Improving Consumer Confidence in Food Safety and Nutritional Quality

Fola Michael Ayokanmbi
Systems & Materiel Engineering Program
Alabama A&M University
Normal, Alabama, USA

Jacob Oluwoye
Community and Regional Planning
Alabama A&M University
Normal, Alabama, USA

***Abstract*— The quality of food products in terms of their safety and nutritional requirements is pertinent to the quality of life. However, escalating and heavily publicized outbreaks of foodborne diseases have negative impact on consumer confidence in the quality, safety, and nutritional value of the food products that they purchase. Hence, consumers are increasingly demanding information about the composition and origins of food products that are purchased for consumption. This has elevated the importance of the ability to monitor a food product from its origin through the supply chain to the grocery shelf. Traceability is an increasingly common element in monitoring food supplies and improving the safety and quality of food products throughout the supply chain. This paper presents a conceptual framework for improving consumer confidence in the safety and nutritional quality of food products that are displayed on grocery shelves by providing consumers with access to traceability data, including nutritional information, using the smartphone.**

Keywords—Food Traceability, Food Safety, Food Quality, Nutritional Information, Health, Consumer Confidence, Globalization, Food Supply Chain, Interoperability

I. INTRODUCTION

The provision of safe and nutritious food enhances population health and well-being. There is an increased focus on ensuring that consumers avoid food products of poor quality, especially those that have been deemed to be responsible for obesity. This has elevated the importance of the ability to trace the origin of foods from the source through the supply chain to the kitchen table. Therefore, there is a growing need to develop a global interoperability traceability system for sharing information throughout the supply chain to manage and mitigate challenges associated with the provision of food product information to the consumer. Interoperability of the system ensures that information exchanged between the supply chain partners are collaboratively used in tracing and tracking products, and traceability is an increasingly common element in monitoring food supplies and improving the safety and nutritional quality of food throughout the supply chain [1]. It is imperative that food supplies are tracked downstream through the distribution network, and traced upstream to determine their origin and characteristics, including processing information [2]. Hence, traceability is important in the management of food safety and nutritional quality and enhancing consumer confidence [3].

Food is a complex product [4], and modern food production, processing, and distribution systems may integrate and commingle food from multiple sources, farms, regions, and countries [5]. Food products may be differentiated through systems of (1) identity-preserved production and marketing (IPPM), (2) segregation, and (3) traceability [6][7]. IPPM ensures that a product is produced, processed, and marketed at a required level of nutritional quality, with appropriate labelling, and delivered to the right customer [7][8]. Furthermore, IPPM systems are important for providing information to consumers about the origin of a product when the attributes may not be visible or detectable in the product. Segregation systems are used to prevent the mixing of novel varieties in the handling of like varieties or to discourage the mixing of a segregated product with like products, if potential food safety concerns exist. Segregation systems assures the consumer that the storage, transportation, packaging, and distribution of the product delivered meet a required certification scheme; and a certified product is separated from a non-certified product to facilitate tracking and tracing of the final product [9]. A traceability system provides a seamless documentation of the path a product takes from the farm, through the supply chain, to the kitchen tables.

Developing an effective system for improving consumer confidence in the safety and nutritional quality of food products, and mitigating challenges associated with outbreak of foodborne risks and recalls requires a precise definition of traceability as well as an understanding of the standards and regulations regarding implementation.

II. TRACEABILITY *AND* CONSUMER *CONFIDENCE*

The European Union defines traceability as “the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing, and distribution” [10]. According to the Codex Alimentarius

Commission (CAC), traceability can also help identify a product at any specified stage of the supply chain: where the food came from (one step back) and where the food went (one step forward). Simply knowing where a food product can be found in the supply chain does not improve food safety, but when traceability systems are combined with safety and quality management systems, they can make associated food safety measures more effective and efficient [11]. Reference [12] defines traceability with respect to a food product, as "the ability to identify the farm where it was grown and sources of input materials, as well as the ability to conduct full backward and forward tracking to determine the specific location and life history in the supply chain by means of records." Reference [13] indicates that traceability is "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."

