BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Developing smart agri-food supply chains

Using technology to improve safety and quality

Edited by Professor Louise Manning
Royal Agricultural University, UK

burleigh dodds
SCIENCE PUBLISHING

Contents

Part 3 Safety, quality and smart systems

Acknowledgements

We wish to acknowledge the following for their help in reviewing particular chapters:

- Chapter 5: John Points, Independent Consultant, UK; and John G. Keogh, Henley Business School, University of Reading, UK
- Chapter 8: Professor Carol A. Wallace, University of Central Lancashire, UK

Introduction

Assuring food safety and quality are essential elements of supply chain management systems. Delivering to the range of business and customer requirements means that supply chain relationships must be developed, maintained and continuously improved. Issues such as potential product contamination, reducing food loss and food waste in the supply chain and more efficient and equitable use of physical, financial and human resources mean that we need to determine what it is to be *smart* in agri-food chains now and in the future. The emergence of the use of technology in food supply chains from field to fork has changed the how we can build a picture of food production, what is happening, when problems arise and how they can be addressed to minimise impact on people, planet and profit. This Introduction outlines a range of themes which are considered in detail in each of the book chapters which, taken as a whole, give an in-depth view of what smart agri-food chains are, and the depth of innovation taking place to assure food safety and quality.

Existing agri-food supply chains need to be economically, environmentally or socially resilient for the long term. Developing management systems in agri-food systems occurs in the shadow of many socio-economic and environmental challenges. Global population rise and greater social inequality, contested access to natural resources at local, national and international scales, reconfiguring of global, national and local governance mechanisms, multiple economic, social and environmental vulnerabilities at localised and global system levels, and evolving business models seeking to capture and drive sustainable value all influence what we produce in our global supply chains as well as where, how and when we produce it. To meet these challenges face on we need to ensure our agri-food supply chains have a central focus on food safety and quality and we can do this through collectively become smarter. Rabobank (2015) describes a smarter food system as being "more productive, more (globally) integrated, less wasteful and more profitable. It is more efficient in using resources to produce and deliver the food consumers need, where and when they need and want it, making it more sustainable." The report argues that there are three elements that are required to build smarter food systems: strengthening supply chains, enabling investment and ensuring societal engagement and approval. These are themes that run right through this book.

The book is structured in three sections:

- Part 1 with four chapters considering tracking and traceability;

- Part 2 that focuses on product integrity and malicious contamination and the controls that can be put in place; and
- Part 3 on safety, quality and smart systems.

The chapters are designed to be read as standalone reviews if the reader is interested in a specific topic e.g. the identification of genetically modified organisms (GMOs), crisis management and product recall, quality assessment sampling, yield identification, cool chain monitoring or market supply innovation, but also link with some common themes. The book seeks to answer some contemporary questions:

- What is the difference between tracking, tracing, traceability and transparency?
- What is the topic of foodomics and how do we consider food not just at the macronutrient or micronutrient level, but at the molecular level too?
- How do we characterise food in quality assurance and what do these characteristics reflect… phenotype, genotype, fingerprint etc.
- How do we demonstrate wholeness, integrity and intentional adulteration?
- What aspects of malicious tampering, bad behaviour, do we need to consider in food chains and what assurance processes can we put in place?
- How do we develop food governance structures that support effective crisis management?
- How can we ensure that the samples we test reflect the population (batch, field, orchard) that we would like answers about?
- How does technology help us to grow, store and transport food smarter?
- What are the challenges of sharing information and the data that we collect? What are the options to address these challenges? Can all stakeholders from microbusinesses through to transnational corporations be a part of the transition to smarter food systems?
- How is innovation being enacted across the agri-food supply chain? What does being smart look like right now?

I hope the chapters provide interesting and informative answers to these questions.

In conclusion, I would like to express my thanks to all the authors who have given of their time and their expertise to bring this book together. I have really enjoyed reading the chapters and working to bring them all together over the last year or so. It has definitely been an exciting activity during the pandemic lockdown. I would also like to thank the Publishers for their support and insight into how to bring this book to fruition.

Louise Manning

Reference

Food & Agribusiness Research and advisory (2015). *Building a smarter food system*. Rabobank Available at: http://agfundernews.com/wp-content/uploads/2015/10/Rabobank-Building-Smarter-Food-Systems-report.pdf.

Part 1

Tracking and traceability

Chapter 1

Advances in traceability systems in agri-food supply chains

Samantha Islam, University of Cambridge, UK; Louise Manning, Royal Agricultural University, UK; and Jonathan M. Cullen, University of Cambridge, UK

1 Introduction

Food is a key building block of human physical well-being. Consumers' food purchasing behaviour is influenced by three key food characteristics: safety, quality and authenticity (Wilcock et al., 2004; Kendall et al., 2019). However, the repetitive occurrence of tragic and costly food crises, such as mad cow disease, dioxin contamination, the horse meat scandal, *Escherichia coli* (*E. coli*) outbreaks and *Salmonella* contamination not only diminishes consumers' confidence in food safety, quality and authenticity but also challenges the underlying credibility of the food industries.

