas, there is change in the conductivity of the nanotubes allowing the retrieval of information from the tag into their smartphone and finally detecting the presence of the targeted gas (Badia-Melis et al. 2015).

4.3 Advances in unique identification and quality of livestock

The main aim of traceability is to improve the production efficiency of food and to minimize the generation of food waste. A model for tracking the quality of vacuum-packed lamb in the supply chain was generated by Mack et al. (2014). This system was provided with a temperature sensor and was capable of recording significant information, analyzing it with the Arrhenius model and making final decision for enhancing the quality of meat during processing and storage.

Shanahan et al. (2009) developed an integrated traceability system involving all the stakeholders along the supply chain which can detect all forms of traceability in beef starting from farm to slaughter. With the accessibility of traceability data to the consumer, their confidence towards the beef products can increase. RFID, biometrics and identifiers can be used as tool for verifying the identity of individual cattle. The ID data of the animal is translated to EPC which is then shared through the EPC global Network for the traceability system.

The traditional ear tagging of calves and printing barcodes in each quarter of the carcass after slaughter provide inadequate data and in harsh condition, the integrity of the label is weak. Hence, RFID tags were recommended instead of barcodes and simple tags (Mc Carthy et al. 2011). Mc Inerney et al. (2010) conducted the *in vivo* study on e-tracking of poultry by printing barcodes with different inks onto the beaks of live broiler chickens. Since the result of this study indicated very poor readability of the data, they further recommended to use various kinds of inks with delayed effect, such as laser printing, etc.

4.4 Isotope analysis and DNA barcoding

Isotope analysis is the study of the relative abundance of stable isotopes (isotopes from same element) and is expressed as isotope ratio which can be used for research purpose. The combination of isotope ratio analysis with other techniques (e.g., chromatography, isotope ratio mass spectroscopy (IRMS), inductively coupled plasma mass (ICP-MS), near infrared spectroscopy (NIRS)) may prove to be a better method for authenticity and traceability of agro-products (Zhao et al. 2014). The analysis of a stable isotope has developed as one of the main techniques for identifying the geographical origin of the agro food products like milk, meat, cereal crops, oil and wine.

Horacek and Min (2010) successfully identified the origin of a beef sample by determining the isotope ratio of carbon, nitrogen and hydrogen in the defatted dry mass of beef samples from different countries. Similarly, Perini et al. (2009) categorized the lambs from seven different regions of Italy on the basis of their feed and by estimating the multi-element stable isotopes. Some of the studies related with the differentiation of the food products using isotope analysis for traceability are listed below:

- Conventional and organic milk by analyzing carbon isotope (Molkentin and Giesemann 2007)
- Rice samples from various areas of Australia, Japan and USA according to the elemental and isotopic composition (Suzuki et al. 2008)
- Wines from different places of Brazil on the basis of isotopic ratios of oxygen of wine water and carbon of ethanol (Dutra et al. 2011)
- Olive oil samples from eight European regions by estimating the stable isotope ratios of H, C and O and 14 other elements (Camin et al. 2009).

The validation of food authenticity mainly depends upon protein analysis and DNA sequencing. Immunological assays, chromatography and electrophoretical methods come under the protein-based analysis methods (Galimberti et al. 2013).

DNA barcoding system has been established as an effective and reliable approach in the actual traceability system of seafood (Becker et al. 2011), mammalian meat (Cai et al. 2011), raw milk (Arcuri et al. 2013), edible plants and also for chocolates, cookies, processed food, purees, fruit residues in juices, etc.

4.5 Chemometrics and near-infrared spectroscopy (NIRS)

Chemometrics is the method which is based on the mathematical and statistical model used for analytical data obtained from different points for getting the necessary chemical information in the system. As compared to the general statistical model, chemometric models are simple, easy to maintain, have better updatability, give accurate data and can be transformed easily into a set of specifications. This will aid in generating the guidelines for decision making on the authenticity of the origin of food, which is vital in the traceability system (Vandeginste 2013). Chemometrics models can be used in integration with other instrumental analytical techniques for developing the authenticity and traceability models that can be used for enhancing the quality and safety of food (Bertacchini et al. 2013).

The combination of near infrared (NIR) spectroscopy and mid infrared (MIR) spectroscopy with multivariate data analysis (like principal component analysis—PCA), partial least squares discriminant analysis (PLS-DA), linear discriminant analysis (LDA), etc. for authentication and traceability of cereals has been studied by Cozzolino (2014) and revealed that the new spectroscopy technologies combined with new algorithms can be the promising tools for traceability and authentication of cereals. Bevilacqua et al. (2012) applied mid-and near-infrared spectroscopic techniques along with chemometric models for the traceability system of extra virgin olive oil and found that the method is inexpensive, fast and non-destructive for the traceability of olive oil.

Versari et al. (2014) found that the integration of chemometrics with other analytical tools can be used for authentication and classification of wines that will later help the traceability process. Nuclear Magnetic Resonance (NMR) and chemometrics was used to track the geographical origin and quality of traditional food (Consonni and Cagliani 2010). Likewise, Near-infrared spectroscopy (NIRS) was combined with chemometrics for evaluating the quality and identifying the geographical origins of black tea (Ren et al. 2013). González-Martín et al. (2014) successfully predicted the geographical origin of wheat grain by combining near-infrared spectroscopy (NIRS) with chemometric.

5. Conceptual Advancements in Actual Traceability

Apart from technological advancements, conceptual approaches have also been developed to validate the actual traceability capacity in food systems.

