Czech University of Life Sciences Prague

Faculty of Agrobiology, Food and Natural Resources

Department of Food Science

Czech University
of Life Sciences Prague

Application of Traceability in the Fresh Fruits and Vegetable Supply Chain in Zambia

Master´s thesis

Chomba Lombe
Sustainable Agriculture and Food Security

Prof. Gianluca Brunori, Ph.D
Doc. Ing. Jaroslav Havlík, Ph.D

Declaration

I hereby declare that I have authored this master's thesis carrying the name ***"Application of Traceability in the Fresh Fruits and Vegetable Supply Chain in Zambia"*** independently under the guidance of my supervisor. Furthermore, I confirm that I have used only professional literature and other information sources that have been indicated in the thesis and listed in the bibliography at the end of the thesis. As the author of the master's thesis, I further state that I have not infringed the copyrights of third parties in connection with its creation.

In Prague on 20th April, 2024

____

Chomba Lombe

Acknowledgments

First and foremost, I express my deepest gratitude to God, whose grace, guidance, and blessings have illuminated my path and sustained me throughout this journey. Without His divine presence, none of this would have been possible.

I am profoundly thankful to my thesis supervisor, Professor Gianluca Brunori, Ph.D., from the University of Pisa, and my thesis consultant Doc. Ing. Jaroslav Havlík, Ph.D., from the Czech University of Life Sciences for their invaluable guidance, unwavering support, and insightful feedback throughout the research process.

I am deeply indebted to the international relations staff from the Faculty of Agrobiology, Food and Natural Resources, for their assistance in various aspects during my studies.

Special thanks go to the senior representatives of commercial horticultural farms, aggregators, and supermarkets, as well as representatives from open-air markets, for their willingness to share their knowledge and experiences, which have enriched the results of this study.

I am thankful to the smallholder horticultural farmers in Chibombo District for their participation and cooperation in this research, despite their busy schedules and commitments.

I express my gratitude to all my lecturers, coursemates and other academic minds for their support, encouragement, and intellectual contributions throughout my academic journey.

Lastly, I would like to express my heartfelt appreciation to my family and friends for their unwavering love, encouragement, and understanding throughout this endeavour. Their support has been my source of strength and motivation.

Thank you all for being part of this journey, and may God continue to guide and bless us all.

Application of Traceability in the Fresh Fruits and Vegetable Supply Chain in Zambia

Summary:

The agri-food supply chain is crucial for the production, distribution, and consumption of agricultural products worldwide. However, challenges such as lack of transparency, inefficiencies, and food safety concerns persist. Traceability is used to ensure product safety by tracking the product from farm to fork. Although there have been some studies on traceability in the food supply chain in Zambia, the existing literature particularly on traceability in the fresh fruits and vegetable supply chain is limited. This research aims to examine the current state of traceability practices in the fresh fruits and vegetables (FFVs) supply chain in Zambia.

The study revealed six major processes and the key actors involved in this supply chain. The study also highlights two distinct marketing channels for FFV: formal and informal. The degree of traceability implementation in the formal horticultural supply chain varies across different entities, with some demonstrating robust systems and certifications while others show room for improvement. The informal channel relies on verbal communication and memory, posing challenges in ensuring reliability and scalability. The study suggests using modern technologies, such as barcodes, RFID tags, IoT, and blockchain, as well as traditional methods, such as community-led record-keeping. The obstacles to traceability include high costs, regulatory and policy gaps, and limited resources and capacity. The study suggests investing in scalable and cost-effective traceability solutions, advocating for government support, grants, or incentives, providing financial support and incentives, developing and enforcing clear traceability regulations and standards, providing training and capacity-building, and conducting awareness campaigns and educational programs.

Keywords: Agri-Food Supply Chain, Food Safety, Food Quality, Traceability, Fresh Fruits and Vegetables

Contents

1. Introduction

1.1. Background

The agri-food supply chain is a complex network of processes and stakeholders that ensure the production, distribution, and consumption of agricultural products (Hasan et al., 2023). As global food demand rises, the agri-food supply chain must become more transparent to ensure food safety, minimize waste, and encourage sustainable practices. Historically, the supply chain has been characterized by a lack of transparency, leading to inefficiencies, mistrust, and challenges in ensuring the authenticity and quality of agri-food products (Hasan et al., 2023). To safeguard the health of consumers, it is of utmost importance to implement effective food safety measures throughout the complex agri-food supply chain. This is due to the unique characteristics of the industry which demand strict adherence to quality control and safety standards (Aung and Chang, 2014).

Food safety refers to the guarantee that food is not harmful to consumers when prepared and consumed according to its intended use (CAC, 1997). This is an issue that affects people's health globally, regardless of whether they live in developed or developing countries. Ensuring food safety is a top priority for public health at both national and international levels (Manfreda and De Cesare, 2014). According to Tagarakis et al. (2021) maximizing food safety throughout the entire supply chain is of great importance and constitutes a major challenge towards the development of reliable agri-food supply chains. Recent incidents like the Bovine Spongiform Encephalitis (BSE) outbreak and the melamine incident in China have forced the food industry to prioritize the safety and quality of food products. To ensure product safety, traceability is used as a tool to efficiently track and trace the product from the origin to the end customer, known as 'Farm to Fork' (Narsimhalu et al., 2015).

According to the European Union (EU) regulation 178/2002, food traceability is defined 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*." On the other hand, Islam and Cullen (2021) define food traceability as *"the ability to access specific information about a food product that has been captured and integrated with the product's recorded identification throughout the supply chain*." Traceability not only enhances food quality and safety standards but also significantly improves other aspects of the food supply chain. It aids in providing consumers with detailed information about the production process, including cultivation methods, use of pesticides or fertilizers, and adherence to hygiene protocols (Tagarakis et al., 2021). Traceability also promotes information transparency across the supply chain, enabling stakeholders to make informed decisions about sourcing, production, and distribution. Additionally, traceability enhances security measures within the food supply chain by enabling better monitoring and control of product movements, thereby detecting and preventing unauthorized activities. Therefore, traceability contributes to the overall resilience and sustainability of the food supply chain, meeting the evolving needs and expectations of consumers in today's dynamic market environment.

Aung and Chang (2014) also highlight the importance of traceability systems for the food industry in preventing the production and distribution of unsafe products. These systems allow for the tracking and documentation of product movements throughout the supply chain, facilitating the identification and containment of potential hazards or quality issues. They also help mitigate liability risks by providing clear records of product origins, handling procedures, and distribution pathways. Effective traceability systems can prevent costly product recalls by promptly identifying and isolating affected products, which saves resources and preserves consumer trust and brand reputation.

In food traceability systems, two main functions are crucial: tracing and tracking. Tracing involves identifying the origin and relevant characteristics of a product by retracing its path upstream in the supply chain, while tracking entails continuously monitoring the product's movement downstream, from production to consumption. Tracing allows for a comprehensive understanding of a product's history, while tracking ensures real-time monitoring and visibility within the supply chain (Bechini et al., 2008; Dabbene et al., 2014; Samarasinghe et al., 2021). Together, these functions form the foundation of a reliable food traceability system, enabling stakeholders to maintain control over the entire lifecycle of a product, enhance food safety and quality assurance, and respond swiftly and effectively to incidents such as recalls or outbreaks.

Many countries have incorporated rules and regulations to ensure food safety through enhanced traceability (Samarasinghe et al., 2021). The European Union (EU) is the most advanced in food traceability due to its comprehensive traceability laws that encompass a wide range of food and animal products, both domestic and imported. In contrast, many other countries have only been successful in ensuring traceability regarding animal products (Charlebois et al., 2014). In the United States of America (USA) food producers have developed an enormous capacity to track the flow of food along the supply chain, though individual systems vary. Some traceability systems are deep, tracking food from the retailer back to the farm, while others extend back only to a key point in the production process (Golan et al., 2004). Canada has implemented food traceability regulation, 'Safe Food for Canadians Regulations' (SFCR) under the Canadian Food Inspection Agency that came into force in 2019 to track food movements one step back and one step forward. Though, it is at the initial stage of implementation (Samarasinghe et al., 2021).

In Africa, Kenya is among the leading countries that has implemented food traceability systems. According to Chemeltorit et al. (2018) and Ouma (2010) the Kenyan horticulture sector has greatly benefited from the evolution of global food safety standards and local conditions, which has encouraged producers and policymakers to collaborate to enhance the competitiveness of the sector on a global scale. For instance, the national horticulture traceability system (HTS) was launched through a partnership between the public and private sectors, aimed at making the horticulture sector more competitive. Although smallholder producers are unaware of the traceability systems, currently being implemented in the Kenyan horticulture sector, it is important to educate these producers on their importance.

1.2. Problem Statement

The fresh fruits and vegetable industry is crucial to Zambia's economy, providing year-round production and marketing opportunities while driving farmer incomes (Mulenga et al., 2021). However, the sector is facing challenges in ensuring comprehensive traceability throughout its supply chain. The industry's formal and informal sectors have distinct traceability practices, posing food safety and market competitiveness issues. Although larger-scale commercial operations have established traceability systems, technological limitations, and complex supply chain dynamics hinder their effectiveness. Conversely, small-scale farmers and local markets lack structured traceability practices because of limited access to technology and resources (Hichaambwa and Tschirley, 2010). This disparity in traceability practices exacerbates the risks to food safety, product quality, and market access, posing significant challenges to the industry.

Although there have been some studies on traceability in the food supply chain in Zambia, the existing literature particularly on traceability in the fresh fruits and vegetable supply chain is limited. Mukuni (2022), for instance, conducted a study on Risk Cultures, Beef Traceability, and Food Safety in the United States and Zambia. The study focused on the differences and similarities in approaches to food safety in the United States and Zambia, specifically regarding the beef industry. Although the paper is a notable reference for this present study, the main focus of their study being the beef industry in the two countries leaves a gap in research focused on the fresh fruit and vegetable value chain. In Zambia, this knowledge gap not only undermines efforts to improve the competitiveness of the sector but also exposes consumers to potential health hazards. Therefore, there is an urgent need for further research to investigate the current state of traceability practices in Zambia's horticulture sector and identify opportunities for improvement.

1.3. Significance of Study

The study will fill the knowledge gap by providing a comprehensive overview of the current traceability practices in the fresh fruits and vegetable sector in selected areas in Zambia. The study will also identify the factors that hinder the effectiveness of traceability systems and will propose strategies to improve them. The findings of the study will also help policymakers, industry stakeholders, and researchers assess the competitiveness of the sector, thus improving food safety and increasing market access. Additionally, the study will contribute to the body of knowledge on traceability practices in the agribusiness sector, particularly in developing countries, where food safety and quality are critical issues.

2. Scientific Hypothesis and Objectives of the Thesis

2.1. Aim of the Research

This research aimed to examine the current state of traceability practices in the fresh fruits and vegetables (FFVs) supply chain in Zambia. The provides useful information for policymakers and industry players, by identifying key challenges and opportunities and showcasing the best practices to enhance traceability and improve food safety, quality control, and market access in the fresh produce supply chain. To achieve this aim, the study pursued the following specific objectives:

1. Identify key players, their roles, and interactions within the FFV supply chain.
2. Assess the degree of traceability implementation by these stakeholders in the FFV supply chain.
3. Investigate the traceability systems and technologies employed in the FFV supply chain.
4. Identify the obstacles to traceability in the horticulture supply chain.

1.1. Research Questions

1. Who are the key players in the horticulture supply chain, and how do their roles and interactions contribute to the overall flow of products from production to consumption?
2. What are the current traceability practices in the FFV supply chain?
3. Are there traceability systems and technologies in the FFV supply chain?
4. What are the primary obstacles to the successful implementation of traceability systems in the horticulture supply chain, and how can these challenges be effectively addressed

2.2. Research Hypothesis

The implementation of effective traceability systems in Zambia's fresh fruits and vegetable supply chain has the potential to improve quality control, decrease food safety risks, lower losses, and increase overall efficiency throughout the supply chain. This can have a positive impact on consumer trust, market competitiveness, and sustainability.

2.3. Conceptual Framework

Connecting the movement of products with the information related to them is essential when establishing and implementing a traceability system in a supply chain. Consistent adherence to industry standards for traceability procedures guarantees mutual understanding among all involved parties regarding the identification of traceable items. This practice promotes openness and consistency of information throughout the entire supply chain (Zhang and Bhatt, 2014). This study adopts the conceptual framework of a food traceability system as shown in Figure 2.1 (Aung and Chang, 2014), this framework is appropriate because it describes internal traceability within the establishment as well as external traceability between the fresh fruits and vegetable (FFV) supply chain actors. The description of supply chain activities is not the only aspect, it also includes critical success factors such as food quality and safety regulations for achieving chain traceability. Food supply chain activities and the elements necessary to achieve chain traceability are more thoroughly described in this framework. Like any other system, a food traceability system is made up of several components that are essential for its effective operation (Aung and Chang, 2014).

2.3.1. External Traceability

External Traceability refers to the exchange of information between companies involved in the food supply chain, regarding a specific product. This traceability encompasses every stage of the chain, from agricultural production to distribution, allowing for complete tracking of the product's journey (Haddad et al., 2019).

To ensure traceability of products, it is important to assign a unique identification number to each item and share information about it with all parties involved in the distribution channel. This identification can be achieved by assigning a;

- Unique product identification number and
- Batch/lot number.

In order to maintain external traceability, it is necessary to communicate the traceable item identification numbers through product labels and business documents. This helps in linking the physical products with the necessary information for traceability, and allows tracking back to suppliers and forward to clients (ITC, 2015; Zhang and Bhatt, 2014).

2.3.2. Internal Traceability

According to Haddad et al. (2019), internal traceability refers to the ability to track a product within an organization, including any raw materials or consumables that undergo internal processing such as displacement, storage, processing, or destruction.

To ensure internal traceability within a company, it is essential to have a system that connects the identities of the raw materials with the finished products. Whenever different materials are combined, processed, repacked, or reconfigured, the end product should have its unique identification. It's crucial to keep a record of the link between the new product and its original materials, including batters, breading, marinades, seasonings, packaging materials, salt, and other inputs. A label with the lot number of the traceable input item should be attached to the packaging until the entire traceable item is used up, even if the item is part of a larger packaging hierarchy such as cases, pallets, or shipment containers. (ITC, 2015; Zhang and Bhatt, 2014).

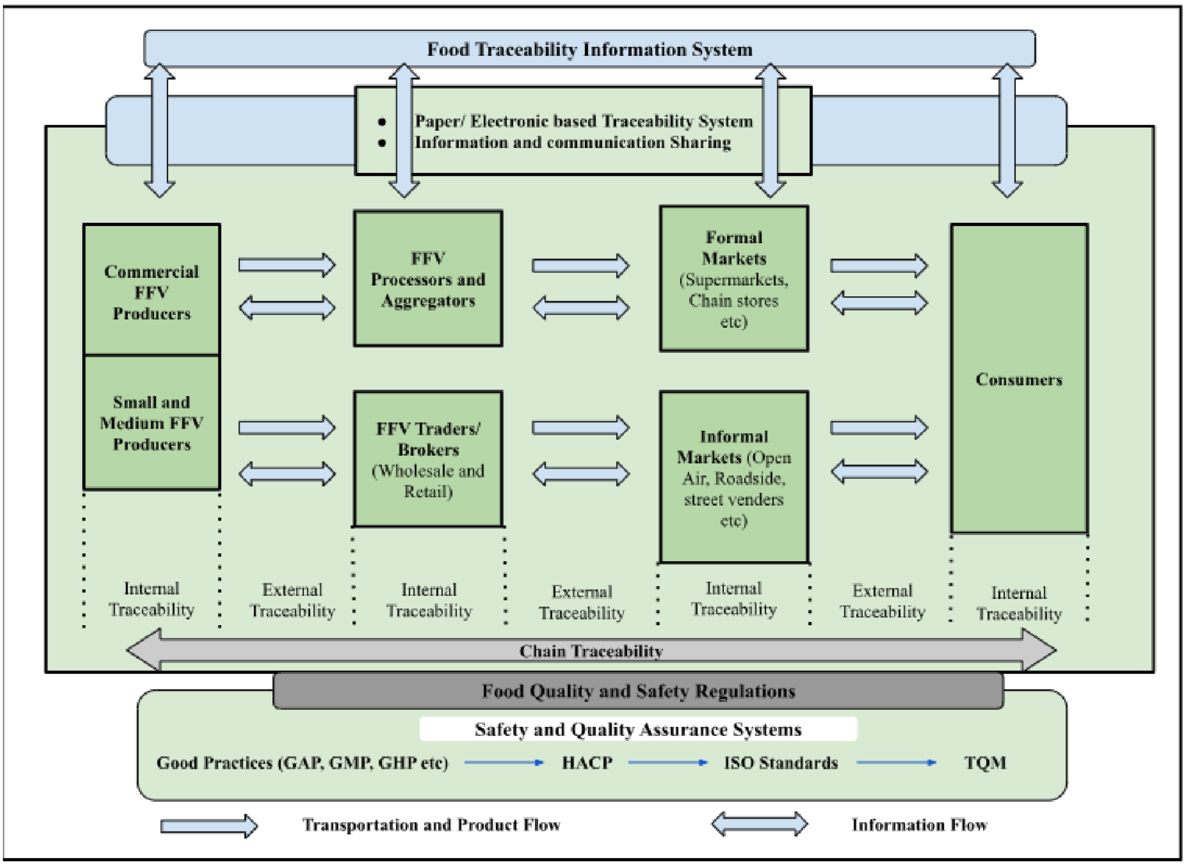

Figure 2.1: Conceptual Framework of the study
Source: Adapted from Aung and Chang (2014)

3. Literature Review

3.1. Introduction

Food safety has become a major concern for people in various nations across the globe due to the rise in animal-borne diseases, like avian flu, and the presence of harmful chemicals in food and animal feed. The recall of unsafe food products has become necessary to safeguard people from food-related illnesses. Traceability is a crucial risk management measure that helps food business operators and authorities track and respond to the need for safe food products. It plays a crucial role in the food safety policy of every country (ITC, 2015).

3.2. Defining Traceability

Traceability has been defined differently by various organizations, legislative bodies, and academic sources (Bosona and Gebresenbet, 2013; EU, 2002; ISO, 2000). They have all provided their unique definitions and perspectives on traceability. This indicates that traceability is a complex concept that operates in diverse situations. As a result of varying perspectives among stakeholders, there is no universally accepted definition of traceability, leading to different interpretations of its significance across different regions and industries. It is important for all parties involved in the food supply chain to work together and have meaningful conversations to develop mutually agreed upon guidelines that encourage successful tracking processes (Behnke and Janssen, 2020).

According to the ISO 9000:2000 guidelines, traceability is defined as *the ability to trace the history, application, or location of that which is under consideration* (ISO, 2000). The guidelines provide additional details, indicating that traceability could pertain to the source of materials and components, the manufacturing process, as well as the delivery and post-delivery distribution of the product. Golan et al., (2004) however, state that this definition of traceability that has been provided is quite general. It does not mention any specific metric for the item being traced (such as a single grain of wheat or an entire truckload), a standard size for the location (like a field, farm, or county), a list of procedures that must be recognized (such as the use of pesticides or animal protection), the format for recording information (whether it should be on paper or in an electronic record, box, container or even the product itself), or any specific technology for record-keeping (such as pen and paper or computer-based systems).

The European Union's regulation 178/2002 provides a narrow definition of traceability concerning food products 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* (EU, 2002). On the other hand, the Codex Alimentarius Commission's definition is more concise and focuses on *the ability to track the movement of food at specific stages of production, processing, and distribution* (CAC, 2005).

However, Islam and Cullen (2021), provide a revised definition of traceability as below:

"Food traceability is an ability to access specific information about a food product that has been captured and integrated with the product's recorded identification throughout the supply chain."