The impact of such food safety incidents is amplified by the globalisation of the food trade, which causes transnational food safety issues (FAO, 2019). According to the World Health Organisation (WHO, 2015), approximately 600 million cases of global illness and 420 000 deaths are caused annually by foodborne diseases, and this leads to considerable economic burden owing to the associated use of healthcare services, product recalls and disposal and loss of sales and export. As estimated by the United States Department of Agriculture (USDA), the yearly cost of foodborne illnesses in the US stands at around $10–83 billion (McLinden et al., 2014), while a single foodborne

http://dx.doi.org/10.19103/AS.2021.0097.01

pathogen, *E. coli*, is responsible for an expenditure of $14.42 million a year for healthcare use in the UK (Naylor et al., 2017). On the other hand, border rejections of export consignments result in significant economic loss; for example, owing to the detection of banned antibiotics and *Salmonella*, sea food supply chains in Asian lower- and middle-income countries are routinely disrupted (Blank, 2018). All these incidents, coupled with a more educated and aware public, underpin the increased demand for improved food traceability and for communication of information vis-à-vis food origins, ingredients, processing, quality and safety throughout food supply chains (FSCs) (Rodriguez-Salvador and Dopico, 2020).

Food traceability has been defined by many different organisations, in legislation and in scientific articles. The commonly used definition from ISO 22005 (ISO, 2005) refers to traceability as 'the ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution' (Fig. 1).

The implementation of food traceability requires the adoption of a food traceability system (FTS) – a specific arrangement of processes such as data capture, data storage and data exchange – that is capable of maintaining and communicating the desired product information through all stages of the FSC

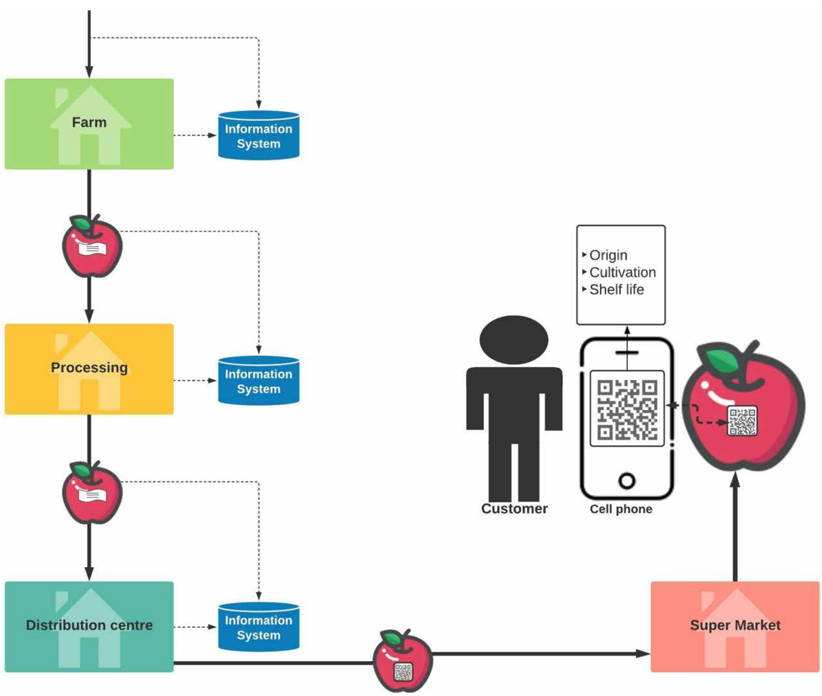

Figure 1 Traceability system in the food supply chain.

(World Economic Forum, 2019). FSCs are becoming increasingly globalised, which poses challenges in guaranteeing symmetry, trust and transparency for the shared product information. Due to their complex and interconnected nature, global FSCs face difficulty in seeking to adopt a single, centralised traceability system architecture – especially if this is in the control of third parties that are monopolistic and opaque in nature. Further, such a centralised traceability system architecture is more vulnerable to collapse, since a single point of breakdown can cause the whole system to crash (Tian, 2017; El Maouchi et al., 2018). Distributed traceability system architectures have emerged as a response to these risks, making use of decentralised information capture and storage to deliver improved information symmetry, security, trust and transparency.

Although manual paper-based traceability systems are still commonly used, deployment of computerised FTSs is rising due to the rapid growth of information and communication technologies (ICTs) and the emergence of Industry 4.0 (the so-called fourth industrial revolution) marked by the automation of production systems. The advancement of FTSs is clearly noticeable in the identification technology practices employed in FSCs, such as the use of radio frequency identification (RFID) which provides increased data capacity, reading speeds and accuracy (McCathie and Michael, 2005; Badia-Melis et al., 2015) and is displacing the extensively used barcode technologies. Wireless sensors can be used to supplement RFID and support traceability-based product quality monitoring (Thakur and Forås, 2015; Alfian et al., 2020; Islam et al., 2021a). These technologies, when integrated with electronic product code information service (EPCIS) data standards, enable efficient product data transfer between supply chain partners (Mainetti et al., 2013) and through to customers. Moreover, blockchain and smart contract technologies allow increased opportunity for transparency and tamperproof data recording in complex and globally distributed supply chains (Pearson et al., 2019).