5.1 Critical tracking events (CTEs) and key data elements

Critical Tracking Event (CTE) is one of the most flexible, efficient, scalable, adaptive and interconnected concepts that can recognize the smallest and significant units in the food logistics supply chain. It combines the modern technologies for tracking the unit of interest and offers fast, accurate and easily understandable information while recalling in the traceability system. The approach of CTE is not to collect the information of a specific product but of the process/events that is responsible for manipulating products in the supply chain. The process/events are monitored, corresponding data are recorded according to time, date and specific locations, and are stored for future recall process (Miller and Welt 2014).

CTEs are classified into four different groups on the basis of the main categories of supply chain (Miller and Welt 2014).

a. **Terminal CTEs:** events present at the terminal end of the supply chain that include the perishable nature and the variability of the products travelling in the chain;
b. **Aggregation/Disaggregation CTEs:** events that come after terminal CTEs, e.g., packaging;
c. **Transfer CTEs:** events involving any type of product movement in the supply chain such as shipping, receiving, and loading;
d. **Commingling CTEs:** Commingling CTEs are the events which arise when a new product is formed by using different products from different sources.

CTEs provide freedom to the operator for selecting methods, tools and technologies to maintain and control the CTE data which is one of the advantages of this concept over other food traceability concepts.

5.2 Track and trace model concept

In the Food Track and Trace Ontology (FTTO) model, a unique body of knowledge is managed through the combination of different concepts and terms that are coming from heterogenous sources of information and users involved in the supply chain. The main objective of FTTO ontology is to involve the most representative food concepts involved in a supply chain, integrate and link them with the key features of the food traceability domain. For this purpose, the information is generally collected from books, dictionary, food databases and internet. Many authors have stated the definition of ontologies based on the particular product or class of products which can be appropriately used again for implementing Global Food Track and Trace Ontology (FTTO) in the traceability system. The major classes that are involved in FTTO ontology are agent, food product, service product and process (Pizzuti et al. 2014).

5.3 Trace food framework

The Trace Food Framework concept is developed so as to formulate international, non-proprietary standards for exchanging the food traceability data. Storøy et al. (2013) have mentioned that for unique identification of products and good traceability practice, a general standard has been formed for the electronic exchange of traceability information. It defines how to construct, send and receive the information and also explains how to analyze and interpret the data elements in the messages. The components that are comprised in this framework are the principle of unique identifications, documentation of transformations of products, generic language for electronic exchange of information, sector-specific language, generic guidelines for implementation of traceability and sector-specific guidelines.

5.4 Internet integrative approach

The Internet of Things (IoT) is a network which integrates, interacts and controls normal objects so that they can be linked with the internet to ease the exchange of information in the system (Giusto et al. 2010). IoT is an emerging technology that can create a world where machines can communicate with each other and permit people to interact with the digital world for enabling the exchange of product information (Atzori et al. 2010, Amaral et al. 2011). This system has three different dimensions which include information items (for identifying and collecting data), independent networks (networks capable of self-configuration, self-healing, self-optimization and self-protection) and intelligent applications (intelligent control and processing).

5.5 Food logistics based actual traceability

Food traceability is a vital part of logistics management as it can store the information which can be retrieved later at any point of time (Bosona and Gebresenbet 2013). Jedermann et al. (2014) have mentioned that intelligent food logistics can minimize the perishable waste in the food supply chain through the reduction of the deviation from the optimal cold chain. Scheer (2006) described that in the traditional tracking and tracing (T and T) systems, the obtained data are only used for recall management. However, they proposed a quality oriented tracking and tracing system (QTT) that utilizes the information retrieved from intelligent logistic tools like wireless sensors. This QTT concept maintains a perfect association between logistics and traceability for improving the products in the supply chain. Jedermann et al. (2014) revealed that shelf life models can be used for combining QTT with FEFO (first expire first out) which will then improve the demand and the supply chain. Van der Vorst et al. (2007) highlighted that if the quality control logistics is implemented in the supply chain networks, the quality of the product can be projected in advance and there will be better flow of product and improved chain design.

5.6 Legal advancements towards actual traceability

As per the Directorate General Health and Consumers Affairs (DG SANCO) of the European Commission (2010), traceability is "the ability to trace and follow a food, feed, food-producing animal or substance through all stages of production and distribution". EU has made tracing and tracking mandatory in 2005 but the specifications in this regulation are low, lacks monitoring of batches and restrict the documentation process (Regattieri et al. 2007). U.S. Food and Drug Administration (FDA) assigned Institute of Food Technologists (IFT) to design pilot product tracing projects to meet the growing requirements of agriculture and food traceability (Bhatt et al. 2013). The main goal of IFT's Traceability Improvement Initiative is to work in the tracing and tracking of food product through several means, pilots and implementation studies in the products like dairy, seafood and other food industries. Some recommendations have been given by IFT for fast and effective investigations during food borne illness outbreaks for improving the protection of public health (Bhatt et al. 2013). A study was carried out by Bhatt and Zhang (2013) on information tracing to identify the contaminated ingredient and probable source, along with the distribution of the product.

6. Conclusion

The increased concern of food safety has raised the consumers and producers attention towards an effective traceability system. The traceability system can be improved by implementing actual traceability techniques and managing the important food product information during the entire food supply chain. The combination of traceability system with planning and logistics can significantly improve the actual traceability practices.

Keywords: Actual traceability, RFID (Radio-frequency identification), technological advancements, conceptual advancements, isotope analysis and DNA barcoding, bulk product traceability

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