In a Food Traceability System (FTS), two main functions are crucial: tracing and tracking. Tracing involves identifying the origin and relevant characteristics of a product by retracing its path upstream in the supply chain, while tracking entails continuously monitoring the product's movement downstream, from production to consumption. Tracing allows for a comprehensive understanding of a product's history, while tracking ensures real-time monitoring and visibility within the supply chain (Bechini et al., 2008; Dabbene et al., 2014; Samarasinghe et al., 2021). Together, these functions form the foundation of a reliable food traceability system, enabling stakeholders to maintain control over the entire lifecycle of a product, enhance food safety and quality assurance, and respond swiftly and effectively to incidents such as recalls or outbreaks.

3.3. The Depth, Breadth, and Precision of Food Traceability Systems

Food traceability systems aim to record essential information that contributes to achieving specific objectives, such as ensuring food safety, enhancing supply chain transparency, or enabling regulatory compliance. However, considering the vast array of attributes associated with food, it is crucial to prioritize the collection of relevant information that directly serves the intended purpose. For instance, critical attributes for food safety may include information about the origin of ingredients, processing methods, storage conditions, and distribution channels, while attributes like color, taste, or aesthetic qualities may be less important. Therefore, the *breadth* of a traceability system describes the amount of information that the system records and should be tailored to capture pertinent attributes while avoiding unnecessary data collection to remain manageable, relevant, efficient, and cost-effective (Golan et al., 2004).

The extent to which a traceability system can track backward or forward is referred to as its *depth.* The extent of a system is vital in deciding how profound it can be. The depth of the system may be determined by safety or quality checkpoints throughout the supply chain. In some cases, the traceability system may only need to go back to the last control point where the safety or quality was checked or confirmed. For example, a traceability system for pathogen control may only need to extend to the last step where the product was treated, cooked, or irradiated, known as the "kill" step (Golan et al., 2004).

The accuracy of a traceability system in identifying a particular food product's movement or characteristics is known as *precision*. Precision depends on the unit of analysis and the acceptable error rate used in the system. The tracking unit, be it a container, truck, crate, or any other unit, determines the precision of the traceability system. For example, when using large tracking units, such as an entire field or storage facility, it can be difficult to identify specific batches or lots with precision. On the other hand, using smaller units, like individual plots or harvest crates, improves precision by allowing more detailed tracking and monitoring of specific crops or batches throughout the production process. Similarly, systems with low acceptable error rates are more precise than those with high error rates. Depending on the goals of the system, either a precise or less precise system may be necessary (Golan et al., 2004).

3.4. Divers of Food traceability

Drivers refer to the factors that motivate or control the need for a Food traceability system. These drivers differ depending on the specific information needs of the stakeholders throughout the supply chain (Norton et al., 2014; Thakur et al., 2011) and they can be grouped into broad categories as represented in Figure 3.1 by Aung and Chang (2014). In addition to these aspects, there is a rising need for improved tracking in worldwide food supply networks due to mounting concerns about the environment, society, and corporate governance, which are often referred to as ESG factors (Aung and Chang, 2014; World Bank, 2022). To gain a competitive edge and safeguard their brand reputation, businesses use traceability of food origin and transparency of worker conditions and processing methods to differentiate their products and supply chains from those that may involve modern slavery, such as forced and child labor (Aung and Chang, 2014).

Figure 3.1: Drivers of traceability
Source: Aung and Chang (2014)

Islam and Cullen (2021) further streamlined these drivers into five categories which are discussed below:

3.4.1. Food Safety and Food Quality

The need for traceability in food is driven by concerns about both food safety and. Quality is determined by the features and characteristics of a product that affect its ability to meet the needs of consumers quality (ISO, 2000). Meanwhile, food safety guarantees that food will not harm consumers if it is prepared and consumed correctly, covering various kinds of hazards that can cause harm to health (CAC, 2005). Incidents like mad cow disease, dioxin contamination, horse meat scandals, E. coli outbreaks, and COVID-19 have disrupted food supply chains (Aung and Chang, 2014; Islam and Cullen, 2021). These events can damage the credibility of food industries and cause consumers to worry about safety and quality. To mitigate these risks, many food industries use food traceability systems which allow stakeholders to quickly respond to food safety incidents, conduct targeted recalls, and maintain consumer confidence in the safety and integrity of food products. By adopting Hazard Analysis Critical Control Point (HACCP) and traceability, firms can manage safety hazards more effectively (Tian, 2017). Additionally, traceability can help reduce food quality loss by providing time-temperature information management (Thakur and Forås, 2015).

3.4.2. Legislation and Certification

In many countries, some laws require tracking of food products throughout the supply chain. For instance, the EU Food Law 178/2002 mandates that all food and feed products sold within its member nations should have a traceability system in place. Similarly, the US Bioterrorism Act of 2002 requires all individuals involved in the food supply chain to maintain records. Other countries with similar laws include China, Japan, and New Zealand, among others(Bechini et al., 2008; Charlebois et al., 2014; Geng et al., 2015; Islam and Cullen, 2021; Qian et al., 2020). Compliance with these legal requirements is a crucial factor that drives food companies to implement traceability systems. Businesses must ensure that they adhere to food safety regulations and industry standards to maintain market access and operational continuity. Regulatory bodies impose strict requirements on food companies to trace the flow of food products throughout the supply chain, from raw materials to finished goods, to mitigate the risks associated with foodborne illnesses, contamination incidents, and mislabeling. Food companies failing to comply with these legal requirements may face severe consequences such as fines, legal liabilities, and reputational damage. Furthermore, non-compliance could result in market exclusion, as regulatory agencies and retailers increasingly prioritize sourcing products from suppliers that can demonstrate robust traceability systems and adherence to food safety standards.

According to Aung and Chang (2014), ensuring effective traceability in the supply chain involves following universal standards that promote seamless communication between various traceability systems. The GS1 global traceability standard is a voluntary business process standard that outlines the traceability procedure while remaining unbiased towards the selection of technology. This standard provides a unique identification code for trade items, assets, logistics units, parties, and locations across the world, making it an ideal choice for implementing traceability (GS1, 2012). EPC Global Inc. is a company that operates under the umbrella of GS1. Its main objective is to promote the use of Electronic Product Code (EPC) Information Services (EPCIS) as a standard solution for facilitating the sharing of EPC-related data across different organizations and businesses (EPC Global, 2009). The ISO has developed standardized guidelines that can assist governments, regulators, and market players in enhancing their traceability regulations. This can lead to uniformity and help prevent technical trade barriers globally (ISO, 2000). Additionally, there are various private food quality and safety standards available, such as Eurep-GAP, the International Standard for Auditing Food Suppliers (IFS), the British Retail Consortium (BRC), Safe Quality Food (SQF), Good Agricultural Practice UTZ, and many more (Norton et al., 2014).

3.4.3. Sustainability

Increasingly, companies are facing pressure from various stakeholders to disclose information about their products that assures their supply chain processes are socially and environmentally responsible. News stories that bring attention to issues such as deforestation, conflict minerals, and animal welfare are becoming more prevalent in the media. Hence, it has become crucial for companies to ensure that their products are sustainable, which can be achieved by verifying the sustainability claims associated with their products. By implementing traceability systems, companies can keep track of their products and materials throughout the supply chain, ensuring that socially and environmentally responsible practices are being followed at every stage (Norton et al., 2014). Third-party audits play a crucial role in maintaining positive relationships with stakeholders by verifying the sustainability claims made by companies. To ensure sustainability and share data with stakeholders, companies can utilize traceability systems. For instance, the Marine Stewardship Council (MSC) has set standards for seafood sustainability that require tracing the entire supply chain from raw material sourcing to product consumption at a batch level. Traceability methods can also be used to verify the implementation of ethical animal welfare practices (Golan et al., 2004).

3.4.4. Efficiency and Value

Organizations are motivated to establish Food Traceability Systems due to the significance of inventory management, efficient product recall, and product distribution (Bourlakis and Bourlakis, 2006). By implementing a traceability system, companies can uncover operational efficiencies and process consistencies that can be replicated for better performance. Numerous companies have reported improved comprehension of their supply chain and the challenges it poses after implementing traceability systems (Norton et al., 2014). Implementing traceability at various stages in the supply chain can help identify effective processes and areas that need improvement. Sharing data and documentation related to traceability implementation can promote discussion about process improvements and spread best practices throughout the supply chain. Traceability standards are crucial for sound business management, resulting in advantages such as product quality and sustainability. Once identified, risks associated with vulnerabilities in the supply chain can be dealt with by switching to reliable alternatives or jointly resolving them.

3.4.5. Customer and Consumer Satisfaction

The need for complete traceability data from those who grow food is on the rise because of the increased attention to food safety concerns and a more knowledgeable population (Rodriguez-Salvador and Dopico, 2020). Customers are now looking for food packaging that assures them of food from a credible, ethical, and sustainable source. Studies by Souza-Monteiro and Caswell (2005), have shown that consumers place a high value on the credibility of the source of information when it comes to purchasing products. Most consumers are willing to pay more for products that come with a guarantee on the origin and production practices. However, research has also found that traceability on its own is not highly valued by consumers. Instead, it is more valuable when it is associated with attributes such as food safety assurance and animal welfare, and when the information is provided before consumption (ITC, 2015).

The results of a survey conducted in the EU showed that consumers are willing to pay more for high-quality meat and vegetables, and are more confident in them if there is a guarantee on their origin and production practices (Arnould and Thompson, 2005; ITC, 2015). Numerous surveys have also indicated that a vast majority of consumers in the EU and US are willing to pay an additional amount for products that have Country of Origin Labelling (COOL) and geographical labelling and certifications (Arnould and Thompson, 2005; ITC, 2015). To provide this information and increase consumer trust, allowing them to endorse producers who prioritize food safety, sustainability, and ethical standards, food traceability systems (FTSs) act as an efficient medium for food supply chains. Companies in Europe began implementing food traceability systems in response to customer preferences even before they were legally required to do so. This shift in consumer demand often precedes the development of formal traceability policies and the design of food traceability systems (Azuara et al., 2012).

3.5. Food TraceabilityBeneficiaries

Various parties receive food traceability services, and there are differences in the complexity and communication level based on the stakeholders involved. (Bendaoud et al., 2012). Below are some of the major beneficiaries of Food Traceability Systems:

3.5.1. Food Producers and Growers

Producers and growers play a crucial role in the food supply chain. They are the primary beneficiaries of traceability services which help them monitor and manage different aspects of food production, from sourcing raw materials to cultivation practices, handling procedures, and compliance with food safety regulations. Traceability data offers valuable insights that enable producers and growers to optimize their operations, mitigate risks, and ensure the quality and safety of their products (Islam and Cullen, 2021; Norton et al., 2014).

3.5.2. Consumers and the Community

It's extremely important to have traceability in the food industry as it helps to build trust and confidence among customers by providing assurance about the origin of the food products. Interestingly, consumers are willing to pay more for food items that can be traced back to their source. For instance, Canadian customers are willing to pay an additional amount for meat products that possess traceable quality attributes (Zhang et al., 2012). According to Jin and Zhou (2014), customers in Japan are interested in the date of harvest, production method, and production certification of fresh produce. Traceability helps consumers make informed decisions about the products they purchase by providing detailed information about their environmental and social impacts. With the advent of smartphone apps, consumers can now scan QR codes on product packaging to learn more about the origin and impact of a specific food item (Norton et al., 2014).

3.5.3. Stakeholders and Business Partners

Many key players in the food industry, such as restaurants, exporters, and grocery stores, require their suppliers to have reliable Food Traceability Systems (FTSs) that can quickly and effectively manage food recalls. For instance, Walmart, a well-known retailer in the United States, has mandated that its suppliers have trace-back capability for delivered food based on radio-frequency identification (RFID), according to Smith et al., (2005). The information provided by the suppliers' traceability system helps supermarkets with optimal sourcing, inventory ordering, sales tracking, and identifying customers who have purchased problematic products. FTSs also aid in validating certain product attributes, such as nutrient content and country of origin, which are difficult to observe. This validation is made possible by the information collected in the system, as mentioned in Golan et al., (2004).

3.5.4. International Standardization, Non-governmental Certification, and Public Bodies

Entities that are accountable for creating public and international standards, as well as non-governmental certification, have a vital role to play in ensuring the safety of customers, animals, and the environment. These organizations benefit greatly from using Food Traceability Systems (FTSs). The US FDA, for example, scrutinizes the background of food items to detect any element that might pose a danger to public health (Smith et al., 2005).

European Union public authorities utilize information on fish catch statistics to plan and oversee fishing activities (Anne-Marie Donnelly et al., 2012). Technical experts are leading traceability implementation projects, which are contributing to the development of international standards and guidelines. The TraceFood framework, which was designed and tested by the EU-funded Trace project, has led to the creation of ISO standards that mandate a set of data elements to be tracked in finfish supply chains (Olsen, 2018). Additionally, non-governmental certification bodies like MSC and UTZ collaborate with stakeholders across the value chain to identify critical traceability information and establish a dependable chain of custody standards for food products (Norton et al., 2014).

3.5.5. Food Business Operator

Traceability is a system that enables food businesses to keep track of food products from the farm to the consumer. It provides detailed information about the origin, processing, and distribution of food items, ensuring quality control throughout the supply chain and reducing the risk of contamination or spoilage. Businesses with advanced FTS systems tend to have better coordination along their supply chains (Golan et al., 2004). Implementing traceability systems helps food businesses comply with food safety and labeling regulations and manage risk by quickly identifying and responding to food safety incidents or product recalls (Dabbene et al., 2014). Producers use traceability to distinguish their products from others by providing attributable information on the food product's packaging. Certain credentials such as country-of-origin, organic, free-range, or earth-friendly are highly valued by customers, providing a competitive advantage, increasing sales, and enhancing the brand value. Traceability is crucial to support product claims and create viable markets for distinguishable products with latent attributes (Islam and Cullen, 2021).

3.5.6. Scientific Community

Food traceability systems (FTS) benefit the scientific community in numerous ways. Traceability data provides valuable information for research related to food safety, nutrition, and sustainability (Norton et al., 2014). Scientists can analyze data on food origins, production methods, and supply chain practices to better understand factors affecting food quality, safety, and environmental impact. This data helps to identify trends, assess risks, and develop policies. Traceability systems also contribute to food safety and public health research by providing insights into the prevalence and causes of foodborne illnesses and outbreaks. By analyzing traceability data, scientists can identify patterns of contamination, trace the source of foodborne pathogens, and assess the effectiveness of food safety interventions. Similarly, traceability data supports scientific research on environmental sustainability and resource management in food production systems.

3.6. Traceability Tools and Digital Technologies for Food Traceability

Automated data collection can be a powerful tool to save time and money on data processing and maintenance. Manual data collection for large operations is a tedious process that involves workers recording information at the location and then either relaying it manually or typing it into a computer system. This approach can result in incorrect data recording, leading to inventory inaccuracies and stock issues. Therefore, most traceability initiatives rely on technology to provide efficient and accurate ways to track and trace products through the supply chain. This involves using technology for product identification, data capture, analysis, storage, and transmission, as well as integrating overall systems (ITC, 2015).

3.6.1. Alphanumeric Codes

One can present and document information using handwritten or printed notes, which is a low-cost method (McEntire et al., 2010). Alphanumeric codes, which comprise a diverse array of sequences containing both letters and numbers, are a vital component of labeling systems. They are utilized as unique identifiers to facilitate efficient organization, tracking, and management in various domains. With a broad range of sizes and complexities, alphanumeric codes offer a flexible means of encoding information, accommodating diverse data structures and formats. However, this approach has some obvious drawbacks such as the possibility of illegibility, transposition, language barriers, fading, physical damage, and so on (McEntire et al., 2010). In recent years, the advent of barcodes has revolutionized the landscape of labeling and identification. The use of barcodes as a means of encoding and retrieving information marks a significant change from the traditional alphanumeric codes. Although alphanumeric codes still have their uses in some situations, the speed and precision offered by barcodes have made them the preferred choice for modern labeling technologies (Aung and Chang, 2014)

3.6.2. Barcodes

Barcodes are a type of optical machine-readable data representation that is attached to an object. They are created by varying the widths and spacing of parallel lines or geometric patterns in two dimensions. Barcodes were initially scanned using specialized optical scanners known as barcode readers, but technological advancements have led to the development of interpretive software and scanners on various devices like desktop printers and smartphones. These developments have made it easy to scan barcodes to retrieve relevant data (ITC, 2015). According to Zhang and Bhatt (2014), barcoding is still the most common industry best practice for labeling packaging hierarchies for shipping logistics units, including cases, pallets, shipment containers, and consumer items. This is because barcode technology provides accurate and fast identification of products, as well as recording and sharing of product information throughout the supply chain.

A research carried out in Vietnam by the World Bank in 2022 highlighted the appropriateness of using barcodes for tracking Fruits and Vegetables (F&V). This is because most of the participants in this supply chain are small to medium-sized and lack sufficient financial resources and knowledge of technologies. Therefore, since barcodes are affordable and easy to use, they are the best option for these parties. By assigning a lot or batch number or by tote or container, fruits and vegetables can be tracked in bulk.

3.6.3. Radio Frequency Identification (RFID)

RFID devices are small chips or tags that use radio waves to transmit data. They have a memory function and can be battery-powered. With RFID, products can be tracked remotely in real-time throughout the supply chain (Zhang and Bhatt, 2014). There are two types of RFID devices: active devices, which constantly transmit a signal, and passive devices, which are only read when near an antenna. By tagging items with RFID tags, users can easily identify and track inventory and returnable assets, such as totes and pallets (World Bank, 2022).

RFID technology offers a fast and reliable way to track items without having to scan individual barcodes or QR codes. By strategically placing antennas and readers, objects can be easily identified throughout the logistics process. With RFID, it is easier to receive products, deduct them from inventory, and reload them onto trucks for delivery to customers. RFID can also help locate missing items on site, reduce transcription errors, and minimize data duplication. Compared to barcodes, RFID can store more data, allowing for increased data volume and more information to be captured and available. Moreover, most read/write tags can be locked to prevent data from being altered, ensuring data integrity (World Bank, 2022).

When businesses are considering implementing RFID technology, there are two important factors to keep in mind. Firstly, they need to have enough financial resources to ensure a return on investment, as the implementation of the technology can be expensive. It is essential to conduct cost-benefit analyses that take into account both procurement costs and long-term maintenance costs. Secondly, it is crucial to assemble a team that is knowledgeable about RFID technology to develop and deploy the system throughout the supply chain. Prior to final system configuration, it is necessary to conduct extensive testing and piloting with various types of equipment and tags, including antennas, readers, and software. The implementation of RFID technology also leads to a change in the volume of product data by around 30% (Shah and Murtaza, 2010), which requires enhanced data analysis and interpretation capabilities. The real-time transmission of data adds to the complexity of managers' ability to process information on time. As a result, automating many routine tasks becomes necessary, so that managers can handle alerts and exceptional cases and make quick decisions in a fast-paced environment (World Bank, 2022).

3.6.4. Near Field Communication (NFC)

NFC is a technology that allows wireless data transmission between two devices at close range. It is an evolution of RFID technology and is commonly used for contactless payments through devices like smartphones, tablets, passports, and credit cards. While NFC has limited applications in the food supply chain, it could be used to authenticate expensive packaged foods and detect counterfeits by embedding it into their materials.

However, for the successful implementation of NFC technology in the F&V industry, users need to have both technical and financial resources. Additionally, it is necessary to have an existing infrastructure, such as cloud storage systems, to support the implementation of NFC. This technology is feasible for large cooperatives and farming companies with adequate labor skills and financial capabilities (World Bank, 2022).

3.6.5. Internet of Things (IoT)

The IoT is a network of connected devices that can gather and share data. Within the agri-food supply chain, IoT devices can monitor important parameters like temperature, humidity, and location, thereby ensuring that food products are of high quality and safe for consumption (Hasan et al., 2023).