Despite the availability of such revolutionary technologies, there are various barriers inherent in food systems which impede successful implementation of FTSs in individual companies or in sub-sections of supply chains (Bosona and Gebresenbet, 2013; Hardt et al., 2017; World Economic Forum, 2019). The barriers to the adoption of FTSs include a lack of awareness and training on traceability and traceability technologies; a lack of standards development; resource deficiencies, including funding and capacity issues; inefficient data management; and finally, technology scaling issues (Islam and Cullen, 2021). The intensity of these barriers is influenced by the supply chain structure, its relationship dynamics, and the position of companies within the supply chain (Sterling et al., 2015). To harness the transformative power of breakthrough technologies and exploit the potential for FTSs to transform, FSCs will require clear strategies and pathways to overcome the barriers identified above.

This chapter considers exclusively the advancements in agri-food traceability systems and technologies, the barriers to their implementation and some potential improvement pathways to overcome these.

2 Traceability drivers

Implementation of FTSs is driven by several motivating factors, which are known as controlling forces (Norton et al., 2014) or *traceability drivers* in the literature. Traceability drivers differ across FTSs depending on what type of information the internal or external stakeholders require. A set of five prominent traceability drivers are adopted from Islam and Cullen (2021) and are discussed in the following subsections.

2.1 Legislation and certification

Traceability has been embedded as an indispensable requirement in the food legislation of several countries, including the EU food law 178/2002; the US Bio-terrorism Act and the US Food Safety Modernization Act (FSMA); and Japan's Food Traceability Act (Bechini et al., 2008; Charlebois et al., 2014; Qian et al., 2020). Many of these food laws require the mandatory recording of the identification of immediate upstream suppliers and downstream customers, in what is known as the 'one up-one down' or 'one step forward-one step back' traceability approach.

A key driver motivating many food companies to execute traceability is to meet the necessary legal requirements so that they can stay functional in markets. Some countries agree to abide by traceability regulations to gain access to export markets and introduce their own guidelines. The traceability regulations developed by various parties (e.g. governments, regulators and market actors) are often heavily influenced by the standards developed by the International Organisation for Standardisation (ISO), such as ISO 22005 (ISO, 2005) which defines the functional requirements for the implementation of practical FTSs (Islam and Cullen, 2021). The market driver for independently verifiable FTSs has led to the development of third-party private certification schemes (Norton et al., 2014).

2.2 Safety and quality

Demonstrating compliance with food safety and quality standards emerges as a strong motivating factor for implementing FTSs, driven by persistent shocks and costly disruptions to FSCs, including the European horse meat (scandal) substitution for beef, and more recently, ethylene oxide recalls across Europe and the COVID-19 pandemic. These incidents impact the perceived trustworthiness of FSCs and lead to calls for increased transparency surrounding the safety and quality of food products (Aung and Chang, 2014). The interaction between traceability and transparency in FSCs is gaining wider interest (Baralla et al., 2021; Feng et al., 2020), especially where public health has to be ensured within complex FSCs (Demestichas et al., 2020).

2.3 Customer satisfaction

Food traceability systems both assure and create consumer confidence in the safety and quality of food (Qian et al., 2020; Zhang et al., 2020), especially in a market where consumers have a high level of food safety awareness (Rodriguez-Salvador and Dopico, 2020). The traceability protocols and the designs of FTSs to reduce food safety risks are framed by these consumer preferences (Food Standards Agency, 2002; Garaus and Treiblmaier, 2021). Indeed, Lam et al. (2020) argue that consumer trust in food safety is based on FTSs and information transparency.

2.4 Sustainability

Traceability has become a strong basis for sustainability-related credence claims that are difficult for consumers to ascertain, such as whether a food has been produced through sustainable production practices (Golan et al., 2004). Companies increasingly make use of traceability to validate sustainability claims and gain a competitive advantage from responsible environmental and social practices (Norton et al., 2014; Gallo et al., 2021; Islam and Cullen, 2021; Islam et al., 2021b). For example, traceability helps companies to authenticate that the good animal welfare practices they claim to adhere to are in place, thereby leading to increased organisational reputation (Golan et al., 2004). With regard to fish supply chains in particular, illegal, unregulated and unreported (IUU) fishing can take place without concern for the environment or strict regulations and fishing quotas. Organisations can make use of FTSs to prevent IUU fish entering fish supply chains (Borit and Olsen, 2012). The Marine Stewardship Council (MSC) Standard for seafood sustainability requires batch-level traceability, confirming that there is no presence of IUU fish, from raw produce through to final consumer (Norton et al., 2014; Lin et al., 2020; Islam and Cullen, 2021). Thus, effective FTSs can underpin sustainability claims with regard to a given product.

2.5 Value and efficiency

Inventory management, effective product recall and product distribution are important motivators for companies implementing FTSs (Islam and Cullen,

Index