Traceability Technologies across the Food Value Chain

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***Abstract*- With the globalization of food industries, vitality of traceability has increased substantially. The need for a reliable identification and tracking system is therefore essential to ensure the safety and quality of food reaching the consumer. Current market for tracing technologies is restrained by various factors like high cost, skepticism about efficiency and liability of technology. This paper gives an overview of relevant food tracing technologies available in the market and a descriptive analysis of their efficiency, liability, features and characteristics.**

***Keywords*- Food Traceability, Technologies, Quality, Bar codes, RFID, Product markers**

I. INTRODUCTION

As per ISO 9000 (2005), "traceability is defined as the ability to trace the history, application or location of an entity by means of its recorded identification" [1]. Thus product traceability is basically tracking and monitoring the movement of a product in the supply chain by linking its physical flow i.e. manufacturing, processing, delivery and storage with the information flow in a real-time manner.

Globalization of Food industries has substantially increased the demand of traceability in food system, driven by many forces like Food Safety (free from extrinsic or intrinsic pathogens) [2], Food Security (free from theft, adulteration or even Bioterrorism) [3] and Consumer demand. In developed countries, traceability is not only a value-added practice for supply chain, it is a law. In European Union, since 2005, traceability system has been obligatory for all food businesses [4]. In U.S., Bioterrorism Act includes the similar requirement regarding tracing "one step forward and one step back" throughout the supply chain [5]. Implementation of traceability system by an industry can be both voluntary and compulsory. The mandatory reason comes from legislation that ensures the establishment of security in food chain. The voluntary one arises from the will of an organized and improved organization [6].Food Traceability provides many advantages like supply chain optimization, product safety, consumer confidence, better market access [7]. Traceability enables corrective actions, such as product recall, to be implemented quickly and effectively when something goes wrong within the supply chain.

Current market for tracing technologies is restrained by various factors like high cost, skepticism about efficiency and liability of technology. An effective traceability technology should provide accurate, timely, complete and consistent information about products through supply chain. It should be a trustworthy technology which can provide detailed information to consumers about where product comes from, what is its production and processing history.

Different tracking and tracing tools are used to deliver different level of security and information. Some traceability systems are shallow, track key steps and ingredients to few steps only, while other systems are deep, making whole supply chain visible and transparent [8].

The main aim of this paper is to provide detailed information on the available food tracing technologies available in the market.

A. Food Traceability

Food Traceability can be divided into five categories i.e. a). Product Traceability- determines the physical location of product in supply chain; b). Process Traceability- includes tracing the type and sequence of activities followed during product formation; c). Genetic Traceability- determines the genetic constitution of the product; d). Input Traceability- determines the type and origin of inputs such as fertilizers, irrigation water, livestock, feed, additives, chemicals etc; e). Disease and pest traceability- it traces the pests, microbiological hazards that can be present in the food.

Traceability can further be of two types i.e. Forward Traceability and Backward Traceability. Forward Traceability is tracking the path of a product from beginning to the end as it moves downstream through the supply chain, whereas Backward Traceability implies tracing the product back to its origin through records i.e. upstream in the supply chain [9]. The combination of two is often known as Bidirectional Traceability [10].

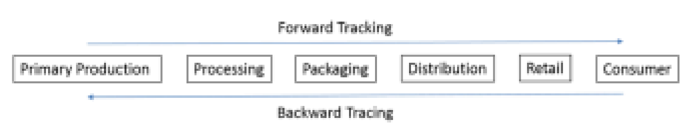

Fig.1 Bidirectional Traceability

Internal traceability takes place when record keeping of the product is done within a particular operation, company or production facility before it is delivered. External traceability refers to tracing the product outside of a business entity, in the entire supply chain between the company and the consumer [11].

An example of traceability system is tracing the meat from farm to consumer. Monitoring the quality and security of meat product starts from farm itself. Cattles reared in the farm are tagged with ear tags for identification of their sex, breed, date of birth, herd of origin etc. Further, in abattoirs, cattle tags are checked, slaughtered, tested and tagged with RFID tags. These RFID tags are detected with the help of handheld readers in further stages of storage and delivery. In this way whole supply chain of meat from farm to fork is tracked and traced.

II. FOOD TRACEABILITY TECHNOLOGIES

To implement traceable food supply chains, technological innovations are needed for product identification, process and environmental characterization, 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 (computer programmes and information systems).