Automating farming tasks such as irrigation, pesticide, and fertilizer application can save farmers time and effort. A good example of this is drip irrigation and nutrition systems, which allow farmers to operate pump systems remotely instead of manually opening and closing them up to eight times a day. Therefore, IoT can be used in agriculture to increase productivity, meet the growing demand for food, reduce costs, promote environmental sustainability, enable data-driven decision-making and improve the quality of agricultural products. By implementing IoT-enabled devices and sensors, farmers can monitor their crops and conditions in real-time, make informed decisions, prevent problems, and automate farming practices (Doshi et al., 2019; World Bank, 2022; Yasay, 2021).

Battery longevity is a major concern for IoT applications because the application layer is often unaware of how much battery power is left, which makes it difficult to determine when the device requires a battery replacement. Additionally, devices that are employed in harsh environments may have a shorter lifespan, which makes it difficult to manage system reliability. Remote locations, poor internet connectivity, and high up-front investment costs are some of the other challenges associated with implementing IoT systems in farming (Doshi et al., 2019; World Bank, 2022; Yasay, 2021).

3.6.6. Blockchain

Blockchain technology, often associated with cryptocurrencies, can revolutionize the agri-food supply chain by providing transparency, traceability, and trust. It offers a decentralized ledger system that records every step of the supply chain process in a secure and immutable manner, ensuring that information about food products remains transparent and tamper-proof. This mitigates risks such as fraud, contamination, and counterfeit goods. The use of blockchain can enhance the efficiency and effectiveness of the industry while increasing consumer confidence in food safety and quality (Hasan et al., 2023).

According to Ahmad and Bailey (2021), Blockchain technology offers several benefits for food traceability. These include complete traceability of the food supply chain from the farm to the fork, recording of all transactions, digital tracking, decentralized file systems, visualization methods to display risks, and the ability to reconstruct the product's history for quality verification.

Rejeb et al. (2020) explained that blockchain technology has great potential to transform the food industry by providing enhanced visibility, transparency, and data integrity. The immutability of the technology can improve trust in extended food supply chains by enabling traceability, efficient recall, and reducing the risk of counterfeits and illicit trade. Additionally, blockchain can ensure the credibility of claims such as sustainably sourced, organic, kosher, or halal by integrating the authoritative source of the claim into the blockchain to verify its authenticity and provide reassurance to business customers and end consumers.

Organizations may encounter certain advantages and difficulties when utilizing blockchain for food traceability. Rejeb et al. (2020) have outlined these potential benefits and challenges in Figure 3.3.

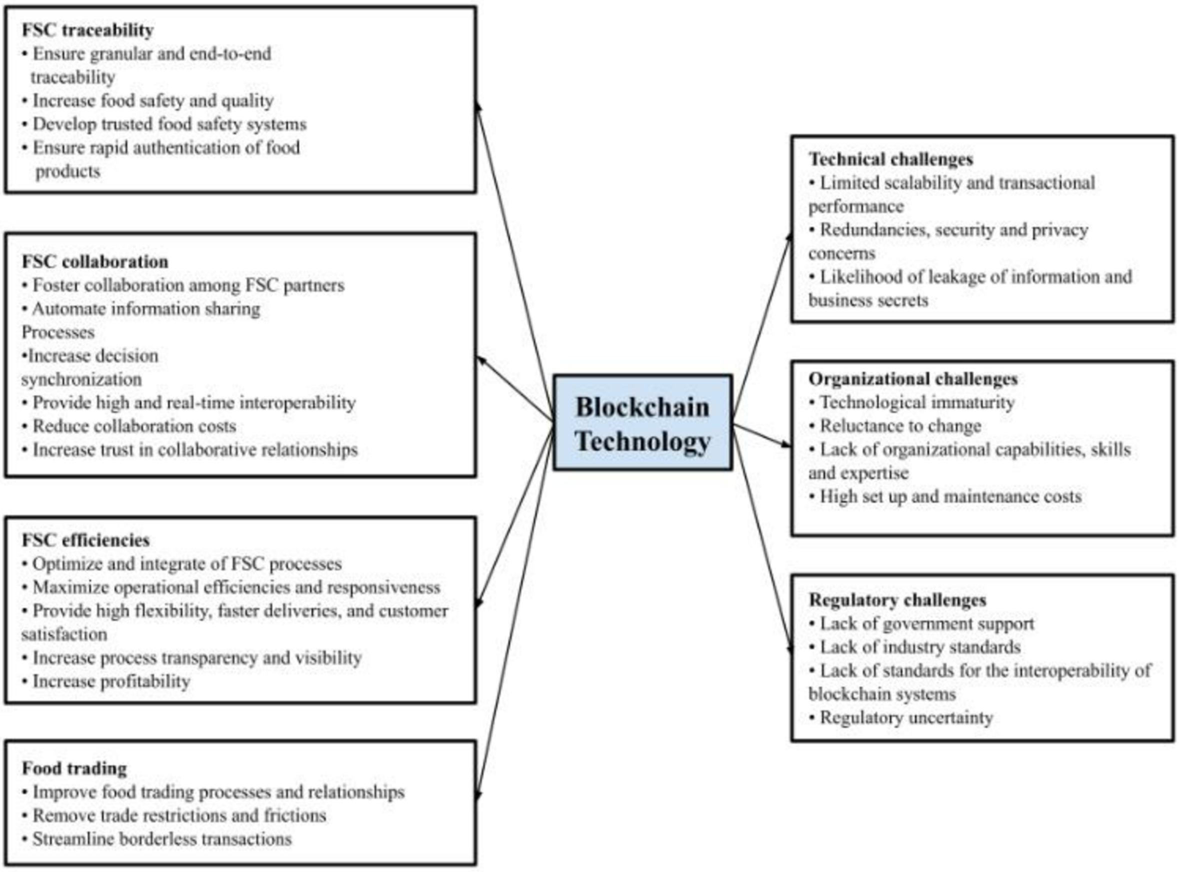

Figure 3.3: Potential benefits and challenges of blockchain
Source: Rejeb et al, (2020)

According to another study by Rejeb et al. (2021) on business-to-business collaboration, blockchain technology is considered to be a highly promising technology that can improve collaboration among organizations. The paper highlights the potential roles of blockchain technology in enhancing collaborative supply chains and provides a useful collaboration framework.

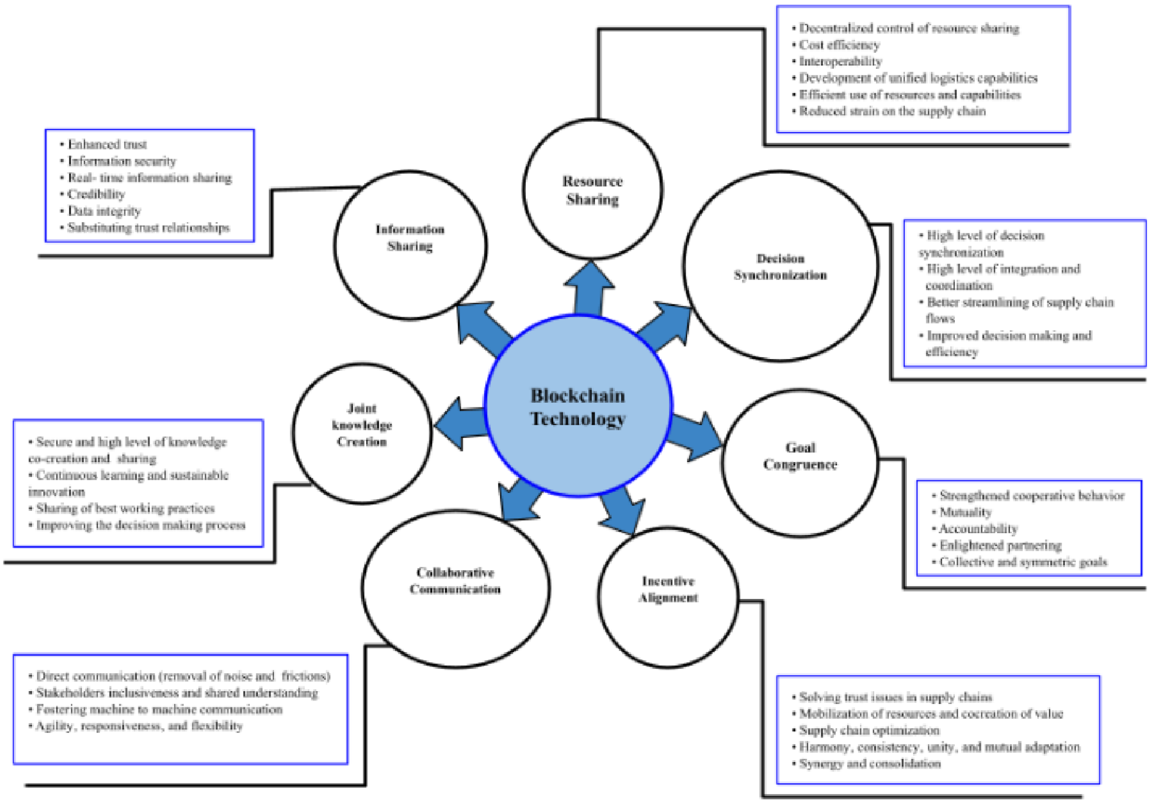

Figure 3.4: Framework for blockchain potentials for supply chain collaboration
Source: Rejeb et al. (2021)

However, there are still challenges and limitations to the widespread adoption of blockchain in the food supply chain, including scalability, interoperability, data privacy, and the need for industry-wide collaboration and standardization (Opara, 2003; Van Hilten et al., 2020).

3.7. International Standards

3.7.1. Intergovernmental bodies

3.7.1.1. Codex

According to the procedural manual of the Codex Alimentarius Commission (CAC, 2008), traceability or product tracing refers to *“the ability to follow the movement of a food through specified stages(s) of production, processing, and distribution.”* A document titled *"Principles for Traceability/Product Tracing as a Tool Within a Food Inspection and Certification System"* (CAC, 2006) provides guidelines to help competent authorities use product tracing to protect consumers from foodborne hazards and deceptive marketing practices, as well as ensure accurate product descriptions. Product tracing on its own is not sufficient to improve food safety outcomes unless it is combined with appropriate measures and requirements. However, it can be useful in making food safety measures more efficient and effective by providing information on suppliers or customers involved in potential food safety issues, which can enable targeted product recall or withdrawal. A product tracing tool should be capable of identifying a product at any stage of the food chain, where it originated (1-step back), and where it went (1-step forward), as relevant to the objectives of the food inspection and certification system. The use of traceability/product tracing should consider the capabilities of developing countries. If an importing country has objectives or outcomes that cannot be met by an exporting country, particularly a developing country, the importing country should consider providing assistance to the exporting country (McEntire et al., 2010).

3.7.1.2. World Organization for Animal Health (OIE)

The OIE helps its member countries and regions in setting up systems to identify and trace animals, which can improve their efforts to prevent and control diseases, ensure food safety, and certify exports. The organization has been working on animal identification and product tracing for a long time, and it created guidelines and standards for this purpose in May 2007 (McEntire et al., 2010). The guidelines explain that animal identification involves the unique identification and registration of an animal, either individually or in groups. Animal traceability involves tracking an animal or group of animals throughout their lifespan. The OIE's Terrestrial Animal Health Code features a section on creating and executing identification systems to achieve animal traceability. In 2009, the OIE hosted a conference in Argentina that resulted in numerous recommendations for its members (McEntire et al., 2010).

3.7.2. Commercial Standards

3.7.2.1. International Organization for Standardization (ISO)

The Quality Management Systems of the ISO 9000 series have certain standards that organizations must adhere to. One such standard is the ISO 9001:2008, which requires the organization to identify the product throughout the production process and maintain records for traceability (Campden BRI, 2009; McEntire et al., 2010). Preservation of the product is also necessary, and the constituent parts of the product must be preserved. Another standard, ISO 22000:2005, mandates the establishment of a product tracing system that enables the identification of product lots and their relation to the raw materials, processing, and delivery records (Campden BRI, 2009). ISO 22005:2007 specifies basic requirements for the design and implementation of a food and feed traceability system. The organization must define the information to be obtained from suppliers, collect information about the product and its processing history, and provide it to customers and/or suppliers (Campden BRI, 2009; McEntire et al., 2010).

3.7.2.2. GS1

GS1 is a neutral, non-profit organization dedicated to improving the efficiency and visibility of supply chains through global standards and solutions. The organization has local Member Organizations in 108 countries, and the US affiliate, GS1 US, is dedicated to helping companies adopt and implement global supply-chain solutions (GS1 US, 2009a). GS1 standards enable efficient tracking and tracing of products and are based on practices used in over 150 countries (GS1 US, 2009b; McEntire et al., 2010). The GS1 System of integrated standards includes Bar codes, E-com, GDSN, EPCglobal, and GS1 Traceability, which helps track and trace items through the supply chain (GS1 US, 2009c). Companies can join GS1 and receive a prefix to uniquely identify the company for supply chain and electronic commerce applications. GS1 also promotes the use of the GTIN to uniquely identify trade items (GS1 US, 2009d).

3.7.2.3. GlobalGAP

The GlobalGAP standard is designed for the primary production sector, which involves crops, livestock, and aquaculture. It includes a growing range of specific products, such as fruits, vegetables, salmon, and trout. Traceability control points are incorporated into the standard to ensure that products registered with GlobalGAP can be traced back to the farm where they were produced (Campden BRI, 2009; McEntire et al., 2010). GlobalGAP is a non-governmental organization that develops voluntary standards for certifying agricultural products, including aquaculture, on a global scale. It is a partnership between producers and retailers, to establish certification standards and procedures based on ISO/IEC Guide 65 for good agricultural practices. The objective is to verify best practices throughout the entire production process. Global GAP certification is carried out by more than 100 organizations in over 80 countries. The organization was formed in 1997 by retailers in the Euro-Retailer Produce Working Group in response to consumer concerns about product safety, as well as environmental and labor standards (McEntire et al., 2010). Its members include retail and foodservice members, producers, suppliers, and associate members from the input and service side of agriculture. GlobalGAP implemented group certification, smallholder manuals, and feedback opportunities to facilitate market access for small-scale farmers (GlobalGAP, 2009).

3.7.2.4. SQF Program Code and Guidance.

The 3-level certification program and management system called SQF 2000 is a HACCP-based code for the food manufacturing and distributing industries. It is part of the Safe Quality Food (SQF) Program and focuses on product identification, traceability, withdrawal, and recall (SGF Institute, 2024). The program requires that product identification methods be documented and implemented during all stages of production and storage. Additionally, the finished product must be labeled according to customer specifications and regulatory requirements and product identification records should be maintained. The program also requires that finished products be traceable to the customer and that product tracing is provided through the process to raw materials, food contact packaging, and other inputs. Furthermore, the effectiveness of the product trace system must be tested at least once a year, and records of product dispatch and destination must be maintained. The SQF program was established in Australia in 1994 and has been administered by the SQF Institute since 2004. The SQF Institute is a division of the Food Marketing Institute, which is an association that represents 1500 member companies around the world and conducts programs in public affairs, food safety, research, education, and industry relations (McEntire et al., 2010; SGF Institute, 2024).

3.8. Traceability and Food Safety in Selected Key Global Markets

Traceability systems (TSs) are an essential component of global supply networks. They facilitate the seamless flow of commodities across international borders by enabling the tracking and tracing of products from production to consumption. This enhances transparency, accountability, and efficiency in trade practices. Many countries have mandated the implementation of TSs within their jurisdictions due to their vital role in ensuring product integrity and compliance with regulatory requirements (Qian et al., 2020).

By ensuring traceability, governments can enforce quality standards and protect consumers from substandard or counterfeit goods. Compliance with international regulations and standards is crucial for accessing global markets and maintaining market competitiveness. Mandates for TS implementation align with requirements set forth by international bodies such as the World Trade Organization (WTO) and the Codex Alimentarius Commission, ensuring consistency and harmonization in trade practices (CAC, 2005; Mahajan et al., 2014; Qian et al., 2020). Qian et al., (2020) in Figure 3.5 below depict how different countries and regions have mandated the implementation of traceability systems.

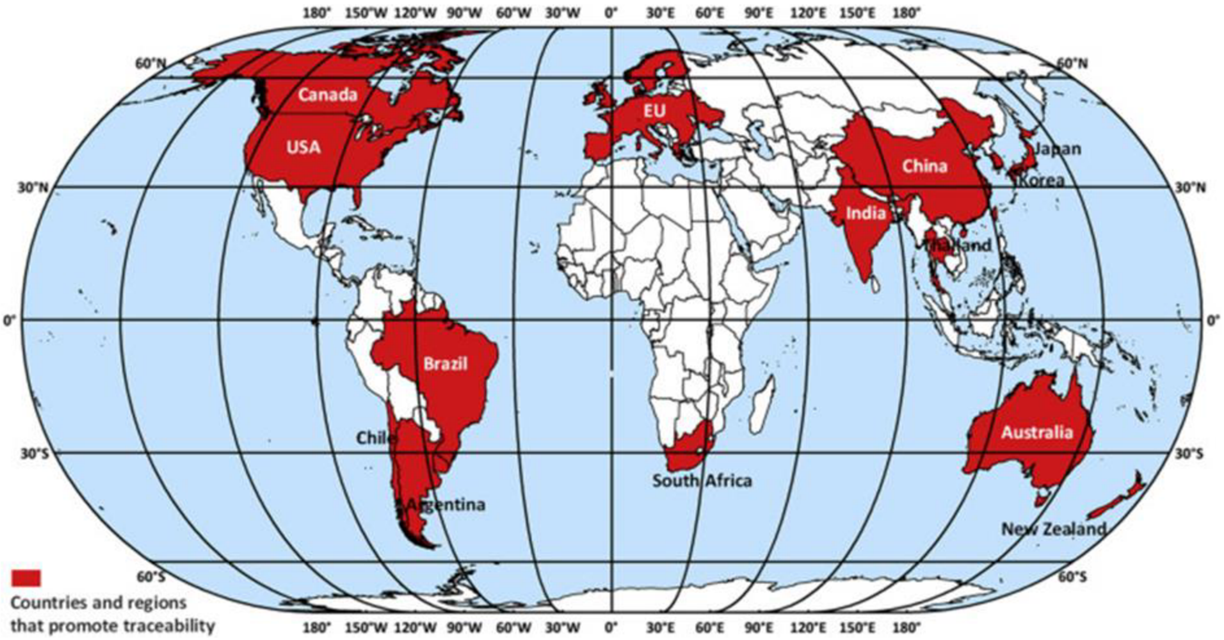

Figure 3.5: Traceability promotion across countries and regions
Source: Qian et al. (2020)

3.8.1. The European Union

In response to the outbreak of mad cow disease in the 1980s and 1990s, the European Union undertook significant reforms of food safety regulations aimed at ensuring a more secure and reliable food supply across its member states (Arienzo et al., 2008). One of the measures implemented was the provision of traceability information to aid consumers and control authorities in the rapid recall of products during emergencies. ITC, (2015) states that risk assessment, risk management, and risk information are the major factors that drive traceability in the European Union. The objective of EU food laws is to minimize risk by implementing HACCP-based programs and traceability efforts, which work in synergy to identify and manage potential hazards.

The General Food Law (EC 2002) is the foundation of EU food control and requires all food and feed products to be traceable, including imported products. The food law outlines the basic principles, regulations, and processes related to food safety. The European Food Safety Authority is responsible for assessing risks independently of risk management. The law also establishes procedures and tools for managing emergencies and crises, including the Rapid Alert System for Food and Feed (RASFF), which ensures that product risks are reported throughout the EU.