Traceability systems can be classified according to their capacity for (1) internal traceability and (2) chain traceability [1]. Internal traceability refers to data recorded within an organization or geographic location, whereas "chain traceability" involves recording and transferring data through a supply chain between various organizations and locations involved in the origin of food. Fundamentally, traceability systems involve the unique identification of food products and the documentation of their transformation through the chain of custody to facilitate supply chain tracking, management, and enhance consumers' confidence [14].

As presented in [12], there are six elements of agricultural and food supply chain traceability system: (1) Product traceability that provides information on the physical location of a product at any stage in the supply chain; (2) Process traceability provides information on the type and sequence of activities performed on the product during the growing and postharvest operations; (3) Genetic traceability that provides information about the genetic structure of the product; (4) Inputs traceability identifies the type and origin of fertilizers, chemical sprays, irrigation water, livestock, feed, and the presence of additives and chemicals involved in production; (5) Disease and pest traceability provides information on the epidemiology of pests and biotic that could impact food safety; and (6) Measurement traceability that links the measurement results from the calibrated measuring device to an accepted reference standard.

Food consumers want to be confident that the food products they buy are safe and meet their desired level of nutritional quality. Hence, the food industry has the responsibility for implementing and maintaining traceability and risk management throughout the entire food supply chain [15]. A survey of consumers in Germany, France, Italy, and Spain was conducted to examine consumers' perception of food quality and safety vis-à-vis improved food traceability [16]. The study found that consumers perceive a link between traceability and food quality and safety, and their purchasing decisions. Reference [17] studied the attitudes and purchasing intentions regarding traceable minced beef/beef stake in England and found that consumers' intention to purchase was influenced by their positive attitude towards traceable products.

Traceability in the supply chain management of products has attracted critical attention over the past decade leading to requirements in the value chain being stricter to ensure product quality and public safety. This is particularly crucial in the food industry, as traceability has become an essential component in the management of the quality and safety of food and improving consumer confidence [3].

III. TRACEABILITY REGULATION STANDARDS

The growing interest in developing systems for food supply chain traceability could also be attributed to the various food safety and health issues consumers all over the world have faced in the recent years [18][19][20][21]. Food traceability regulations are established to prevent consumer fraud. However, the significance of food traceability regulations continues to increase due to the globalization of food products.

The Food Safety Modernization Act (FSMA) was enacted in 2011 to ensure safety of U.S. food supply chain by shifting existing food supply focus from a reactive approach to a preventive control emphasis [22][23][24]. The FSMA sets standards and guidelines for reducing health risks associated with foodborne illness through (1) preventive control that requires food facilities to develop control plans against potential hazards that could impact food safety; (2) safe production and harvesting of fruits and vegetables; (3) inclusion of possibility of radioactive contamination in hazard analyses; and (4) protection against intentional contamination of food; and (5) verification of the safety of foods from foreign suppliers by importers of food.

The hazard analysis and critical control point (HACCP) standards, developed by CAC, provides a preventative approach for identifying and assessing hazards associated with food, from farming to marketing, determining critical control points (CCPs) to control any hazard; and establishing procedures for monitoring and maintaining food safety [25][26]. The food safety management systems of the International Organization for Standardization, ISO 22000:2007 (Traceability in the feed and food chain), provides organizations that are directly or indirectly involved in the food supply chain, including feed producers, animal food producers, harvesters of wild plants and animals, farmers, producers of ingredients, food manufacturers, retailers, and organizations providing food services, catering services, cleaning and sanitation services, transportation, storage and distribution services, suppliers of equipment, cleaning and disinfectants, packaging materials and other food contact materials with the guidelines for controlling food safety hazards [27][28].

The Global Standard for Food Safety of the British Retail Consortium "provides a framework to manage product safety, integrity, legality and quality, and the operational controls for these criteria in the food and food ingredient manufacturing, processing and packing industry [29]. The uniform quality assurance and food safety standard of the International Features Standards (IFS), developed by the manufacturers, retailers, and food service companies, assesses suppliers' food safety and quality systems [30]. The Safe Quality Food (SQF) International provides a food safety certification program for controlling food safety hazards, and a quality certification programs for monitoring and controlling food quality related threats, respectively, using the HACCP for control of food safety hazards [31].

