3 Traceability: An Essential Mechanism to Underpin Food Integrity

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Introduction

Historically, traceability has been aligned with product identity, the origin of materials and parts, product processing history, and the distribution and location of the product after delivery (Bertolini *et al*., 2006). Bosona and Gebresenbet (2013) argue that the driving force for the adoption of food traceability systems is unease with respect to safety, quality, economic, regulatory, technological and social factors.

Traceability has been associated with food safety procedures (Charlebois and Haratifar, 2015). It allows businesses to document production practices, through a chain of custody, demonstrate regulatory compliance, and is said to afford businesses within the supply chain the opportunity to respond to food security threats (Thakur and Hurburgh, 2009).

However, along with the ability to respond comes an onus to actually address problems if they are identified. More recently, food traceability has been seen to encompass wider notions of food integrity and authenticity (Charlebois and Haratifar, 2015), or to allow the certification of geographical origin of products, surveillance and monitoring of the chain, and to facilitate the preservation of food provenance (Pizzuti and Mirabelli, 2015). Therefore, traceability of a given food and/or its component parts provides consumers with assurance as to the source (provenance) and the safety of food. Traceability also allows for the identification of the source of contaminated or substandard product, assists in plant and animal disease control, and medicine and chemical residue monitoring, and satisfies the requirements of labelling regulations (Leat *et al.*, 1998). Drawing on current literature, this chapter aims to determine the essential requirements of a traceability system, including the underlying elements of tracking and tracing, and thus how traceability can be effectively implemented in the food supply chain. The chapter first explores the legal and market requirements, leading then to a discussion on the metrics and systems for the delivery of traceability within a supply chain. Next, intelligent packaging systems and data are assessed with respect to their value in ensuring transparency of geographic origin and traceability.

Legal and market requirements for traceability

The regulation EC/178/2002 (EU, 2002) 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. At the very least, unless specific provisions or market requirements exist, the prescribed level of traceability within legislation is for businesses to:

- Identify the immediate supplier of the product or food ingredient in question (trace)
- Determine the immediate subsequent recipient (track).

Whilst the regulations exempt retailers from the need to track to final consumers, traceability should deliver 'one step back-one step forward' traceability, a requirement that others have called tracking 'forward traceability' and tracing 'backward traceability' (Aung and Chang, 2014). In essence, this concept represents B2B2B (business to business to business) traceability.

In high information input supply chains such as fast moving consumer goods, the market requirements for traceability often need to exceed the legislative requirements for 'one step back-one step forward'. To ensure traceability within extended supply chains, means serving the customer with a more comprehensive 'field to fork' approach to traceability, with the extent of tracing and tracking contingent on the complexity and length of the supply chain. This market prerequisite for traceability is seen in many multi-national food service and multiple retail food supply chains. In complex multinational supply chains, tracking, as a process, records important information at relevant points in the supply chain and is delivered: "Through the analysis and elaboration of the information previously recorded by each actor involved in the chain" or product lifecycle (Pizzuti and Mirabelli, 2015:18).

Tracking and tracing material flow through handling and production operations and distribution processes requires the collation of a set of data that must be clearly linked to each specific phase of the process (Bertolini *et al*., 2006). In order to demonstrate the variance in conceptualisation of traceability, the literature has been synthesized into three types:

- Those which distinguish tracking as an individual construct of traceability (e.g. Thakur and Hurbugh, 2009; Bechini *et al*., 2008)
- Those which distinguish tracing as an individual construct of traceability (e.g. Opara, 2003: Kher *et al.* 2010); or
- Those which integrate the requirements of both tracking and tracing (e.g. Aung and Chang, 2014; Foinas *et al*, 2006).

These types of systems underpin the value of traceability for both organisations and the wider supply chain.

The transactional value of traceability

Transactionally, traceability adds value to the product and the overall food safety and quality management system by providing first the communication linkage for identifying, verifying and isolating sources of noncompliance, and second enabling supply chain partners to determine and meet product standards and customer expectations (Pizzuti and Mirabelli, 2015). Effective traceability requires an information trail that follows the physical trail of the food item through the supply chain (Fallon, 2001; Smith *et al*., 2005), and information sharing in supply chains "improves coordination between supply chain processes to enable the material flow and reduces inventory costs" (Li and Lin, 2006:1642). Further, Lin *et al*. (2002) assert that the higher the level of information sharing, the lower the total costs, the higher the order fulfilment rate and the shorter the order cycle time. The quality of information influences organisational and supply chain agility and the ability to be responsive, for example during a food safety outbreak (Zhou *et al*., 2014). Thus, if a suspected outbreak of foodborne illness or a food safety incident occurs within a complex, multi-actor, low information input food supply chain, the lack of whole chain traceability makes it difficult to trace products back to source. This was demonstrated with the 2011 European *E. coli* O104 outbreak, whereby the mixing of produce ingredients in salads and buffets at food service level and the generally low information nature of food service, hindered the identification of the implicated food source (Manning and Soon, 2013).

Metrics of information quality determine the extent to which mutually shared information meets the requirements of each organisation in the supply chain (Zhou *et al.,* 2014; Petersen, 1999). Characteristics of information quality include:

accuracy, adequacy, availability, credibility, completeness, frequency, relevance, reliability and timeliness (Delone and McLean, 1992; McCormack 1998; Li *et al.*, 2005, cited by Zhou *et al.*, 2014).

Metrics of traceability: Batch, lot, traceable resource unit

A traceability system should establish and enable the identification of product lots and their relation to batches of raw materials, processing and delivery records (BS EN ISO 22000:2005). Moe (1998) defined the Traceable Resource Unit (TRU) as a unique batch that is distinguishable from other batches in terms of its innate traceability characteristics, through which each individual resource unit or lot can be identified. A lot is a group of items produced under homogeneous conditions in terms of location, e.g. production lot, processing lot or distribution lot, type and date of treatments (Pizzuti and Mirabelli, 2015). Aung and Chang (2014) suggest there are three types of TRU:

- **Batch** (quantity going through the same process),
- **Trade unit** (a unique unit sent from one organization to another e.g. pack, box, tray)
- **Logistic unit** such as a pallet or a container.

Yet a batch may remain a unique unit and be recombined or added to others, as described previously with the E.coli outbreak. TRU are not static, instead they are constantly being changed and reassembled. These changes and reassemblages can include mixing, splitting, joining, aggregation of resources, segregating, transfer storage or rejection, and discarding of TRUs as new lots or batches are created (Foras *et al.*, 2015). This creates challenges when seeking to develop and implement effective food traceability systems that both track and trace food materials.

Therefore, whilst production processes can, on the one hand, be seen as a series of discrete operations, all of which can be identifiable, in some systems the process is continuous and as a result, the units of production are not then by their nature discrete. An example of this would be the continuous filling of a bulk bin with consecutive deliveries of a food ingredient (Dabbene and Gay, 2011). In this instance of continuous unit operations, the batch can only be differentiated as a result of a specific task that has taken place, e.g. bin cleaning or machine servicing. For bulk products, it is very difficult to associate any label, marker or identifier in order to directly identify the lot, instead processes of fuzzy traceability may be used, often based on the concept of dynamic simulation of the traceability associated with the process used (Dabbene *et al.*, 2014), i.e. using computer programs to model the varying behaviour of a system over time. This approach sits at odds