According to Article 18 of the law, food traceability must be ensured throughout all stages of production, processing, and distribution. Companies are required to identify their raw material suppliers and customers to authorities if asked. All food marketed in European Union member states should be labeled and identified to enable traceability, and the legal framework follows the principle of 'one step back-one step forward' (Van der Meulen, 2013). Although Article 18 does not give a specific set of instructions on the type of information that operators must keep or for how long they must maintain records, businesses need to identify and document the necessary data to prevent any violation of regulatory or legal requirements (Charlebois et al., 2014; EU, 2002; World Bank, 2022).

The European Union has implemented mandatory requirements for various types of products, including those of animal origin and high-risk agricultural products such as sprouts and seeds intended for sprout production. For food of animal origin, detailed guidance on traceability requirements has been provided by the EU regulation, which defines the information that food business operators (FBOs) must provide to customers and competent authorities regarding consignments of food of animal origin. In response to a Shiga toxin-producing *E. coli* outbreak in May 2011, the EU issued a regulation in 2013 that established traceability requirements for sprouts and seeds intended for sprout production. Sprout business operators are required to maintain information about batches of seeds and sprouts at all stages of production, processing, and distribution using the 'one step back-one step forward' principle. Such information must be updated daily and kept for a sufficient time after the sprouts are consumed (Qian et al., 2020; World Bank, 2022).

3.8.2. United States of America

The United States' food supply chain is important worldwide, and ensuring its safety and security is crucial. Both the private sector and government have acknowledged this fact and emphasized the need for tracking and tracing solutions in the supply chain (FDA, 2011; ITC, 2015). Importers and processors are obligated to maintain records that indicate the origins of their foods, while facilities that produce, process, pack, or import food for human consumption must register with the US Food and Drug Administration (USFDA). As per the Bioterrorism Act of 2002, anyone involved in making, handling, storing, or importing food is responsible for maintaining records. If the FDA suspects that a food item poses a significant health risk, it has the right to inspect those records (Aung and Chang, 2014; Levinson, 2009). The FDA Food Safety Modernization Act (FSMA) has provisions to ensure fresh vegetables and other foods are regulated and safe for consumers, including measures to improve traceability within the U.S. food supply (FDA, 2011; ITC, 2015).

The FSMA has granted the FDA with new powers and obligations which involve making it mandatory for food facilities to have preventive controls, enforcing safety standards for produce, and preventing intentional contamination (FDA, 2011; ITC, 2015). The FDA will supervise compliance with these regulations through mandatory inspections based on risk, access to industry food safety plans, and testing by accredited laboratories. Additionally, the FDA has been given the power to mandate recalls, administrative detention, and suspension of registration, as well as enhanced food tracing abilities if any issues arise. Moreover, the FDA will establish a food tracking system for both domestic and imported foods and will explore and assess methods to identify recipients of food to avoid or manage foodborne illnesses (FDA, 2011; ITC, 2015).

The FDA plans to propose a set of rules that would require certain facilities involved in the production, processing, packaging, or storage of high-risk foods to maintain proper records. This measure will help the FDA enforce U.S. standards for imported goods by holding importers accountable, implementing third-party certification, and creating programs for high-risk foods. Section 204 of the FSMA is focused on improving the traceability and tracking of food products, as well as enhancing record-keeping practices (FDA, 2011; ITC, 2015).

Charlebois et al., (2014) also state that in order to trace processed food products, there are voluntary practices that use lot and package identification to trace products in the fresh fruit and vegetable industry supply chain in the United States. The Produce Marketing Association (PMA) leads a program called the Produce Traceability Initiative (PTI) which uses a Global Fruit and Vegetable Traceability Implementation Guide and tools established by GS1 to standardize traceability guidelines. The PTI recommends using standardized GS1 and produce codes set by the International Federation for Produce Standards. The PMA has also expanded its scope to other countries to lead broader initiatives for global produce traceability. The association has offices and produce traceability initiatives in several regions and countries including Europe, Australia and New Zealand, and Brazil. Additionally, traceability guidelines are being established in three other key food sectors in the United States including beef and poultry, seafood, and dairy, deli, and bakery.These guidelines have been established by national meat associations, the National Fisheries Institute, and the International Dairy Foods Association and International Dairy-Deli-Bakery Association, respectively, along with GS1.

3.8.3. Canada

The Canadian Food Inspection Agency (CFIA) is responsible for ensuring food safety in Canada and is considering implementing traceability requirements for Canadian food businesses (ITC, 2015). This initiative is part of the Safe Food for Canadians (SFCA) Act 2012, which aims to protect Canadian families from food safety risks. The SFCA legislation will consolidate all food inspection regulations in Canada under one overarching law, allowing the CFIA to apply consistent regulatory requirements and inspection approaches across all regulated food commodities (ITC, 2015). The legislation also permits the CFIA to establish a stronger system for tracing products throughout the production chain to quickly identify and remove unsafe foods from the supply chain, as well as enhance industry requirements for record keeping and documentation.

The CFIA intends to improve the safety of imported food and reduce the risks posed by pathogens such as *E. coli* (ITC, 2015). Traceability systems will be required for most food businesses involved in importing, exporting, interprovincial trade, growing, harvesting, storing, and handling meat products. These businesses must maintain records that include common names of the food and lot codes, names of the persons involved in manufacturing, preparing, storing, packaging, or labeling the food, and dates of transactions. These records must be accessible in Canada and maintained for two years (ITC, 2015).

3.8.4. Australia and New Zealand

Australia prioritizes risk management and market access, which are considered as important drivers for businesses. The food supply chain is a vital part of the Australian economy, with connections to primary production, processing, and value-addition operations for export/import trades. Ensuring the safety of food is a top priority in Australia. The government at both State and Federal levels emphasizes the need for authenticating export products, documentation, and approved business activity. Electronic certification within electronic commerce is encouraged to achieve this goal (ITC, 2015).

In retail, businesses focus on improving productivity and differentiating their products by implementing measures such as authentication, Country of Origin Labelling (COOL), cost reduction, inventory control, and minimizing shrinkage (ITC, 2015). For food processing businesses, traceability is crucial to identify the source of all food inputs, including raw materials, additives, ingredients, and packaging. These businesses need to have a proper system that includes procedures for identifying suppliers, customers, and products, and maintaining records such as the supplier and customer's name and address, transaction or delivery date, batch or lot identification, volume or quantity of product supplied, and other relevant production records (ITC, 2015).

Food businesses in Australia are required to follow specific traceability regulations outlined in the Australia New Zealand Food Standards Code available at https://www.foodstandards.gov.au/ . These regulations include the need for businesses to keep track of the food they receive, where it came from, and the ability to recall unsafe food if necessary. The regulations also outline specific traceability requirements for businesses involved in the production or processing of seafood, dairy, poultry, eggs, and seed sprouts. These regulations are in place to ensure food safety and prevent the spread of unsafe or contaminated food products in the market (ITC, 2015).

The National Animal Identification and Tracing Act (NAIT) of New Zealand utilizes RFID technology to monitor animals from birth until they are either slaughtered or exported live (Charlebois et al., 2014). The Ministry of Primary Industries (MPI) has set forth regulations for importing cattle, buffalo, and deer, which require ear tags to be left in place until slaughter. If an ear tag is removed or altered without a valid reason, this is considered a violation under the Biosecurity Act of 1993. The numbers associated with each ear tag must be recorded and verified on all relevant certificates and reports, and in certain cases where microchips are required, the microchip number must also be included on accompanying documentation and conform to ISO standards. If an electronic reader is not available, the importer must ensure that the MPI Inspector can identify the animal at any stage (Charlebois et al., 2014).

3.8.5. China

China's Food Safety Law (FSL) was implemented in 2015, and it is considered one of the most comprehensive and strict food safety regulations in existence (Geng et al., 2015). The Chinese Food and Drug Administration (CDFA) and the National Health and Family Planning Commission of China (NHFPC) have crucial roles in ensuring food safety. The CDFA oversees food production and supply chain, while the NHFPC focuses on risk analysis related to food safety. The Ministry of Agriculture of China (MOA) is responsible for managing the quality and safety of agricultural products. The FSL regulates the marketing and sales of primary consumable agricultural products, develops safety standards, publishes safety notifications, and manages the quality and safety of agricultural inputs. There are 52 food safety regulations and laws in China, and the government has established local regulations to enhance inspections and provide financial support for food safety (Tang et al., 2015). Companies are required to document the entire food supply chain, from procurement to distribution, under the Agricultural Product Quality Safety Law and Food Safety Law (Geng et al., 2015; Qian et al., 2020; Tang et al., 2015).

The Chinese government has recently recognized the significance of food traceability in ensuring food safety, and has introduced several traceability programs that concentrate on high-risk and signature products, particular supply chains, and IT standards (World Bank, 2022). These programs have resulted in the creation of food safety tracking and tracing systems for various products, such as seafood, cantaloupe, pork, tea, and chicken. The government has made it mandatory for all commodities to meet specific requirements and has also established voluntary technical standards for traceability systems. Furthermore, the government supports the use of IT by food producers and traders to establish food safety traceability systems. QR codes are widely used in China for this purpose (World Bank, 2022).

3.8.6. Africa

According to McEntire et al. (2010), the African region has different approaches to food safety and traceability policies. A conference was held in 2007 to discuss the current situation and future goals for national and regional traceability. The general opinion was that, although traceability is important, food security issues take priority in Africa. Therefore, product tracing is not a significant effort in this region unless there is a specific disease outbreak. Many countries lack food legislation or have outdated laws from their colonial authorities that do not prioritize the health of their citizens. Additionally, there are multiple food authorities, which make food policy in the region more complex. Qian et al., (2020) also elaborate the lack of comprehensive food traceability promotion across the African continent as shown in Figure 3.5 above.

3.9. Case Studies on Traceability and Food Safety from Selected African Countries

3.9.1. Beef Value Chain in Malawi

A recent research study conducted in Malawi by Kumvenji et al. (2022), to investigate the implementation status of the traceability system in the local beef and beef sausages supply chain. The main objective of the study was to identify the factors that are hindering the implementation of the traceability system and to find solutions to these issues to ensure the safety of these food products for the consumers. The study found that it was difficult to track the attributes of local beef and beef sausages from retail outlets to cattle feedlots. The personnel involved in the supply chain had insufficient knowledge about food traceability and safety, and regulatory enforcement officers were unable to effectively address the issues due to the limitations of the legislation. Consequently, the research concluded that the supply chain of local beef and beef sausages in Malawi is not traceable, which is a serious concern for food safety and public health that needs to be addressed on an urgent basis.

Morse et al., (2018) also add that in Malawi, similar to many other African countries, there is no comprehensive regulation for food safety and food traceability systems . The regulation of food safety in Malawi is fragmented and overlaps between various government ministries. The Ministry of Local Government and Rural Development (Local Councils) and Ministry of Agriculture (Department of Animal Health) are responsible for regulating the local beef and beef sausages supply chain, along with the Malawi Bureau of Standards (MBS) through the MBS Act of 2012 and the Meat and Meat Products Act of 1975.

3.9.2. Date Palm Value Chain in Egypt

The cultivation of date palms in Egypt has been important in enhancing food security, nutrition, and income generation in rural areas due to its ability to produce large amounts of fruit and withstand arid conditions (FAO, 2023). The Ministry of Trade and Industry stated that date palm is an important crop for Egypt as it is the largest producer of dates worldwide. The country has 16 million palm trees, which account for 18% and 24% of global and Arab production respectively. In 2020, Egypt produced 1.7 million tonnes of dates, which represented 17.8% of the world's production (FAOSTAT, 2022). Other major date producers include Saudi Arabia, Iran, Algeria, and Iraq. The sector supports over one million Egyptian families, with 70% being smallholder farmers (FAO, 2023).

According to a study by FAO (2023), the date palm value chain in Egypt involves various actors such as input suppliers, producers, collectors/traders, packers, wholesalers, processors, retailers, and exporters. The value addition constraints are mainly associated with food quality and safety issues, and the actors recognize the importance of addressing them. The producers need to improve their harvest and post-harvest management, comply with international sanitary and phytosanitary standards, and acquire voluntary certificates to ensure food safety management system standards at packing houses. A traceability system is required to identify bottlenecks in the value chain and collect data for certification to increase quality and improve selling prices (FAO, 2023). Although there are issues with managing the supply chain, logistics, and cold storage, the domestic market suffers from a lack of awareness around food transparency. This is because there is no standardized quality control system in place, which results in significant food losses and reduced profitability for businesses. Smaller producers face limited market access and often have to accept prices set by buyers based on the size and variety of their products. As a result, there is a growing demand among producers to explore market opportunities by improving transparency throughout the value chain (FAO, 2023).

The study also highlights the lack of effective vertical linkages between value chain actors results in food loss and quality deterioration. The Union of Producers and Exporters of Horticultural Crops (UPEHC) collaborates with small and medium-sized producers to improve their business capacity. However, the private sector faces difficulties in sharing information due to land fragmentation and the large-scale focus of the Horticultural Export Improvement Association (HEIA). Installing a traceability system is not a priority due to perceived costs and the need for vertical integration. Additionally, data collection for traceability and transparency is challenging, and the lack of trust among actors could affect the reliability of recorded information.

According to FAO (2023), there is currently no effective system in place to track and provide transparent information about the production process in the date palm sector. The study indicates that this lack of traceability and transparency negatively affects all stakeholders, especially small and medium-sized producers who struggle to share information quickly. Furthermore, the adoption of digital solutions in this sector is still in its early stages, despite the presence of facilitators such as regulatory frameworks and access to finance. These facilitators are not sufficient to remove the barriers to digital technology adoption.

3.9.3. Olive Oil Value Chain in Tunisia

The olive oil industry is of great importance to Tunisia's economy and society. It plays a significant role in achieving various national objectives such as economic development, food security, employment generation, increased export earnings, and conservation of natural resources. In 2020, olives (both table and oil) accounted for 17.5% of the total agricultural products in Tunisia, and olive oil exports comprised 58.4% of the total value of crop and livestock product exports. Tunisia is the fourth-largest olive oil producer in the world, after Spain, Italy, and Greece. In 2019, it produced around 240,000 tonnes, which accounted for 7.7% of the world's total olive oil production (Astill et al., 2019; FAO, 2023a).

According to FAO (2023), Tunisia faces challenges in adding value to its olive oil exports due to difficulties in obtaining certifications and traceability. Adulteration and fraud have also damaged the country's reputation. Although Tunisia enjoys a competitive advantage due to low labor costs, operational efficiency can be improved. The lack of a market information system means that farmers cannot access timely, reliable information on prices. Greater transparency in information could help farmers plan the best time to harvest and secure better prices.

The same study also states that some private companies are motivated to develop a digital traceability system, while most believe it would be costly to initiate and maintain. Small and medium-scale farmers, who make up 72% of the industry, are highly fragmented and lack the infrastructure to benefit from digital technologies. Additionally, digital literacy levels remain low, and there is no national traceability system for olive oil, which poses challenges for data management and standardization.

The findings of the study revealed that the use of advanced technologies such as blockchain, IoT, and remote sensing is helping Tunisia's olive oil sector improve traceability and transparency. One of the major producer companies, CHO, has implemented IBM's Food Trust to monitor its Terra Delyssa extra virgin olive oil (EVOO) production across eight quality checkpoints, providing consumers with a QR code on the bottle to view the entire production process. This application of technology by CHO will enhance product quality and traceability, benefiting distributors and consumers globally. However, it's important to note that the digital system for traceability and transparency has been implemented by individual companies, rather than at a national level.

3.10. Traceability and Food Safety in Zambia

Zambia is located in Central Southern Africa and is surrounded by eight other countries: Mozambique, Malawi, Tanzania, the Democratic Republic of Congo, Angola, Namibia, and Zimbabwe as shown in Figure 1.1 below. The country has an estimated population of 19.6 million people, with 60% living in rural areas and 40% in urban areas (Zamstats, 2022).

Figure 3.6: Geographical Location of Zambia
Source: http://www.worldatlas.com/webimage/countrys/africa/zm.htm

3.10.1. Overview of the Fresh Fruits and Vegetable Value Chain

Agriculture is a significant contributor to Zambia's economy, employing half of the country's workforce and accounting for 6-9 percent of its GDP (Mulenga et al., 2021). With a majority of Zambia's population living in rural areas, where poverty rates are high, agriculture does not only remain crucial for reducing poverty and promoting economic growth in the country but also represents a significant potential for generating employment opportunities.

The horticultural industry plays a crucial role in enhancing farmers' incomes by providing year-round production and marketing (Mulenga et al., 2021). In the year 2021, key horticultural products such as rape, cabbage, tomato, and onion have had relatively stable prices. As stated by Mulenga et al., (2021), Zambia has experienced a constant growth in the production, sales, and consumption of horticultural products, which is expected to continue in the medium term. The shift towards healthy eating, with fruits and vegetables being the primary ingredients for healthy foods, is a significant driving force behind this growth. In the year 2018, the annual consumption of horticultural products in Zambia was estimated at 1 million metric tonnes (MT), valued at over USD 330 million, and was projected to rise to 1.4 million MT, worth USD 500 million by 2020. On the other hand, the estimated production of horticultural products in 2018 was 1.4 million MT, valued at USD 235 million, and was expected to increase to 2.2 million MT by 2020 (Mulenga et al., 2021). AgBIT, (2015) indicates that the contribution of smallholder horticulture to the rural economy is much more significant than that of maize, on a per capita basis. For example, during the 2010/11 production and 2011/12 marketing season, the value of production at the national level was 1.38 times higher (1.85 times higher for sales). It was also 1.34 (1.78 for sales) and 3.25 times higher (9.04 times higher for sales) compared to the maize subsector among the female-headed and smallholder households cultivating less than one hectare respectively.

According to Hichaambwa and Tschirley (2006), Smallholder farmers in Zambia play a vital role in the country's agricultural output as they are the backbone of the fresh produce supply chain. Although they are dominant in terms of sheer numbers and localized production, it is important to recognize the complementary role played by large-scale farms. Large farms bring considerable advantages in terms of economies of scale, technological innovation, and the ability to meet broader market demands.

In Zambia, tomato, rape, and onion are the top three staple vegetables that make up a significant portion of consumer expenditure, second only to cereals and staples and meat and eggs (Tschirley et al., 2011). These three vegetables account for two-thirds of all vegetable consumption in the country, while expenditure on vegetables is four times higher than that of fruit. Although expenditure on vegetables decreases with income, absolute expenditure on vegetables increases fourfold from the lowest to the highest income group due to rising incomes. Due to the high costs of inputs, labor, and transportation, very few farmers in Zambia can produce enough vegetables to cater to the market demand. Except for rape, most of the production of tomatoes and onions occurs in rural areas, not urban ones. Although peri-urban agriculture has some involvement in the cultivation of rape, it does not contribute much to the production of tomato and onion. More than half of the onion reaching Lusaka is imported from neighboring regions, rather than locally grown within Zambia. (Hichaambwa and Tschirley, 2006; Tschirley et al., 2011).

3.10.2. Main Market Channels and their Characteristics

There are different types of fruit and vegetable markets available for farmers, which can be categorized into two types: *Informa/Traditional markets* and *Formal/Modern markets*, which are dominated by smallholder and commercial farmers respectively (AgBIT, 2015; Hichaambwa and Tschirley, 2010, 2006). Understanding the structure and operation of these markets adds a new dimension to understanding the complexity of traceability in the Zambian FFV value chain.