Regulation 178/2002 of the European Food Safety Authority defines 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" [32]

IV. FOOD TRACEABILITY SYSTEM FRAMEWORK

The definitions of traceability suggest that an effective traceability system depends largely on integrated technological innovations required for product identification, data recording, information gathering, analysis, storage, and transmission throughout the supply chain. These technologies include hardware, such as labeling and identification, and information system solutions [1]. This would include (1) effective product identification system for accurate labeling for traceable supply chain which would have the ability to trace back the history and consistently track the physical location of the products in the overall supply chain to identify production and processing steps that resulted in the creation of the product, as well as the ability to trace forward and identify all derivative of the product that are used as an ingredient in other products; (2) quality and safety measurement system for ensuring that the expectations of the consumer and other stakeholders are met; (3) genetic analysis system for analyzing the genetic constitutions and contamination of foods and other biological products that would meet the requirement for preserving and identifying product supply chains and the demand for genetic traceability; and (4) environmental monitoring system for tracking environmental conditions, such as temperature and relative humidity, atmospheric composition of the air, including pollutants [12].

Traceability systems allow for the identification of contamination in the supply chain [6], which enables a transparent chain of custody, raises credibility, and makes it possible to transfer information on the steps taken to alleviate food safety concerns [1][33]. Food contamination may occur at the farm, during processing or distribution, in transit, at retail or food service establishments, or at home. Traceability facilitates recall because information on all possible sources and supplies of contaminated food can be traced one step forward, one step back, or end to end. It provides supply chain partners with the readiness to supply needed information when an outbreak of foodborne illness is being investigated so that targeted, efficient, and effective withdrawals can be undertaken.

Reference [34] tackled the main issues arising in developing traceability systems at different conceptual stages. They pointed out that all the involved parties would be required to systematically bind the physical flow of materials and products to the corresponding information flow in order to implement a traceability system within a supply chain from an information management perspective. On the other hand, a traceability information system from an abstract viewpoint could be thought of as a single massive, centralized data storage capturing all the information from each lot along the different stages of the supply chain. They concluded that preliminary investigations to point out problems and solutions at different abstraction levels would be necessary for the design and implementation of traceability systems. In this regard, the adoption of generic data model for traceability would be the foundation for any possible discussion about the development of the systems. To achieve data integration along the supply chain for traceability purposes, they suggested that a common, widely accepted set of specifications for collaboration is required.

The main requirements of traceability and how these conditions could be addressed with a technology such as radio frequency identification (RFID) were examined by [35]. The requirements cited included item identification, bills of lots recording, operation recording, item observation/data capture, and links management and data retrieval. They suggested that the cost associated with a traceability system and the ease of its deployment have a significant impact on the technological approach used. Subsequently, he proposed an information infrastructure for RFID-enabled traceability in a supply chain that aimed to provide full and verifiable traceability across a supply chain in a cost-effective and efficient way for the chain's partners.

Reference [36], utilizing the soybean value chain, developed a model for information capture at various stages in the soybean chain. The model they developed was based and inspired by the TraceFood Framework created under the European Commission sponsored TRACE project, which provided a toolbox with principles and guidelines on how to implement electronic chain traceability.

Distinct components involving data collection using standards measurement procedures, the analysis, storage and transmission of the recorded information, and full backward and forward control system for tracking product history [12]. Data collection will support traceability by providing information about food quality and safety. Traceability data will include cultivation data to provide information regarding fertilizer dose, type, properties, and the date of application; soil properties; the origin of irrigation water; and properties of pesticides used. Also, food processing data at all stages (production, testing, storage, packaging, distribution, and retailing), and labor and equipment used will be gathered.

V. TRACEABILITY SYSTEM

This paper presents a traceability model integrated with Personal Digital Assistant (PDA), barcode, RFID, and QR code technologies to increase consumer confidence by providing easy access to product traceability data that include cultivation, transportation, storage, processing, and distribution (Figure 1).