A. Alphanumerical codes

These are the sequences of numbers and letters of various sizes present on package or product labels [12]. Writing and reading codes is done manually which requires significant human resources and cost. Manual management of data leads to errors and poor performance. There is no particular standard for Alphanumerical codes and are usually generated by company or organization itself [12]. Due to this reason the risk of data integrity corruption is very high in case of alphanumerical codes. Today, alphanumerical codes are not much popular as bar codes offer several significant advantages over them.

B. Bar codes

Initially patented in 1952 in Philadelphia (first used in around 1970), barcodes can be described as a series of parallel bars and spaces of varying widths printed on an item or product.The dark colored bars of code absorbs light and white spaces reflect light. The code's data are extracted using a scanner with an integral light source (most commonly used laser scanner). As the laser passes over the bar code, a photodetector measures the amount of light reflected and convert it into electrical energy which is transformed to a digital signal. The digital signal is then decoded based on the symbology formulas. This automatic, high reading speed, precise technology provides simpler, more economical, and accurate traceability systems [13, 14, 15].

Barcodes have two encoding types, one dimensional (1-D) code and two dimensional (2-D) code. The former can be read with fast speed, but has smaller data storage capacity (20 bytes) [16] and cannot be used to hold bigger data. The latter one can carry information both in vertical and horizontal direction, can store more information (2000 bytes) including text, images, fingerprint and signature in limited space and can be printed or displayed everywhere [16]. 2-D Codes can be scanned using mobile phones and can be used online as well. Two Dimensional (2-D) codes can be further grouped into two different categories i.e. Stacked- linear and Matrix. Stacked-linear codes are rows of width- modulated bar codes stacked on the top of each other. Each row is of same length and resembles a single-line bar code. Matrix codes are two dimensional patterns of data cells in shape of tiny squares, circles, polygons. Unlike other barcodes, matrix codes cannot be decoded by a laser scanner. They can be read with an image- based reader or camera. Various 2D Barcodes like Data Matrix, QR codes, Aztec code, Vericode, Codablock F, PDF 417, PDF 417 Truncated and Code One exist in the market. Among all, QR Codes is the most appropriate one in terms of storage capacity, identification speed and readable direction [16].

Most widely accepted standards for barcodes are GS1. GS1 is a nonprofit international organization that has developed standardized codes for use in the supply chain. As a member of GS1, a food company will be allocated a series of unique numbers for product identification. GS1-128 barcodes are used to encode product data for units such as cartons, cases, pallets, and reusable packaging or transport equipment (returnable assets) and help manage fast and accurate tracking of inventory. Specific information can also be encoded in GS1-128 barcodes to add security and sustainability to supply chain, such as Best before Date, Batch/Lot Number, Serial Number, Global Trade Item Number (GTIN) and the GS1 System's Serial Shipping Container Code (SSCC) [17].

C. RFID

Radio frequency identification (RFID) is a technology that uses radio waves to identify, classify and locate "articles" (objects, people or animals). Yet being in use since Second World War, this technology is new in food sector. The main characteristic of RFID is that there is no requirement of physical contact or line of sight orientation between reader and tags. RFID system consist of 3 main components-

1). A Tag or a Transponder: RFID tags are the labels attached to the objects. These tags can be either Read-only or Read-Write both. An RFID tag contains integrated circuit that controls the communication with the reader. It contains at least two sections - One section that provides communication with the reader and a memory section which stores identification codes or other data [14]. RFID tags can be active, passive or semi-passive. A passive tags have no battery and are cheaper. The battery of semi-passive RFID is used to only power the sensor and recording logic. Unlike active tags, semi-passive tags do not use the battery to communicate with the reader

[18]. Passive and semi-passive RFID send their data by reflection or modulation of the electromagnetic signals emitted by readers within the range of 10 cm to 3 m. Active tags have higher signal strength and extended communication range of up to 100 meters [19].RFID tags are small and compatible with food (their material are aseptic).

2). A Reader or transceiver: A reader contains electronic components which send and receive signals to and from the proximity tag [14]. In order to receive and transmit data from the tag, the reader is provided with an antenna.

3*). A Data Processing System*- it is a device usually a computer containing database and information management software which checks and decodes the data received and store it in the memory.

Electronic Product Code (EPC), a unique serialized code is one of the common type of data stored in a tag. EPC is managed by EPCIS i.e. EPC Global. EPC Global issues unique numbers to be used in RFID tags for identifying products in the supply chain [20].