3.10.2.1. Informal/Traditional Markets

The traditional system also known as open marketing is the main method for selling fruits and vegetables, and the Soweto wholesale market in Lusaka is at the centre of this system. Over 80% of the staple vegetables in Zambia including tomatoes, rape onions, and cabbages are sold through Traditional markets such as local, regional, roadside, street/pedestrian walkways, residential, Chisokone in Kitwe, Kasumbalesa on the border with Congo DR., and Soweto markets in Lusaka, which can either be *wholesale* or *retail*. These markets are often open-air and have limited refrigeration or storage facilities available. Although they are easily accessible and do not require high-quality produce, they may offer lower prices to farmers. The quality of produce sold in such markets is often affected by the hot, dirty, and unhygienic conditions. The farmers may also have to sell their produce to *middlemen* who may take a larger cut than necessary, reducing the profits earned by the farmers (AgBIT, 2015; Hichaambwa and Tschirley, 2010, 2006; Tschirley et al., 2011). Although supermarkets are becoming more widespread, and their market share may increase in the future, the traditional marketing system will continue to be the primary way of selling for many years to come. As a result, the system's effectiveness will significantly impact consumer welfare.

3.10.2.1.1. The Role of Brokers

Brokers, who earn money on commission without taking ownership of the commodity, are a common and controversial presence in the wholesale markets of East and Southern Africa (Gabre-Madhin, 2001). Farmers in Zambia have varying opinions about brokers also known as middlemen. According to a study conducted by Hichaambwa and Tschirley (2006), some farmers felt compelled to sell through brokers due to threats of theft if they attempted to sell their products independently. However, a group of fresh vegetable farmers who supply Soweto market through a micro-irrigation project in Chongwe district believed that brokers provide valuable services. These brokers charged a commission of around 10% on sales, but over time, farmers developed mutual relationships with them, leading to better sales opportunities and greater security for their products in the market. Nonetheless, this group also experienced problems with brokers adding price markups without the farmers' knowledge, in addition to charging a commission. This issue puts farmers who are less familiar with these agents at a higher risk of exploitation.

3.10.2.2. Formal/Modern Markets

In the Modern market system, there are several opportunities for farmers such as supermarkets, hotels, industrial processors, mines, and schools, that offer higher prices for their produce. However, accessing these markets requires farmers to have better information and connections with individuals working in these markets. Additionally, farmers need to be able to produce large quantities of high-quality crops that meet the requirements of these markets. Unfortunately, smallholder farmers in Zambia face challenges in accessing these modern markets. Although supermarkets are becoming more popular in Zambia, with large chain stores such as Foodlovers market, Shoprite/Freshmark, Fruit and Veg City, and Pick N' Pay, supermarkets currently account for only 14-21% of the produce market in Zambia. However, this percentage is expected to increase as urban populations are set to rise by 170% over the next 30 years (AgBIT, 2015; Hichaambwa and Tschirley, 2010, 2006). This will create more opportunities for smallholder farmers to sell their produce as there will be an increased demand for fresh produce that is conveniently available. Table 3.1 below shows some of the differences between traditional and modern markets in Zambia.

Table 3.1: Comparisons between Traditional and Modern markets in Zambia.

	Traditional markets	Modern or higher-value markets
Type of transaction	Informal	Often more formal. Sometimes contracted
Purchase agreement	• Processors • Supermarkets • Hotels • Restaurants • ExportWholesale • Retail	Usually retail
Pricing	Usually offers lower prices due to oversupply	Can offer higher prices if high quality produce can be delivered consistently
Stability of prices	Low	High
Supply & demand	Unregulated	Regulated
Type of Crops	Generally, more traditional and leafy vegetable	Traditional vegetables and more exotic produce e.g. Peppers
Quality standards	Inconsistent quality	Consistent quality (size, packaging shape, colour, etc)
Volume	High volumes	Often lower volumes at a time
Market access	Relatively easy to access especially local or roadside markets	Depends on the buyer and farmer location
Location	• Local markets • District • Township/Residential • Roadside • Soweto • Chisokone • Kasumbalesa • Masala	• Processors • Supermarkets • Hotels • Restaurants • Export
Who are the clients?	Lower and middle-income	Middle to high-income
Unit of measure	Volumetric	Weight
Storage	Poor	Good
Packaging & presentation	Poor - average	Good

3.10.3. Regional and International Trade

Hichaambwa and Tschirley, (2010, 2006) indicate that the local horticultural system in Zambia is linked to a regional and international market. Large amounts of onions are imported from South Africa and Malawi to Lusaka, and then exported to other parts of the country and neighboring countries such as the Democratic Republic of Congo (DRC). Tomatoes are not imported but are exported to other countries such as the DRC and Namibia through Livingstone, although most of this trade is informal and statistics are not available. Oranges, bananas, apples, and pears are also imported mainly from South Africa, while some oranges come from Zimbabwe (Hichaambwa and Tschirley, 2010, 2006). Private traders who charter transport from South Africa, and have rented warehouses in Lusaka, distribute these fresh products throughout the country and export them to the DRC. Freshpikt, the largest fresh produce processing company in Zambia, produces processed tomatoes, pineapples, onions, and other products for the domestic and regional markets. Zambia also exports its horticultural produce to the EU as its biggest market among others (Hichaambwa and Tschirley, 2010, 2006).

In 1984, a non-profit association called the Zambia Export Grower's Association (ZEGA) was established to support the interests of growers who want to export fresh horticulture produce (Hichaambwa and Tschirley, 2010, 2006). According to www.zambiaexportgrowers.com, ZEGA is an independent and professional organization that aims to provide efficient air freight services, coordinate input procurement and technical assistance, offer advice on financing, provide information on marketing opportunities, lobby government, and other organizations on behalf of growers, and provide technical support and training to its members. ZEGA has approximately 50 members who have paid their dues, out of which 35 are direct exporters.

3.10.4. Food Safety and Traceability

Food safety in Zambia is guided by the Food Safety Act of 2019 which is meant to ensure that food is manufactured, sold, and used in a way that does not pose a risk to public health or involve fraudulent practices. It also aims to make the process of obtaining regulatory clearances for food premises more efficient. The act establishes the Food Safety Coordinating Committee with defined functions and powers. It requires health inspection reports and report notices and sets up the National Food Laboratory. This act repeals the Food and Drugs Act of 1972 and sections 79 and 83 of the Public Health Act of 1930. Additionally, it covers any matters related to or incidental to the above (National Assembly of Zambia, 2019).

According to the National Assembly of Zambia, (2019) the Food Safety Act of 2019 defines food safety as “a scientific discipline describing the production, manufacture, handling, preparation, and storage of food in a manner that prevents food-related diseases and harm.” Although the Act does not explicitly mention traceability, it does provide detailed labeling requirements. This could be seen as an indirect way of enforcing traceability, as the labeling process helps to identify the origin and composition of the food products (Mukuni, 2022; National Assembly of Zambia, 2019).

Mukuni, (2022) conducted a study on Risk Cultures, Beef Traceability, and Food Safety in the United States and Zambia. The study uses a comparative analysis to demonstrate differences and similarities in approaches to food safety in the United States and Zambia, specifically regarding beef, as it is a common food in both countries. The study reveals that in Zambia, the process of traceability is well-documented in formal sectors, and information related to beef is easily accessible within these settings and is subject to regulation. However, in informal sectors, traceability can be complex as it relies mainly on verbal agreements and trust-based relationships between buyers and sellers.

4. Methodology

4.1. Geographic Focus

The study was conducted in Zambia, specifically focusing on Lusaka and Chibombo districts. Lusaka is the country's capital and the distribution and processing hub for horticultural products in Zambia. A significant proportion of the vegetables consumed by households in urban areas pass through a marketing system that involves wholesale and retail markets, with the Soweto market in Lusaka being the main hub and the largest retail market in the city and the entire country (Hichaambwa and Tschirley, 2006; Tschirley et al., 2011). Lusaka is also home to some of the biggest horticultural farms that supply fresh fruits and vegetables (FFV) to both the local and the international market. Additionally, the major processing companies for FFVs are also located in Lusaka.

Chibombo is a rural district and one of Zambia's major producers of horticultural produce. Located approximately 90 km north of Lusaka, the district is largely agricultural, with 90% of the population depending on farming for their livelihoods. The agricultural sector in the district comprises both commercial and small-scale farmers. Small-scale farmers account for over 75% of crop production, while commercial agriculture is mainly concentrated in the southern part of the district and mostly focuses on the export market. For Chibombo district the study was conducted in Katuba, Chibombo Central, and Chiyuni areas where horticultural production is dominant.

Lusaka City being urban and Chibombo Town being rural make a good representation of the horticulture traceability situation in Zambia and can form the basis of the challenges and recommendations for the sector.

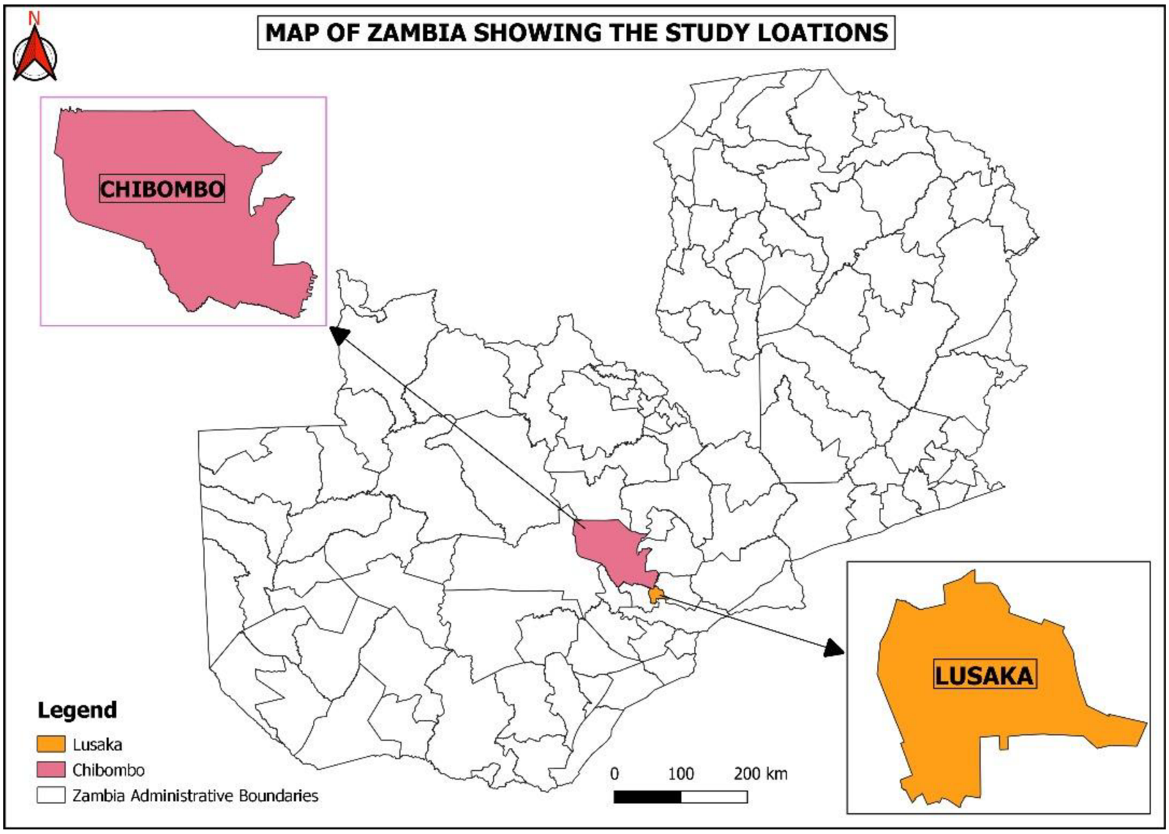

Figure 4.1: Study Locations
Source: Technical Services Branch of the Ministry of Agriculture in Zambia (2024).

4.2. Study Design and Data Collection

This research was a case study with a qualitative approach and was built upon three data collection methods: A desk review, semi-structured interviews with key informants and stakeholders and focus group discussions with smallholder horticultural producers. The data was collected between July and September 2023. These methods are described in detail below:

4.2.1. Desk Review

A desk review of traceability systems both within and beyond the horticulture industry in the general sense was conducted. In this study, the words *horticulture* and *fresh fruits and vegetables* were used interchangeably to mean the same thing. The review started by understanding traceability in the general sense and how traceability has been applied in various leading global markets. It was further narrowed to other studies on how traceability has been applied in selected countries in Africa. Finally, the review focussed particularly on Zambia by looking at similar traceability studies that have been conducted previously in the country. A review of the horticulture supply chain in Zambia was also conducted by identifying the key players and interrogating how these key players apply traceability and how they interact with each other.

4.2.2. Semi-Structured Interviews with Key Informants

After identifying the key players within the horticulture supply chain, semi-structured interviews with 8 key informants of industry players from the formal FFV market channel were conducted. These actors were purposely sampled for their active participation in the horticulture industry. Checklists (see appendix 1, 2, 3 and 4) as interview guides based on research questions to obtain accurate data from each participant and get an in-depth understanding of traceability were developed. Managers or senior representatives from the following stakeholders, as shown in table 4.1. For purposes of confidentiality and ease of identification each of the players were assigned alphabetical identities such as A, B, and D.

Table 4.1: Fresh Fruits and Vegetable Industry Players Interviewed

Type of Industry Player	Role in the FFV Industry	Number of Industry Players Interviewed	Personnel Interviewed
Commercial Farms	Producer	3	Managers / Senior Representatives
Assemblers/Aggregators	Product Aggregation	2	Managers / Senior Representatives
Chain stores and Supermarkets	Retail	2	Managers / Senior Representatives
Open air Markets	Wholesale and Retailing	1	Market representative

4.2.3. Focus Group Discussions

Focus group discussions, with checklists (refer to appendix 5) as discussion guides, with smallholder horticulture producers, were conducted. The study purposely sampled two locations in Chibombo district namely; Chibombo central, Katuba, and Chiyuni areas where horticultural production is dominant. With the help of Camp Agricultural Extension Officers in these areas, one (1) focus group discussion (FGD) comprising 15 to 20 farmers was conducted in each area resulting in a total of 3 focus group discussions. Each of the FGDs was assigned numerical identities such as 1, 2, and 3 for Chibombo Central, Katuba, and Chiyuni areas respectively for ease of identification. According to the Ministry of Agriculture of the Republic of Zambia accessible at https://www.agriculture.gov.zm/?page_id=1335 a Camp Agricultural Extension Officer is the first line of contact between the farmers and the Extension service. These officers live in the same localities with the farmers and provide some valuable information about the general state of agricultural activities in their catchment areas of operation. Figure 4.2 below shows a focus group discussion in session with small holder farmers in Katuba area.

Figure 4.2: Smallholder farmer focus group discussion in session in Katuba area

4.3. Data Analysis Method

This study employed Content Analysis as a method of data analysis. This method was suitable because of the qualitative nature of the study and the type of data collection methods employed. Kleinheksel et al., (2020) and Kondracki et al., (2002) state that content analysis is a research method that can be used to evaluate various types of qualitative data, including interviews, observations, articles, diaries, medical records, websites, and more. While it is most frequently used with text-based data such as open-ended survey questions or print media, it can also be applied to visual media like photographs, cartoons, and film footage. The method involves identifying important concepts within the data and organizing them in a way that can be used to describe or explain a phenomenon (Kolbe and Burnett, 1991). It is particularly useful when there is a large amount of unanalyzed textual data, as it allows researchers to identify patterns and associations within the data. Overall, content analysis is a powerful tool for understanding the meaning behind different forms of communication.

4.4. Limitations of the Study

This study was limited by inadequate funding, as it was self-financed, which constrained the scope of data collection. However, the evidence gathered in the study is adequate to draw informed conclusions and practical recommendations about the current state of traceability in the fresh fruits and vegetable supply chain in Zambia. It also provides a reasonably accurate picture of the traceability status in this supply chain.

5. Results and Discussion

This chapter presents the results and discussion of data collected from desk reviews, key informant interviews, and focus group discussions.

5.1. Principal Entities in the Fresh Fruits and Vegetable Supply Chain in Zambia

Results of the principal entities in the FFV supply chain in Zambia indicate that the supply chain involves six major processes including research, input supply, production, processing and aggregation, marketing, and consumption of FFVs. On the other hand, the major respective actors include universities and government research institutes, seed companies and agro-dealers, smallholder and commercial farmers, brokers, aggregators, and processors, markets (including supermarkets, local shops, and open-air markets) and local and international consumers of FFVs. These results are presented in Figure 5.1 below.

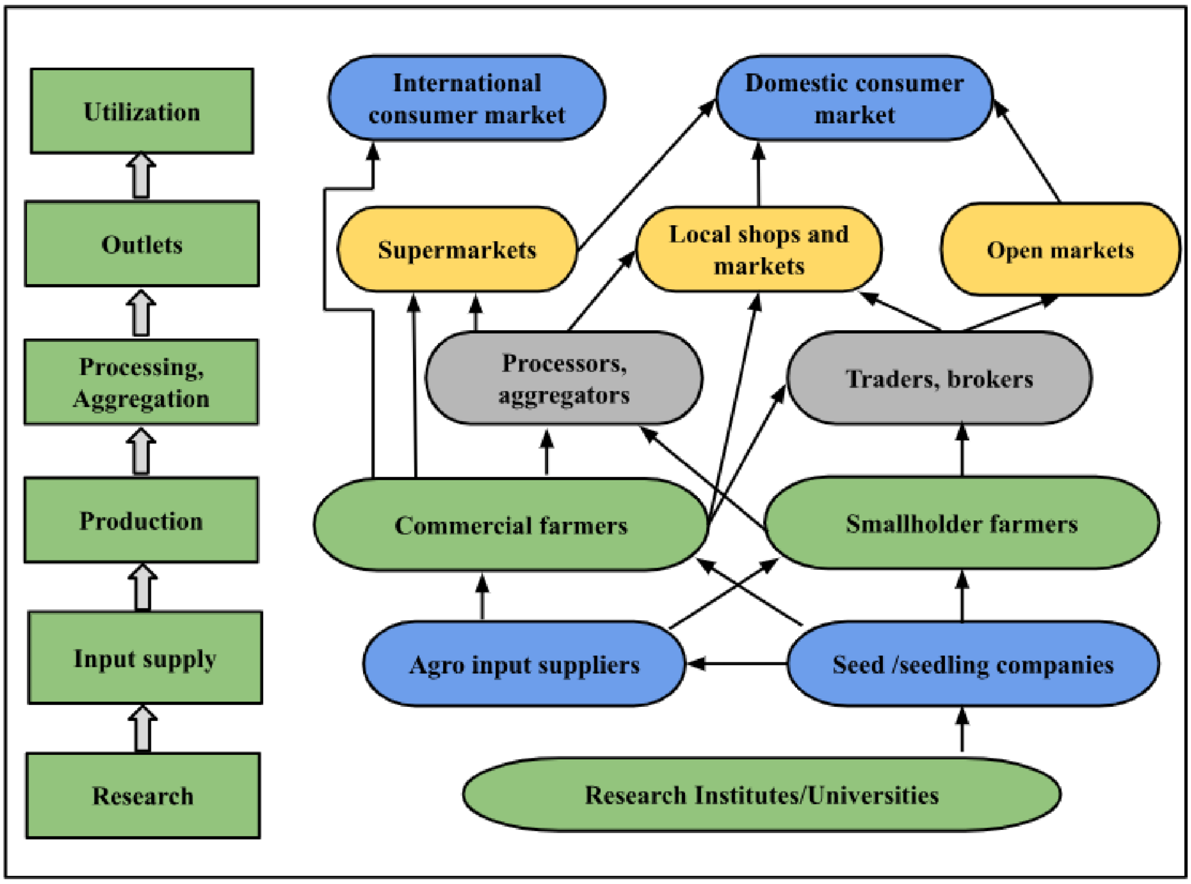

Figure 5.1: Value Chain Diagram for Fresh Fruits and Vegetables in Zambia
Source: Adapted from Horticulture Sub-Sector Study Report (AgBIT, 2015)

The study indicates that universities and research institutes have a critical role in providing enhanced agricultural technology to seed and seedling suppliers and other stakeholders. The University of Zambia, through the School of Agricultural Sciences, and the Zambia Agriculture Research Institute (ZARI), are the leading institutions in this respect. ZARI, a department in the Ministry of Agriculture (MoA), focuses on developing agricultural production technologies suitable for all farmer categories and different farming environments.