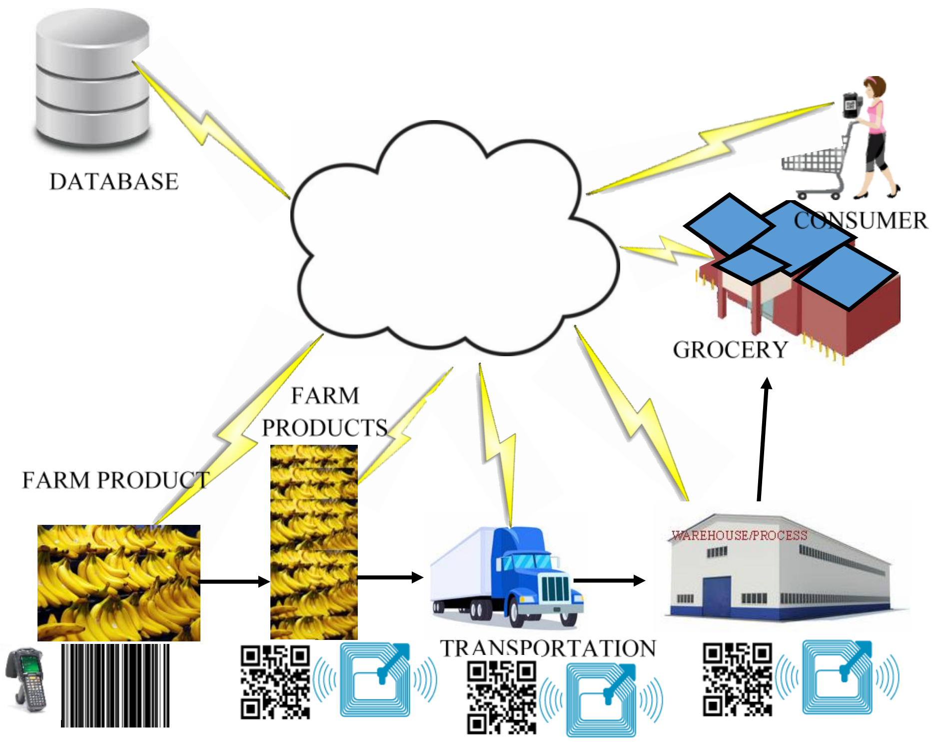

Figure 1. Food Product Traceability System Framework

Traceability system will require the labeling of food products by using the barcode technology. Harvested products will be packaged in traceable units (TRUs) and each TRU will have an RFID tag. The TRUs will be processed through the supply chain, and information about each TRU will be capture with a barcode scanner and transferred to the database.

The accuracy and reliability of product identification is critical for an effective interoperable traceability system. Data on the life of the product through the supply chain, including processing, storage, transportation, and distribution activities will need to be captured and stored, and made accessible to customers. The tracking process starts from the point of origin through production, processing, transportation, and other supply chain activities. Traceability barcode labels are attached to harvested products. A Personal Digital Assistant (PDA) is used for data acquisition and temporary storage of cultivation data, and the records are transferred to the traceability system database. The database will have the storage capacity to store and share product data with all supply chain partners. Barcode labels attached to each unit of the product and scanned to send the product data to the centralized database. Data on relevant origination data are stored in a database and made available to supply chain partners. The products are packaged into cases or pallets to which RFID tags, and Quick Response (QR) code labels that contain traceable cultivation data that can be read with a smartphone, are attached. Where necessary, processing and nutritional traceability information that include ingredients used are documented and captured in the traceability QR code and attached to processed food products. The products are packaged according to consuming or distribution and transportation mechanisms.

Figure 2. Grocery Store Price Label

QR code will be included on the grocery price tag label (Figure 2). The consumer will scan the QR code with a smartphone to access the traceability database, which will return product traceability information.

VI. CONCLUSIONS

The escalating outbreaks of foodborne diseases have raised awareness of the need to improve consumer confidence in the safety and quality of food products and strengthen consumers' purchase intentions regarding the foods that they consume. Therefore, it is imperative that consumers have knowledge of the nutritional quality of the food they purchase. Consumer surveys suggest that traceability influences consumers' perception of food safety and quality, and purchase decisions. Hence, traceability is becoming an index of food safety, nutritional quality, and purchase decision for consumers. It is vitally important that a system whereby consumers are provided with the ability to trace the origin and characteristics of food products throughout the food supply chain is developed to improve consumer confidence. This paper has proposed an interoperable traceability model integrated with PDA, barcode, RFID, and QR code technologies for enhancing consumer confidence by making traceability data accessible to consumers by scanning a QR code on the price label, using a smartphone, in the grocery store shelf. Global traceability standards and regulations are reviewed to ensure interoperability throughout the supply chain.

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