Various special feature of RFID, for example large data storage capacity in less physical space, automatic reading/writing facility, simultaneous readability of several tags, ability to work under different conditions of temperature, humidity, acid corrosion, ammoniacal gases, saline solutions with inhibiting substances, sugars, colorant pigments, preservative substances and oils etc., provide advantage to use this technology in food sector [21].

D. Wireless Sensor Networks

Various Wireless Technologies like Bluetooth, ZigBee contains huge potential to be used in food traceability due to their suitability in data collection and monitoring in tough environment such as cropland, warehouses, refrigerated trucks etc. [16]. A WSN system is comprised of radio frequency transceivers, sensors, microcontrollers and power sources [16]. The main difference between a WSN and a RFID system is that WSN comprises of relatively inexpensive sensor nodes which allows different network to pologies and multihop communication [16].

E. Product Markers

Markers placed on the food product can be chemical, physical or biological. Physical markers include unique molecules or atoms which can be detected easily by UV rays, X-ray fluorescence. Chemical markers include those that create a distinct flavor, aroma or absorbance. For example-vitamin placed in alcoholic beverage. Biological markers are based on the intrinsic properties of food like unique nucleic acids, particularly mitochondrial nucleic acids, unique proteins (e.g. prions). Microorganisms (Wild or genetically engineered) occurring naturally or added during production, can be used as indicators to trace the food.

F. DNA Barcodes

DNA Barcoding is a molecular based system in which short genetic sequence from organism's genome are compared with reference sequences to identify its relationship to a particular species. DNA based markers used in barcoding can be hybridization based markers (in which target DNA is digested with restriction enzyme and compared with labeled probe) or Polymerase Chain Reaction based markers (in which amplified specific DNA fragments are separated electrophonically and banding pattern are detected by different staining methods like autoradiography) [22]. A DNA bar coding locus should have high taxonomic coverage and high resolution [23]. For example, mitochondrial Cytochrome C Oxidase 1 gene ("CO1") is used as a standard barcode for almost all animals, whereas chloroplast gene matK and rbcL are used as barcodes for plants [24]. DNA barcoding includes 3 main steps-

1).Collection of Specimens: specimens are collected from a variety of sources like history museums, herbaria, zoos, aquaria, seed banks etc.

2).Laboratory Analysis: DNA is extracted from specimen; barcode region is isolated and sequenced.

3).Database Collection: After obtaining the barcode sequence, it is placed in public reference library like Barcode of Life Data Systems (BOLD) database, The International Nucleotide Sequence Database U.S., Nucleotide Sequence Database of the European Molecular Biology Lab, and the DNA Data Bank of Japan.

4). Data Analysis: species of the samples are identified by comparing it with the recorded reference database.

G. Geospatial Science and Technology

The integration of geographic information systems (GIS), remote sensing (RS) and global positioning systems (GPS) enable data to be remotely collected on animals, plants, and agricultural farm, which can be processed, transmitted and presented as visual spatial information [25]. *GPS* is a satellite based radio-positioning system [26]. The radio signals sent by satellite are picked up by the GPS receiver which shows exact location on the ground. Widely used in agricultural traceability, this computer based tool can provide general configuration and features of earth's surface so that cultivated area can be divided and coded according to the geographical information. Each area is given a unique ID code in the database which can be used to map the geospatial variability of selected attributes such as yield, product quality, fertilizers, pesticide, water quality used etc. [25].

III. CONCLUSION

Globalization of Food industries has substantially increased the demand of traceability in food system, driven by many forces like Food Safety, Food Security and Consumer demand. Food Traceability has now become a new parameter of food quality and basis for trade across the borders. A good traceability system can facilitate stakeholders to trace a food product at any step in the supply chain i.e. trace back to its original producer as well forward to its consumer. It also facilitates rapid and effective recall of products. Many modern technologies exist which can be used to develop integrated food traceability system. Alphanumerical codes, Bar codes, RFID, Wireless Sensor Networks, different physical and chemical product markers, DNA Barcodes, Geospatial technology are some of the examples of already existing technologies. Current market for tracing technologies is restrained by various factors like high cost, skepticism about efficiency and liability of technology. Developing an appropriate traceability technology for small and medium food businesses, especially in least developed countries offers considerable challenges and opportunities for researchers and practitioners in this sector.

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