Seed and seedling suppliers are responsible for the commercial multiplication of quality seeds and seedlings for both smallholder and commercial farmers. However, before these products are released to the market, they must undergo certification by the Seed Control and Certification Institute (SCCI) under the Ministry of Agriculture. Additionally, agro-input suppliers provide inputs such as fertilizers, pesticides, and irrigation equipment to smallholder and commercial FFV farmers.

The findings also indicate that there are two distinct channels of marketing for FFV: the formal and the informal channels, which have different characteristics and players who interact differently. The formal channel is characterized by organized and defined systems, which may provide more control over food safety and traceability, as can be supported by similar findings by the World Bank (2022). Farmers in this channel trade with aggregators, processors, supermarkets, local shops, and the international export market, which often have more strict regulations and standards for food safety and traceability. As a result, it may be easier to track the origin of the produce and ensure that it meets the required standards. On the other hand, the informal channel is characterized by less organized and defined systems, which may pose challenges to food safety and traceability. Small and medium-scale producers in this channel sell their produce to processors, aggregators, traders, local shops, and open-air markets, which may not have the same level of regulations and standards as the formal market. Similar characteristics are reported by Chemeltorit et al. (2018) in food traceability in the domestic horticulture sector in Kenya. This lack of transparency and accountability can make it difficult to trace the origin of the produce and ensure that it is safe for consumption.

These results are also supported by Mwango et al. (2019) who conducted a study on the informal food markets in Zambia where they identified three different categories of businesses that vary in their degree of organization and formality. They reported that the first group consists of open market traders who account for 26% and operate outside of established market structures and are the least formal and most vulnerable as they don't have access to proper shelter. The second group is the largest, accounting for 65%, and consists of organized or enclosed traders who operate inside designated market facilities and pay levies to the council. Finally, the third group which represents 9% is the informal import markets that sell imported fruits and vegetables from neighboring countries around Soweto market. Hichaambwa and Tschirley (2010) in their study on the structure of Lusaka's fresh produce marketing system and implications for investment also reported similar results that the fresh produce retailing system consists of two main components: the traditional system comprising open-air markets and the "ka sector", which includes numerous small vendors located in busy pedestrian walkways and residential areas; and the modern system, which includes supermarkets, minimarts, and grocery shops.

Figure 5.2: Trading set up Soweto open-air market

These findings have significant implications for food safety and traceability policies and practices and therefore calls for the need to strengthen the regulatory frameworks for the informal market to ensure that it meets the required standards for food safety and traceability.

5.2. Degree of Traceability Implementation in the Horticulture Supply Chain

5.2.1. Degree of Traceability Implementation in the Formal Sector

This subchapter provides results and discussion on the degree of traceability among players in the formal sector. These players include commercial farmers, aggregators, and supermarkets. As stated earlier in the methodology, for purposes of confidentiality and ease of identification each of the players was assigned alphabetical identities such as A, B, and C respectively. Therefore, to answer this objective the study highlights the degree of traceability implementation by commercial farmers A, B, and C, aggregator A, and supermarkets A and B.

5.2.1.1. Commercial Farm A

Commercial Farm A has been growing and packing fresh vegetables and roses for both local and export markets since the mid-1980s. The company was established as an export company in 1996 and currently operates two farms covering a total of 1740 hectares. Their main exports include baby corn, sugar snap peas, snow peas, chilies, and fine beans which are exported to Germany, the United Kingdom, New Zealand, and South Africa. It also produces tomatoes, baby marrow, broccoli, cauliflower, sweet corn, and chilies for the local market. The company also operates one packhouse, which is located just a few meters away from the farm. The packhouse serves the purpose of storing, sorting, and packing products for both local markets and export. It has an area of approximately 4500 square meters and can accommodate up to 450 workers in various production roles.

Results from commercial Farm A indicate that the farm practices internal traceability between the farms and the packhouse as well as external traceability with its external customers both local and international. During crop production the farm through the farm manager records and stores all the production practices in each plot. At harvest, the harvested produce is taken to the packhouse with a corresponding produce received voucher (PRV) contains the following information; farm name, plot number, section number, product name, variety of product, number of crates harvested from the plot, kilograms of product harvested from plot and date of harvest.

The PRV will have a PRV number which will be linked to the plot number in the traceability book and consequently the PRV becomes the traceability number which is passed on to the customer through external traceability. The following excerpt from a personal interview is a response to the extent of traceability within and outside the firm.

"The traceability system here starts from the field, from the plot itself where the product is coming from. We use what we call the produce received voucher (PRV). There is the name of the plot there, we give the plot numbers and that number is what we will use throughout the process. Now from the packhouse point of view that plot we will give it the number (PRV

number). So this becomes the traceability number and this is the number that will go all the way up to the customer. So should the customer have a problem with this product they will quote this number, then this number will take us to the plot." (Personal communication with packhouse manager from Commercial Farm A, 01/09/2023).

These results indicate a well organised internal traceability system between the production end, the packhouse, and management. It also indicates a clear and well organised external traceability system between the business and its customers.

"We apply traceability throughout the process up to the customer." (Personal communication with packhouse manager from Commercial Farm A, 01/09/2023).

Results further indicated that commercial farm A also conducts traceability tests once every two months. This test aims to continuously monitor the effectiveness of the company's entire traceability system.

"That is just to see if our traceability is still effective or not, what we do is we will get a PRV number and then just see how the product moved, and to which customer did it go. When was it packed? How much did we receive from the field? How much did we pack? How much did we discard? So from the customer up to the field, the plot and see if everything moved on well. Even the documents we put them in place, all the documents which were involved we put them in place and file them." (Personal communication with packhouse manager from Commercial Farm A, 01/09/2023).

This involves both forward tracking of the product from the producer to the customer and backward tracing of the product from the customer back to the farm's plot. The other activity conducted in this firm is a mock recall also aimed at monitoring the effectiveness of traceability. The mock recall is done once every year. Figure 5.3 below shows a simplified traceability framework for commercial farmer A.

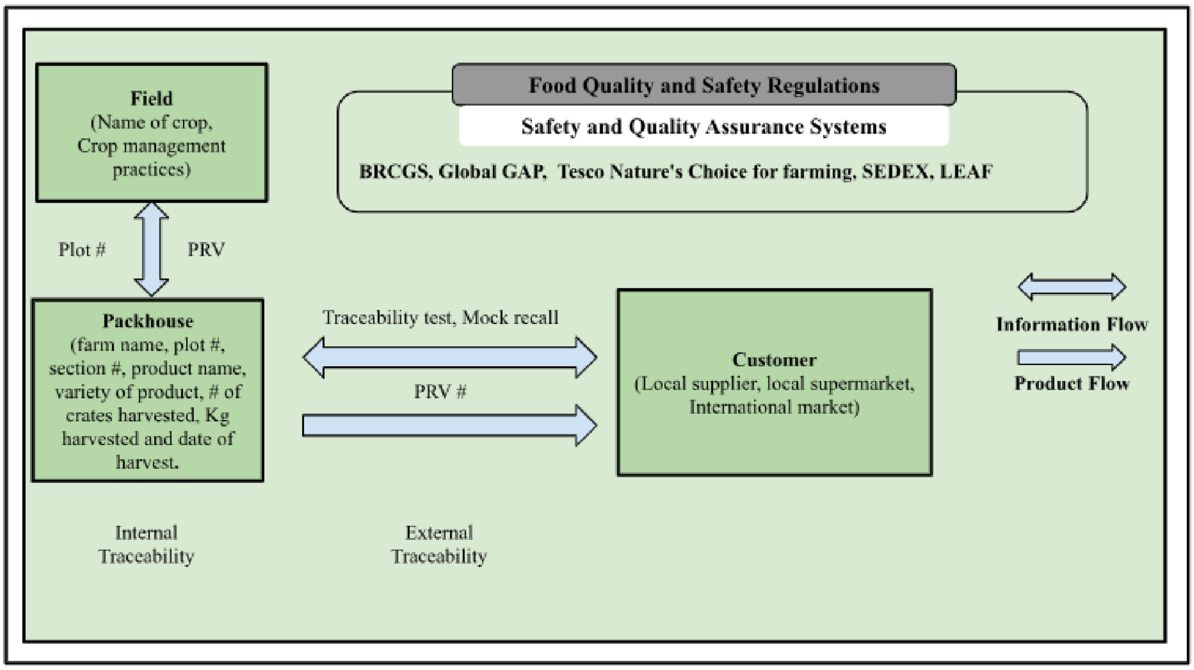

Figure 5.3: Traceability framework for commercial farmer A

Commercial farm A also subscribes to various international standards, including the British Retail Consortium Global Standards (BRCGS) for packaging standards, Global GAP standard for farming, Tesco Nature's Choice for farming, Supplier Ethical Data Exchange (SEDEX) for labor and social compliance, and Linking Environment And Farming (LEAF) for environmental and farming practices.

From the results above the traceability practices of Commercial Farm A have significant and diverse implications, affecting various stakeholders and aspects of its operations. By implementing internal traceability procedures and maintaining detailed records of production practices, Commercial Farm A can ensure the quality and safety of its products (Aung and Chang, 2014). This traceability allows for swift identification and resolution of any issues that may arise, reducing the risk of contaminated or substandard products reaching consumers. External traceability procedures, facilitated by the use of PRV numbers, promote transparency and accountability in Commercial Farm A's interactions with customers. Similar to Chemeltorit et al. (2018) this transparency builds trust and confidence among consumers, who can easily trace the origin of the products they purchase and verify their quality and authenticity.

Further, commercial Farm A's traceability framework facilitates seamless coordination and communication between different stages of the supply chain, from farm to packhouse to customers. This streamlines inventory management, logistics planning, and response to market demands, ultimately optimizing overall supply chain efficiency. This is in tandem with Bosona and Gebresenbet (2013) who studied food traceability as an integral part of logistics management in the food and agricultural supply chain. By adopting international standards such as BRCGS, Global GAP, and SEDEX, Commercial Farm A ensures regulatory compliance and industry best practices. This compliance not only mitigates legal and regulatory risks but also demonstrates the farm's commitment to ethical, sustainable, and socially responsible business practices. Its adherence to rigorous traceability standards and continuous improvement practices sets it apart from competitors in the market. The farm's reputation for reliability, transparency, and product quality can serve as a competitive differentiator, attracting discerning customers and enhancing its market share and profitability.

The regular traceability tests and mock recalls conducted by Commercial Farm A serve as proactive measures to identify and address potential vulnerabilities in its traceability systems. This proactive approach to risk management helps mitigate the impact of supply chain disruptions, product recalls, and other crises, safeguarding the farm's reputation and financial stability. By showcasing best practices in traceability and supply chain management, Commercial Farm A emerges as a leader and innovator in the FFV industry in Zambia. Its commitment to continuous improvement and adherence to international standards sets a benchmark for other players in the sector, driving industry-wide innovation and advancement.

5.2.1.2. Commercial farm B

Commercial farm B operates on a 100-hectare land where they grow potatoes, cauliflower, green beans, and tomatoes. They mainly produce potatoes, cauliflower, green beans, and tomatoes which they supply to local supermarkets. They don't have a packhouse but instead, they use a storage shelter to keep their produce after harvesting.

Commercial farm B practices both internal and external traceability through record-keeping but to a lesser complexity than commercial farm A. They are assigned a unique grower code (GC) by the supermarkets to identify them as a supplier. They display the harvest and shipping date of their products on all their products. This helps them trace back the products to the date of harvest and the field of production. With this information, commercial farm B can trace all its products back to the field and the production practices used.

One unique thing about Commercial Farm B is that they work with smallholder farmers through an outgrower scheme. These farmers are given strict production guidelines to follow during crop production and harvest. However, the lack of a standardized formal traceability system between commercial farmer B and the smallholder farmers poses a challenge in ensuring food safety and food quality standards.

"Yeah I mean, you've got what I call serious smallscale growers that are interested, they are on their plots they farm they are there 24 hours a day like we do here on the farm and then you've got what I call "flybanerts" or "briefcase farmers". They farm when they want to farm, they don't do this when they want do it and you weed them out you know you slowly but surely…..they will say ah we can do XYZ they can't do it and they come once or twice and then you end up rejecting their products." (Personal communication with the proprietor of Commercial Farm B, 17/08/2023).

The study also reviews that commercial farm B does not subscribe to any international standards citing the high cost of these certifications. However, they follow the local phytosanitary measures stipulated by the Ministry of Agriculture through the department of Plant Quarantine and Phytosanitary Service (PQPS). They further indicate that whenever export opportunities arise, they will supply through another certified commercial farm.

From these results Commercial Farm B's approach to traceability, while less complex than that of Commercial Farm A, comes with several implications for the industry. Although Commercial Farm B practices internal and external traceability by keeping records and displaying harvest and shipping dates, the absence of a formal traceability system with smallholder farmers may pose challenges in ensuring consistent product quality and safety standards. Without standardized traceability procedures between Commercial Farm B and smallholder farmers, there is a risk of variability in production practices and adherence to quality standards, which could impact the overall quality and safety of the produce supplied to supermarkets. This agrees with Chemeltorit et al. (2018). It also exposes commercial farm B to risks associated with product recalls, contamination incidents, or non-compliance with quality standards.

Additionally, commercial Farm B's decision not to subscribe to international standards due to the high cost of certification reflects a common challenge faced by small and medium-sized farms in meeting stringent regulatory requirements (Chemeltorit et al., 2018). While adherence to local phytosanitary measures mandated by the Ministry of Agriculture is essential for compliance and market access, the inability to obtain international certifications may limit export opportunities and market reach in the long term. However, collaborating with certified commercial farms for export supply is a viable strategy to access international markets while mitigating the costs and complexities associated with certification.

5.2.1.3. Commercial farm C

Commercial Farm C was established in 1995 and has acquired 1400 hectares of land. Currently, the farm has 400 hectares of irrigated land and 10 hectares of greenhouse. Commercial Farm C utilizes its arable land to produce a wide range of vegetables and herbs that are supplied to the local consumers, as well as exporting fresh peas and commercial seed to the Netherlands. They follow Global Gap standards for their traceability, which includes both internal and external traceability.

One unique aspect of Commercial Farm C is that it not only trades in the formal market and adheres to strict traceability standards but also trades in the informal sector by supplying potatoes to the Soweto Market.

As can be observed commercial farm C adheres to Global GAP standards for traceability and implements both internal and external traceability systems, the farm ensures transparency, accountability, and product integrity throughout the supply chain, contributing to consumer confidence and market acceptance. This commitment to quality assurance, food safety, and sustainability enhances the farm's competitiveness in international markets, particularly for exported produce destined for the Netherlands. In addition, by balancing formal and informal market engagement while upholding global standards for traceability and quality, the farm has positioned itself for growth, resilience, and success in the dynamic agricultural landscape.

5.2.1.4. Aggregator A

Aggregator A is Zambia's biggest center for the procurement and distribution of fresh fruits and vegetables. They supply the largest supermarket in the country with fresh produce. Being the largest buyer and distributor of fresh fruits and vegetables in the country, Aggregator A works with many local growers both smallholder and commercial farmers. They source the majority of their fresh produce directly from these growers, ensuring a fresh promise to the customers.

Aggregator A applies traceability by assigning a unique grower code (GC) to each farmer or supplier. The GC is then attached to the product when it is packed or processed at the Aggregator A facility. Traceability documents are available to trace the product back based on the code added to the product. Additionally, a pack date code or a sell-by date is attached to the product, which provides more specific traceability to it.

Aggregator A acts as a connection between producers/growers and retailers. It employs both internal and external traceability by sharing traceability data from growers to retailers. Aggregator A trades with both smallholder and commercial farmers, but only trades with growers it trusts to ensure product quality and safety. Smallholder farmers who want to become suppliers to Aggregator A are continuously monitored and assessed for their crop production practices.

From the results above it can be pointed out that aggregator A's commitment to traceability standards and quality control measures is in line with regulatory requirements and industry best practices. Compliance with food safety regulations, traceability guidelines, and labeling requirements not only ensures legal compliance but also improves market acceptance, brand reputation, and competitiveness (Bosona and Gebresenbet, 2013; CAC, 2008; Chemeltorit et al., 2018; World Bank, 2022). To ensure compliance with quality standards and mitigate potential supply chain disruptions, Aggregator A continuously monitors and assesses smallholder farmers seeking to become suppliers. By providing market opportunities and access to a broader customer base, Aggregator A empowers growers, enhances their income-generating potential, and stimulates agricultural productivity and innovation.

5.2.1.5. Supermarket A

On the fruits and vegetable section supermarket A trades in green beans, baby marrow, okra, cauliflower, broccoli, tomato, onion, and local indigenous vegetables obtained from the local market. It also trades in oranges, apples and grapes etc among many other imported FFVs.

Supermarket A performs both internal and external traceability. The most important information required by the supermarket is the grower code (GC), harvest date and sell by dates which allow them to trace the produce to the source. It is worth noting that supermarket A runs a centralized trading system by only trading with trusted suppliers who are able to meet the required food safety and quality standards. This study established that supermarket A only trades with aggregator A mentioned above. This strategic partnership underscores the supermarket's unwavering commitment to upholding food safety and quality standards. By partnering with reputable suppliers who follow rigorous quality control measures, Supermarket A mitigates risks related to product contamination, spoilage, and non-compliance. This proactive approach safeguards the supermarket's reputation and brand integrity, while ensuring that customers receive fresh and high-quality products.

5.2.1.6. Supermarket B

Supermarket B demonstrates a somewhat unique trading system when it comes to the source of its produce. It runs a decentralized trading system by obtaining its produce from many sources within the local suppliers. Although supermarket B practices traceability through supplier identification numbers it remains vulnerable to loopholes in food quality and safety standards which may arise from the different suppliers.

Arising from the above, it can be argued that Supermarket B's decentralized trading system offers opportunities for product diversity and market agility but at the same time it also presents challenges related to traceability, quality control, and consumer trust. By proactively addressing these challenges and collaborating with suppliers to enhance standards and practices, Supermarket B can strengthen its competitive position and maintain its reputation as a trusted provider of fresh produce in the marketplace.

5.2.1.7. Summary of Degree of Traceability Implementation in the Formal Sector

The degree of traceability implementation in the formal horticultural supply chain varies across different entities, with some demonstrating robust systems while others show room for improvement. Commercial Farm A and Commercial Farm C exhibit a high degree of traceability implementation, following comprehensive internal and external traceability practices, adhering to international standards, and conducting regular tests and recalls. Aggregator A and Supermarket A also demonstrate a high level of traceability implementation, ensuring accountability and quality assurance throughout their operations.

On the other hand, Commercial Farm B and Supermarket B exhibit moderate levels of traceability implementation. While they practice internal and external traceability to some extent, there are gaps in formalized systems, particularly concerning smallholder farmer integration and centralized traceability measures. These entities could benefit from strengthening their traceability systems, collaborating more closely with suppliers, and investing in technology and processes to enhance transparency and accountability.

5.2.2. Degree of Traceability Implementation in the Informal Sector

This subchapter provides results and discussion on the degree of traceability among players in the informal sector. These players include smallholder farmers, traders, and open air markets.

5.2.2.1. Smallholder Farmers

5.2.2.2. Focus Group Discussion (FGD) 1

This focus group discussion (FGD) was held in Chibombo central area and constituted 16 smallholder farmers of which 9 were male and 7 were female. It revealed a consistent lack of understanding among smallholder farmers regarding traceability. None of the participants demonstrated familiarity with the concept.

"We have never heard of that word, what is it again? Here we just know how to produce food, we have never heard about traceability. Maybe the government through the camp extension officer should educate us more about it. They have taught us well about conservation agriculture, climate change, and many more so maybe they should do the same with that traceability." (FGD participant, 19/07/2023).

This finding underscores a significant knowledge gap concerning traceability practices among smallholder farmers in Chibombo central area. It highlights the need for targeted educational interventions and capacity-building initiatives to raise awareness and improve understanding of traceability within this community.

5.2.2.3. Focus Group Discussion (FGD) 2

This focus group discussion (FGD) was held in the Katuba area and constituted 20 smallholder farmers of which 13 were male and 7 were female. It revealed a notable lack of awareness among smallholder farmers regarding traceability. Out of the 20 participants, 19 expressed that they were unfamiliar with the concept of traceability, indicating a significant knowledge gap in this area.

However, one male farmer recalled encountering traceability practices during his previous employment with a commercial farmer, though he does not currently implement it himself.

"I remember when I worked for this commercial farm years back, I was young and very energetic you know, I worked there as a casual worker………we did everything……we used to plant, we used to spray, everything. So every time we did any activity in the field we used to write in the book the date of planting, the date of spraying, the type of chemical, everything, and then the farm manager would come to check if what we wrote was correct. They said if we do not keep records, it is bad for business so they made sure that all the records were kept properly." (FGD participant, 21/07/2023).

Interestingly, upon receiving an explanation of traceability in the local language, participants showed a degree of comprehension, suggesting that the concept is not entirely foreign to them once it is demystified.

"Ahh, so traceability is similar to record-keeping? Even though I do not keep records in a book I can remember the variety of the crop which I planted. For example, I hang the empty sachet of the seed I planted on a small stick and put it in the field. That way even my wife and children know exactly which variety is in the field. I can even remember the chemicals I sprayed and which agro dealer I bought from. Maybe I can forget or mix up the dates of spraying if am spraying a lot of chemicals, especially in tomatoes because it needs a lot of chemicals, especially in the rainy season. So Mr camp extension officer you should tell your bosses up there that the farmers here want to learn more about traceability." (FGD participant, 21/07/2023).

This indicates a potential for education and awareness-building initiatives to enhance understanding and adoption of traceability practices among smallholder farmers.

5.2.2.4. Focus Group Discussion (FGD) 3

This focus group discussion (FGD) was held in the Chiyuni area and constituted 15 smallholder farmers of which 8 were male and 7 were female. Similar to the first FGD, the study unveiled a persistent lack of comprehension among smallholder farmers regarding traceability. None of the participants showed any familiarity with the concept.

"I do not know what traceability means. When government people come here they teach us about cooperatives, conservation farming, food security, the Farmer Input Support Program (FISP), etc. So initially, when the camp extension officer told me about this meeting I thought this was going to be a FISP meeting because the camp officer is currently doing farmer registration. So that traceability to be honest we don't know it. Even other people in the village when you ask them they will say they don't know traceability." (FGD participant, 10/08/2023).

The discussion highlighted a consistent absence of understanding among smallholder farmers regarding traceability. However, some participants mentioned engaging in limited record-keeping practices on their farms, primarily to address issues such as theft by workers and, to some extent, to document production practices for economic purposes.

"We don't want things to be done incorrectly because I can end up scorching my crop, and I end up losing my crop. Also the theft part whereby my workers steal my chemicals."(FGD participant, 10/08/2023).

5.2.2.5. Interview with Open Air Market Representative

This interview took place at Soweto market, the largest open-air market in the country. The market handles both wholesale and retail trade of fresh fruits and vegetables. The wholesale side involves brokers also known as middlemen, who are agents who arrange sales without actually owning the commodity but earn their income through commission. In this interview, the market representative indicated that he had never heard of traceability.

"My response would be I don't know, I have never heard of it,...... I am just learning it now because even when I was at Natural Resources Development College (NRDC) they never mentioned anything like this. The only thing people do here is to know the price and the number of crates. We don't even write, it is just by word of mouth, you know Soweto….we have been practicing this for many years so it is just by word of mouth." (Personal interview with open-air market representative, 04/08/2023).

However, upon further discussion, the representative demonstrated some understanding of traceability, particularly in the context of informal practices at the market. He described how traders at Soweto market maintain informal records of transactions, allowing them to trace products back to specific farmers or suppliers based on memory and verbal communication. This informal traceability system relies on the familiarity between marketeers and traders, enabling them to identify the source of a product if issues arise.

"If a marketeer buys from Soweto he knows exactly the particular person he bought from because those guys (traders) are almost prominent here, so if there is a problem with the tomato for example which the consumer bought and takes it back to the marketeer and if the marketeer is asked where did you buy this from, definitely the marketeer…..not everyone but those who have been in the business for a long time, definitely the marketeer will take you back to the trader and the trader will ask you which day did I sale you this tomato? If you say yesterday or the other day the trader knows exactly which farmers he was dealing with and he will take you to that farmer."(Personal interview with open-air market representative, 04/08/2023).

While this informal traceability system may be useful within the context of the market's operations, it presents challenges in terms of reliability and scalability. The reliance on memory and verbal communication limits the ability to trace products sold over an extended period, making it difficult to address issues that may arise after a significant amount of time has passed. This result is similar to what Mukuni (2022) reported concerning traceability in the informal sector.

Therefore, while informal traceability practices exist within the informal sector, particularly Soweto market, they may not provide the level of traceability required to effectively address food safety and quality concerns in the supply chain. Implementing more structured and comprehensive traceability systems could enhance transparency, accountability, and consumer confidence in the market. This system could be helpful in the informal sector but it poses a challenge due to the time factor. It is not possible with this system to trace a product which was sold or traded over an extended period of time.

5.2.2.6. Summary of Degree of Traceability Implementation in the Informal Sector

The FFV informal sector exhibits a limited degree of traceability implementation, primarily relying on informal practices and verbal communication rather than structured and comprehensive traceability systems. This poses challenges in ensuring transparency, accountability, and consumer confidence in the supply chain, particularly concerning food safety and quality concerns.

To address these challenges and enhance traceability within the informal sector, there is a need for targeted educational interventions and capacity-building initiatives aimed at raising awareness and understanding of traceability concepts among smallholder farmers and market actors. Additionally, implementing more structured and comprehensive traceability systems, possibly leveraging technology where feasible, could improve transparency, accountability, and reliability within the supply chain, ultimately enhancing consumer confidence and food safety standards.

5.3. Traceability systems and technologies employed in the Fresh Fruits and Vegetable Supply Chain

5.3.1. Traceability Systems and Technologies in the Formal Sector

The results suggest that all commercial farmers A, B, and C, as well as Aggregator A, rely primarily on paper-based traceability systems, often supplemented with Microsoft Excel spreadsheets. Commercial farmer A employs traceability books, produce received vouchers (PRVs), and notebooks alongside Excel spreadsheets for data storage. They express a preference for paper-based systems due to their perceived reliability compared to computer-based systems.

Commercial farms B and C also utilize paper-based traceability, although specifics were not provided, and they do not integrate computer-based applications. Aggregator A combines paper-based traceability with computer-based applications like Microsoft Excel, and notably, they also incorporate barcode systems, although these are primarily used for logistics and inventory management rather than traceability. Aggregator B, in contrast, relies solely on paper-based traceability systems.

Similarly, Supermarkets A, B, and C employ paper-based traceability systems, often centered around grower codes. Additionally, they utilize barcode systems and barcode readers for logistics and inventory management purposes, similar to Aggregator A.

Figure 5.4: Barcode technology used by aggregator A and supermarkets A, B, and C

The results above reveal that the formal horticulture industry in Zambia still heavily relies on paper-based traceability systems, which are prone to inefficiencies, errors, and limited scalability. Chemeltorit et al. (2018) and (FAO, 2023a) report similar traceability limitations faced by many developing nations today. These can also pose a risk of data loss or damage, limited accessibility, and reduced analytical capabilities. These limitations can lead to non-compliance with regulatory requirements and hinder the transparency and visibility of product flows. Despite the limitations, however, most industry players prefer paper-based traceability systems because it is the most affordable alternative.

The prevalence of paper-based systems presents an opportunity for improvement. By transitioning towards digital traceability solutions such as RFID, IoT, and blockchain technologies described by Ahmad and Bailey (2021) as well as Rejeb et al. (2021), stakeholders can enhance the efficiency, accuracy, and resilience of traceability processes. Digital platforms offer features such as real-time data capture, automated data analysis, and secure data storage, which can overcome the limitations of paper-based systems and unlock the full potential of traceability in the horticulture supply chain. Therefore, investing in digital traceability solutions is crucial for stakeholders to address the challenges posed by paper records and to improve the resilience and effectiveness of traceability practices across the supply chain.

5.3.2. Traceability Systems and Technologies in the Informal Sector

As indicated above, due to a limited degree of traceability implementation, primarily relying on informal practices and verbal communication rather than structured and comprehensive traceability systems. The FFV informal sector currently does not implement any traceability systems. Therefore, it is important to explore the use of appropriate technologies, such as mobile applications and barcodes, to facilitate traceability in the informal sector. These technologies can help streamline data collection, storage, and retrieval processes, making traceability more efficient and accessible to smallholder farmers and market actors. A few lessons can be learned from Chemeltorit et al. (2018) on the implementation of these mobile-based traceability applications for smallholder farmers.

5.4. Obstacles to Traceability in the Horticulture Supply Chain.

5.4.1. Obstacles to Traceability in the Formal Sector

This subchapter outlines the major obstacles hindering traceability in the formal sector of the FFV supply chain in Zambia. Additionally, it provides recommendations for possible solutions to these problems.

5.4.1.1. High Cost of Implementing Traceability Systems

The results of a study indicate that the cost of implementing digital traceability platforms is the major obstacle for aggregator B and all 3 producers including commercial farmers A, B, and D as it often involves high upfront costs, which can be a significant burden on their businesses. Although aggregator A and supermarkets A and B highlight cost as an obstacle, they appreciate the use of digital systems they currently use such as barcoding and related scanners in logistics and inventory management. These results agree with similar results obtained from a feasibility study by (FAO, 2023b). To address this challenge, it is crucial to invest in scalable and cost-effective traceability solutions that align with an organization's budget and operational requirements. These solutions may include cloud-based software platforms, mobile applications, or open-source traceability tools that offer flexible pricing models and customizable features.

It is also important to advocate for government support, grants, or incentives to subsidize the implementation costs of traceability systems. Businesses can work with industry associations, development agencies, or public-private partnerships to access funding opportunities and technical assistance programs. This approach can help reduce the financial burden of implementing traceability systems and promote their adoption across the industry.

5.4.1.2. High cost of international certifications and compliance with stringent regulatory requirements.

The study reveals that obtaining international certifications such as Global GAP, BRCGS, or SEDEX often involves substantial financial investment. The certification process typically requires fees for assessment, auditing, and ongoing compliance, which can be prohibitive for industry players with limited financial resources. These costs may include fees for inspections, audits, documentation, and training, as well as expenses associated with implementing required practices and infrastructure upgrades. Failure to obtain or maintain international certifications can result in exclusion from certain markets such as the EU or loss of business opportunities as can be seen with commercial farmer B. Non-compliance with traceability standards may lead to reputational damage, legal liabilities, or regulatory sanctions, further exacerbating the financial risks associated with certification. As a result, farms and businesses may face pressure to prioritize certification efforts despite the associated costs.

To mitigate this, governments, international organizations, and industry associations can provide financial support and incentives to help farms and businesses cover the costs of certification. This support may include grants, subsidies, or low-interest loans specifically targeted at facilitating certification for targeted industry players.

5.4.1.3. Regulatory and Policy Gaps

The current regulatory frameworks and government policies in Zambia do not adequately address traceability requirements or provide incentives for compliance in the formal sector. For example, the Food Safety Act of 2019 does not explicitly provide a comprehensive food regulatory framework for food traceability. The lack of enforcement mechanisms or regulatory oversight may diminish the motivation for stakeholders to invest in traceability systems or adhere to best practices voluntarily. Rejeb et al. (2021) also highlight the role of policy and regulation in implementation of food traceability systems. Regulatory and enforcement institutions such as the Ministry of Agriculture (MoA), Ministry of Health (MoH), Ministry of Local Government and Rural Development (MLGRD), and the Zambia Bureau of Standards (ZABS) among others lack a clearly defined food traceability framework. Advocating for the development and enforcement of clear traceability regulations and standards by government authorities can create a conducive regulatory environment for traceability adoption. Offering incentives such as tax breaks, subsidies, or certification schemes can motivate compliance and reward adherence to best practices.

5.4.1.4. Lack of standardized formal traceability system with smallholder farmers.

The lack of a standardized formal traceability system with smallholder farmers as in the case of Commercial Farm B leads to inconsistency and potential gaps in product quality and safety standards. This can be mitigated by providing training and capacity-building to facilitate the implementation of standardized traceability protocols among smallholder farmers associated with industry players such as Commercial Farm B.

5.4.2. Obstacles to Traceability in the Informal Sector

5.4.2.1. Lack of Awareness and Understanding

One of the primary obstacles is the limited awareness and understanding of traceability concepts among stakeholders, including smallholder farmers, traders, and market representatives. The study reveals that many participants in the informal sector may be unfamiliar with traceability practices, terminology, and their importance in ensuring food safety, quality, and accountability. To address this obstacle, comprehensive awareness campaigns and educational programs should be conducted to increase understanding of traceability concepts and their benefits among stakeholders. Training workshops, farmer field schools, and extension services through the Ministry of Agriculture can help disseminate information and build capacity at the grassroots level.

5.4.2.2. Limited Resources and Capacity

The study also reveals that smallholder farmers and participants in the informal sector often face constraints in terms of financial resources, technical expertise, and infrastructure necessary to implement robust traceability systems.

"Look, the cost of inputs is very high, we are currently buying a bag of fertilizer for K1,200 then we also add the cost of seed and chemicals………it is too expensive. So if traceability will cost me extra without any benefit then why should I do it. But if the government can subside traceability the way they do with inputs under FISP then we can do it, no problem." (FGD participant, 19/07/2023).

The costs associated with acquiring and maintaining traceability technology or training personnel may exceed the available resources, making it challenging to invest in traceability solutions. This barrier agrees with the discussion by (FAO, 2023). Solutions include providing financial assistance, grants, or subsidies to support the adoption of traceability technologies and training programs. Partnerships with NGOs, development agencies, and private sector organizations can facilitate access to resources, expertise, and infrastructure needed for traceability implementation.

5.4.2.3. Informal Practices and Documentation

The study reveals that the informal nature of transactions in the horticulture supply chain, characterized by verbal agreements, informal contracts, and limited documentation, poses a significant obstacle to traceability. In the absence of formal record-keeping practices or standardized documentation, tracing products back to their source becomes challenging, if not impossible, especially over extended periods. Introducing simple and user-friendly digital tools, such as mobile apps or cloud-based platforms, can help formalize record-keeping practices and streamline documentation processes. Training programs by both government and non-governmental organizations on proper record-keeping and data management can also promote the adoption of standardized traceability practices.

5.4.2.4. Fragmented Supply Chains

The Zambian informal horticulture supply chain comprises multiple intermediaries, traders, and marketplaces, resulting in fragmented and complex supply chains. With products passing through various hands before reaching consumers, maintaining traceability becomes increasingly challenging, as each intermediary may have different record-keeping practices or communication channels. Qian et al. (2022) report similar obstacles in food supply chains involving many processors. Establishing industry-wide standards and protocols for traceability data exchange can promote interoperability and consistency across different segments of the supply chain. Creating centralized platforms or databases where stakeholders can input and access traceability information can help bridge gaps between various intermediaries.

5.4.2.5. Limited Access to Technology

Smallholder farmers and stakeholders in the informal sector in Zambia lack access to technology or digital infrastructure required for implementing advanced traceability solutions, as many of them are located in rural areas where access to such facilities is limited. Without access to smartphones, computers, internet connectivity, or electricity, stakeholders may struggle to adopt digital traceability platforms or barcode systems, which are more prevalent in formal supply chains. Chemeltorit et al. (2018) and FAO (2023) report similar obstacles. Initiatives such as providing subsidized or low-cost smartphones, internet connectivity, and digital literacy training can empower stakeholders to adopt digital traceability solutions. Developing offline-capable applications or leveraging SMS-based platforms can overcome connectivity challenges in remote areas.

5.4.2.6. Resistance to Change

Resistance to change and cultural norms within the informal sector may present obstacles to the adoption of formal traceability practices in Zambia. FAO (2023) also reports cultural norms as a high barrier to the adoption of traceability. Traditional practices and norms, such as reliance on oral agreements or mistrust of external interventions, may hinder efforts to introduce new traceability technologies or systems, even if they offer potential benefits. Engaging local communities, traditional leaders, and opinion leaders in dialogue and consultation processes can help address cultural barriers and build support for traceability initiatives. Highlighting the tangible benefits of traceability, such as improved market access, product quality, and consumer trust, can incentivize stakeholders to embrace change.

5.4.2.7. Quality of Infrastructure and Logistics

Challenges related to infrastructure, transportation, and logistics, such as inadequate storage facilities, poor road networks, or inefficient distribution channels, can exacerbate traceability obstacles in the informal sector. Without proper infrastructure to support the timely and secure movement of products, maintaining traceability becomes more difficult. Investing in infrastructure upgrades, such as cold storage facilities, transport vehicles, and market infrastructure, can enhance the efficiency and reliability of the supply chain. Public-private partnerships and infrastructure development projects can help address logistical challenges and improve traceability capabilities.

6. Conclusion and Recommendations

This research aimed to examine the current state of traceability practices in the fresh fruits and vegetable (FFV) supply chain in Zambia. The first objective was to identify key players, their roles, and interactions within the FFV supply chain. The study revealed six major processes, including research, input supply, production, processing and aggregation, marketing, and consumption. The key actors involved in this supply chain are universities and government research institutes, seed companies and agro-dealers, smallholder and commercial farmers, brokers, aggregators, processors, markets (including supermarkets, local shops, and open-air markets), and local and international consumers of FFVs. The study also highlights two distinct marketing channels for FFVs including formal and informal. The formal channel is characterized by organized systems, trading with aggregators, processors, supermarkets, and international markets, ensuring better control over food safety and traceability. In contrast, the informal channel lacks organization, selling produce to processors, traders, local shops, and open-air markets, posing challenges for traceability and food safety.

The second objective was to assess the degree of traceability implementation by stakeholders in the FFV supply chain. The study revealed that the degree of traceability implementation in the formal horticultural supply chain varies across different entities, with some demonstrating robust systems and certifications while others show room for improvement. While they practice internal and external traceability to some extent, there are gaps in formalized systems, particularly concerning smallholder farmer integration. These entities could benefit from strengthening their traceability systems, by collaborating more closely and investing in technology and processes to enhance transparency and accountability. On the other hand, the informal channel relies on informal traceability practices, such as verbal communication and memory. This poses challenges in ensuring reliability and scalability, and may not meet the standards required for effective food safety and quality assurance. By integrating approaches in these two sectors, it is possible to create a comprehensive traceability system that covers the entire supply chain from production to consumption. This can include using modern technologies, such as barcodes, RFID tags,` IoT, and blockchain, as well as traditional methods, such as community-led record-keeping, to track products and ensure their safety and quality. By working together and sharing information, both formal and informal players can contribute to a more transparent and accountable horticulture supply chain that benefits everyone involved.

The third objective was to investigate the traceability systems and technologies employed in the FFV supply chain. The study revealed that the horticulture industry in Zambia still relies heavily on paper-based traceability systems, which are prone to inefficiencies, errors, and limited scalability. However, stakeholders can enhance the efficiency, accuracy, and resilience of traceability processes by transitioning towards digital traceability solutions such as RFID, IoT and blockchain technologies. On the other hand, the FFV informal sector currently does not implement any traceability systems, making it important to explore the use of appropriate technologies, such as mobile applications and barcodes, to facilitate traceability in the informal sector.

The fourth objective was to identify the obstacles to traceability in the horticulture supply chain. The study revealed these obstacles to traceability, including the high cost of implementing traceability systems, the high cost of international certifications and compliance with stringent regulatory requirements, regulatory and policy gaps, lack of standardized formal traceability system with smallholder farmers, lack of awareness and understanding of traceability in the informal sector, and limited resources and capacity. It suggests solutions such as investing in scalable and cost-effective traceability solutions, advocating for government support, grants, or incentives to subsidize the implementation costs of traceability systems, providing financial support and incentives to help farms and businesses cover the costs of certification, advocating for the development and enforcement of clear traceability regulations and standards by government authorities, providing training and capacity-building to facilitate the implementation of standardized traceability protocols among smallholder farmers and conducting comprehensive awareness campaigns and educational programs to increase understanding of traceability concepts and their benefits among stakeholders.

7. References

AgBIT, 2015. Horticulture Sub-Sector Study Report 2015: Mapping Investment Opportunities in the Horticulture Sub-Sector: The Case of Vegetable Value Chains in Zambia. AgBIT (Agribusiness Incubation Trust Limited). Available at https://www.rvo.nl/sites/default/files/2016/08/Final-Report-Horticulture-Subsector-in-Zambia.pdf.

Ahmad, A., Bailey, K., 2021. Blockchain in Food Traceability: A Systematic Literature Review, in: 2021 32nd Irish Signals and Systems Conference (ISSC). Presented at the 2021 32nd Irish Signals and Systems Conference (ISSC), IEEE, Athlone, Ireland, pp. 1–6. https://doi.org/10.1109/ISSC52156.2021.9467848

Anne-Marie Donnelly, K., Mari Karlsen, K., Dreyer, B., 2012. A simulated recall study in five major food sectors. Br. Food J. 114, 1016–1031. https://doi.org/10.1108/00070701211241590

Arienzo, A., Coff, C., Barling, D., 2008. The European Union and the Regulation of Food Traceability: From Risk Management to Informed Choice?, in: Coff, C., Barling, D., Korthals, M., Nielsen, T. (Eds.), Ethical Traceability and Communicating Food, The International Library of Environmental, Agricultural and Food Ethics. Springer Netherlands, Dordrecht, pp. 23–42. https://doi.org/10.1007/978-1-4020-8524-6_2

Arnould, E.J., Thompson, C.J., 2005. Consumer Culture Theory (CCT): Twenty Years of Research. J. Consum. Res. 31, 868–882. https://doi.org/10.1086/426626

Astill, J., Dara, R.A., Campbell, M., Farber, J.M., Fraser, E.D.G., Sharif, S., Yada, R.Y., 2019. Transparency in food supply chains: A review of enabling technology solutions. Trends Food Sci. Technol. 91, 240–247. https://doi.org/10.1016/j.tifs.2019.07.024

Aung, M.M., Chang, Y.S., 2014. Traceability in a food supply chain: Safety and quality perspectives. Food Control 39, 172–184. https://doi.org/10.1016/j.foodcont.2013.11.007

Azuara, G., Luis Tornos, J., Luis Salazar, J., 2012. Improving RFID traceability systems with verifiable quality. Ind. Manag. Data Syst. 112, 340–359. https://doi.org/10.1108/02635571211210022

Bechini, A., Cimino, M.G.C.A., Marcelloni, F., Tomasi, A., 2008. Patterns and technologies for enabling supply chain traceability through collaborative e-business. Inf. Softw. Technol. 50, 342–359. https://doi.org/10.1016/j.infsof.2007.02.017

Behnke, K., Janssen, M.F.W.H.A., 2020. Boundary conditions for traceability in food supply chains using blockchain technology. Int. J. Inf. Manag. 52, 101969. https://doi.org/10.1016/j.ijinfomgt.2019.05.025

Bendaoud, M., Lecomte, C., Yannou, B., Bendaoud, M., Lecomte, C., Yannou, B., 2012. A Methodological Framework to Design and Assess Food Traceability Systems. https://doi.org/10.22004/AG.ECON.120861

Bosona, T., Gebresenbet, G., 2013. Food traceability as an integral part of logistics management in food and agricultural supply chain. Food Control 33, 32–48. https://doi.org/10.1016/j.foodcont.2013.02.004

Bourlakis, M., Bourlakis, C., 2006. Integrating logistics and information technology strategies for sustainable competitive advantage. J. Enterp. Inf. Manag. 19, 389–402. https://doi.org/10.1108/17410390610678313

CAC, 2008. Codex Alimentarius Commission. Procedural Manual 18th Ed. Joint FAO/WHO Food Standards Programme. World Health Organization/Food and Agriculture Organization of the United Nations. Rome.

CAC, 2006. Principles for traceability/product tracing as a tool within a food inspection and certification system. CAC/GL 60-2006.

CAC, 2005. Codex procedural manual (15th edition). https://www.fao.org/fao-who-codexalimentarius/publications/procedural-manual/en/.

CAC, 1997. Codex Alimentarius food hygiene basic texts, 1st edn. World Health Organization and Food and Agriculture Organization of the United Nations, Rome.

Campden BRI, 2009. Traceability in the food and feed chain: general principles and basic system requirements. Guideline nr 60. Gloucestershire, U.K: Campden BRI.

Charlebois, S., Sterling, B., Haratifar, S., Naing, S.K., 2014. Comparison of Global Food Traceability Regulations and Requirements. Compr. Rev. Food Sci. Food Saf. 13, 1104–1123. https://doi.org/10.1111/1541-4337.12101

Chemeltorit, P., Saavedra, Y., Gema, J., 2018. Food traceability in the domestic horticulture sector in Kenya: An overview.

Dabbene, F., Gay, P., Tortia, C., 2014. Traceability issues in food supply chain management: A review. Biosyst. Eng., Operations Management in Bio-production Systems 120, 65–80. https://doi.org/10.1016/j.biosystemseng.2013.09.006

Doshi, J., Patel, T., Bharti, S.K., 2019. Smart Farming using IoT, a solution for optimally monitoring farming conditions. Procedia Comput. Sci. 160, 746–751. https://doi.org/10.1016/j.procs.2019.11.016

EPCglobal, 2009. The EPCglobal Architecture Framework. https://www.gs1.org/sites/default/files/docs/architecture/architecture_1_3-framework-20090319.pdf.

EU, 2002. Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002, laying down the general principles and requirements of food law, establishing the European Food Safety Authority, and laying down procedures in matters of food safety. OJ L 31.

FAO, 2023a. FAO Strategic Priorities for Food Safety within the FAO Strategic Framework 2022-2031. FAO. https://doi.org/10.4060/cc4040en

FAO, 2023b. Feasibility study for application of digital technologies for improved traceability and transparency along the agrifood value chains. FAO. https://doi.org/10.4060/cc7582en

FAOSTAT, 2022. Trade, crops and livestock products. Rome, FAO.

FDA, 2011. Background on the FDA Food Safety Modernizaϴon Act (FSMA). https://www.fda.gov/food/food-safety-modernization-act-fsma/background-fda-food-safety-modernization-act-fsma.

Gabre-Madhin, E., 2001. The role of intermediaries in enhancing market efficiency in the Ethiopian grain market. Agric. Econ. 25, 311–320. https://doi.org/10.1016/S0169-5150(01)00088-3

Geng, S., Liu, X., Beachy, R., 2015. New Food Safety Law of China and the special issue on food safety in China. J. Integr. Agric. 14, 2136–2141. https://doi.org/10.1016/S2095-3119(15)61164-9

GlobalGAP, 2009. Available from: http://www.globalgap.org/cms/front_content.php?idcat=9.

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K., Price, G., 2004. Traceability in the U.S. Food Supply: Economic Theory and Industry Studies. Economic Research Service, U.S. Department of Agriculture, Agricultural Economic Report No. 830. https://www.ers.usda.gov/webdocs/publications/41623/28673_aer830_1_.pdf?v=0.

GS1, 2012. GS1 Global Traceability Standard, Business Process and System Requirements for Full Supply Chain Traceability. GS1 Standards Document. https://www.gs1.org/docs/traceability/Global_Traceability_Standard.pdf.

GS1 US, 2009a. Available from: www.GS1US.org.

GS1 US, 2009b. GS1 global traceability standard. Available from: http://www.gs1.org/traceability/gts.

GS1 US, 2009c. Products and solutions. Available from: http://www.gs1.org/productssolutions.

GS1 US, 2009d. Global activities. Available from: http://www.gs1.org/traceability/activities.

Haddad, F.M., Toma, I., Popa, M.E., Pipirigeanu, M., 2019. The Traceability of Food Products in Relation with Food Integrity – A Review.

Hasan, I., Habib, M., Mohamed, Z., 2023. A Systematic Literature Review on Agri-Food Supply Chain Transparency 12. https://doi.org/10.59160/ijscm.v12i4.6200

Hichaambwa, M., Tschirley, D., 2010. How are Vegetables Marketed into Lusaka? The Structure of Lusaka's Fresh Produce Marketing System and Implications for Investment Priorities. http://wwwaec.msu.edu/agecon/fs2/zambia/index.htm.

Hichaambwa, M., Tschirley, D., 2006. Zambia Horticultural Rapid Appraisal: Understanding the Domestic Value Chains of Fresh Fruits and Vegetables.

Islam, S., Cullen, J.M., 2021. Food traceability: A generic theoretical framework. Food Control 123, 107848. https://doi.org/10.1016/j.foodcont.2020.107848

ISO, 2000. International Organization for Standardization (ISO) 9000:2000. Quality Management Standards. http://www.iso.ch/iso/en/aboutiso/introduction/index.html#six.

ITC, 2015. Traceability in Food and Agricultural Products.Bulletin No. 91/2015. https://www.cold.org.gr/library/downloads/Docs/Traceability%20in%20food%20and%20agricultural%20products.pdf.

Jin, S., Zhou, L., 2014. Consumer interest in information provided by food traceability systems in Japan. Food Qual. Prefer. 36, 144–152. https://doi.org/10.1016/j.foodqual.2014.04.005

Kleinheksel, A.J., Rockich-Winston, N., Tawfik, H., Wyatt, T.R., 2020. Demystifying Content Analysis. Am. J. Pharm. Educ. 84, 7113. https://doi.org/10.5688/ajpe7113

Kolbe, R.H., Burnett, M.S., 1991. Content-Analysis Research: An Examination of Applications with Directives for Improving Research Reliability and Objectivity. J. Consum. Res. 18, 243. https://doi.org/10.1086/209256

Kondracki, N.L., Wellman, N.S., Amundson, D.R., 2002. Content Analysis: Review of Methods and Their Applications in Nutrition Education. J. Nutr. Educ. Behav. 34, 224–230. https://doi.org/10.1016/S1499-4046(06)60097-3

Kumvenji, D.C.E., Chamba, M.V.M., Lungu, K., 2022. Effectiveness of food traceability system in the supply chain of local beef and beef sausages in Malawi: A food safety perspective. Food Control 137, 108839. https://doi.org/10.1016/j.foodcont.2022.108839

Levinson, D.R., 2009. Traceability in the food supply chain. Retrieved from http:// oig.hhs.gov/oei/reports/oei-02-06-00210.pdf.

Manfreda, G., De Cesare, A., 2014. The challenge of defining risk-based metrics to improve food safety: Inputs from the BASELINE project. Int. J. Food Microbiol. 184, 2–7. https://doi.org/10.1016/j.ijfoodmicro.2014.01.013

McEntire, J.C., Arens, S., Bernstein, M., Bugusu, B., Busta, F.F., Cole, M., Davis, A., Fisher, W., Geisert, S., Jensen, H., 2010. Traceability (Product Tracing) in Food Systems: An IFT Report Submitted to the FDA, Volume 1: Technical Aspects and Recommendations. Compr. Rev. Food Sci. Food Saf. 9, 92–158. https://doi.org/10.1111/j.1541-4337.2009.00097.x

Mukuni, V.F., 2022. Risk Cultures and Meat Traceability in The United States and Zambia. J. Interdiscip. Food Stud. Disiplinlerarası Gıda Çalışmaları Derg. 2, 1–14. https://doi.org/10.5281/zenodo.6783656

Mulenga, B.P., Kabisa, M., Chapoto, A., 2021. Zambia Agriculture Status Report 2021. Indaba Agricultural Policy Research Institute.

Mwango, M., Kaliba, M., Chirwa, M., Guarín, A., 2019. Informal food markets in Zambia: Perspectives from vendors, consumers and policymakers in Lusaka and Kitwe Discussion paper). https://www.iied.org/sites/default/files/pdfs/migrate/16659IIED.pdf.

Narsimhalu, U., Potdar, V., Kaur, A., 2015. A Case Study to Explore Influence of Traceability Factors on Australian Food Supply Chain Performance. Procedia - Soc. Behav. Sci. 189, 17–32. https://doi.org/10.1016/j.sbspro.2015.03.188

National Assembly of Zambia, 2019. The Food Safety Act No. 7 of 2019 of the National Assembly of Zambia. https://www.parliament.gov.zm/node/8206 [WWW Document]. URL (accessed 2.5.24).

Norton, T., Beier, J., Shields, L., 2014. A guide to traceability: A practical approach to advance sustainability in global supply chains. The United Nations Global Compact and BSR Report.

Olsen, P., 2018. Food traceability in theory and in practice https://ninum.uit.no/bitstream/handle/10037/15408/thesis_entire.pdf?sequence=9&isAllowed=y.

Opara, U., 2003. Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects. Food Agric Env. 1.

Ouma, S., 2010. Global Standards, Local Realities: Private Agrifood Governance and the Restructuring of the Kenyan Horticulture Industry. Econ. Geogr. 86, 197–222. https://doi.org/10.1111/j.1944-8287.2009.01065.x

Qian, J., Dai, B., Wang, B., Zha, Y., Song, Q., 2022. Traceability in food processing: problems, methods, and performance evaluations—a review. Crit. Rev. Food Sci. Nutr. 62, 679–692. https://doi.org/10.1080/10408398.2020.1825925

Qian, J., Ruiz-Garcia, L., Fan, B., Robla Villalba, J.I., McCarthy, U., Zhang, B., Yu, Q., Wu, W., 2020. Food traceability system from governmental, corporate, and consumer perspectives in the European Union and China: A comparative review. Trends Food Sci. Technol. 99, 402–412. https://doi.org/10.1016/j.tifs.2020.03.025

Rejeb, A., Keogh, J.G., Simske, S.J., Stafford, T., Treiblmaier, H., 2021. Potentials of blockchain technologies for supply chain collaboration: a conceptual framework. Int. J. Logist. Manag. 32, 973–994. https://doi.org/10.1108/IJLM-02-2020-0098

Rejeb, A., Keogh, J.G., Zailani, S., Treiblmaier, H., Rejeb, K., 2020. Blockchain Technology in the Food Industry: A Review of Potentials, Challenges and Future Research Directions. Logistics 4, 27. https://doi.org/10.3390/logistics4040027

Rodriguez-Salvador, B., Dopico, D.C., 2020. Understanding the value of traceability of fishery products from a consumer perspective. Food Control 112, 107142. https://doi.org/10.1016/j.foodcont.2020.107142

Samarasinghe, Y.M., Kumara, M., Kulatunga, A., 2021. Traceability of Fruits and Vegetables Supply Chain towards Efficient Management: A Case Study from Sri Lanka. Int. J. Ind. Eng. Oper. Manag. 03, 89–106. https://doi.org/10.46254/j.ieom.20210203

SGF Institute, 2024. https://www.sqfi.com/. Accessed 05/02/2024.

Shah, J.R., Murtaza, M.B., 2010. Impact of RFID on Data Sharing and Business Processes. http://www.swdsi.org/swdsi08/paper/SWDSI%20Proceedings%20Paper%20S601.pdf.

Smith, G.C., Tatum, J.D., Belk, K.E., Scanga, J.A., Grandin, T., Sofos, J.N., 2005. Traceability from a US perspective. Meat Sci., 51st International Congress of Meat Science and Technology (ICoMST) 71, 174–193. https://doi.org/10.1016/j.meatsci.2005.04.002

Souza-Monteiro, D.M., Caswell, J.A., 2005. The Economics of Traceability for Multi-Ingredient Products: A Network Approach. https://www.researchgate.net/publication/23505883_The_Economics_of_Traceability_for_Multi-Ingredient_Products_A_Network_Approach.

Tagarakis, A.C., Benos, L., Kateris, D., Tsotsolas, N., Bochtis, D., 2021. Bridging the Gaps in Traceability Systems for Fresh Produce Supply Chains: Overview and Development of an Integrated IoT-Based System. Appl. Sci. 11, 7596. https://doi.org/10.3390/app11167596

Tang, Q., Li, J., Sun, M., Lv, J., Gai, R., Mei, L., Xu, L., 2015. Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation. Biosci. Trends 9, 7–15. https://doi.org/10.5582/bst.2015.01004

Thakur, M., Sørensen, C.-F., Bjørnson, F.O., Forås, E., Hurburgh, C.R., 2011. Managing food traceability information using EPCIS framework. J. Food Eng. 103, 417–433. https://doi.org/10.1016/j.jfoodeng.2010.11.012

Tschirley, D., Hichaambwa, M., Mwiinga, M., 2011. Comparative assessment of the marketing structure and price behaviour of three staple vegetables in Lusaka, Zambia., in: Mithöfer, D., Waibel, H. (Eds.), Vegetable Production and Marketing in Africa: Socio-Economic Research. CABI, UK, pp. 127–147. https://doi.org/10.1079/9781845936495.0127

Van der Meulen, B.M., 2013. The structure of European food law. Laws 2, 69–98.

Van Hilten, M., Ongena, G., Ravesteijn, P., 2020. Blockchain for Organic Food Traceability: Case Studies on Drivers and Challenges. Front. Blockchain 3, 567175. https://doi.org/10.3389/fbloc.2020.567175

World Bank, 2022. Digital Technology for Traceability in Vietnam's Fruit and Vegetable Value Chains. Washington, DC. https://doi.org/10.1596/40559

Yasay, J.J., 2021. Internet of Things in the Philippine Agribusiness 6, 518–525. https://doi.org/10.48175/IJARSCT-1409

Zamstats, 2022. 2022 Census of Population and Housing Preliminary Report. https://www.zamstats.gov.zm/publications/.

Zhang, C., Bai, J., Wahl, T.I., 2012. Consumers' willingness to pay for traceable pork, milk, and cooking oil in Nanjing, China. Food Control 27, 21–28. https://doi.org/10.1016/j.foodcont.2012.03.001

Zhang, J., Bhatt, T., 2014. A Guidance Document on the Best Practices in Food Traceability. Compr. Rev. Food Sci. Food Saf. 13, 1074–1103. https://doi.org/10.1111/1541-4337.12103

8. Appendices

Appendix 1: Key informant's checklist for Horticultural producers

- What is your role/position in the establishment?
- Which horticultural products do you produce and what are your estimated volumes per annum?
- Who are the major customers of your products?
- What do you understand about food traceability?
- To what extent do you apply traceability within and outside your establishment?
- In case you do not apply traceability in your establishment, why? What is the possibility of introducing traceability to your establishment?
- What traceability system(s) do you use in your establishment (paper-based or electronic system)?
- What traceability software do you use in your establishment?
- What are the major benefits of traceability your establishment has enjoyed?
- What major challenges and limitations have you experienced in your application of traceability in the horticulture supply chain.
- What possible recommendations would you give to both the government and the private sector to improve traceability in Zambia.

Appendix 2: Key informant's checklist for Aggregators

- What is your role/position in the establishment?
- What are the major fresh fruits and vegetables and related processed products do you trade in?
- Who are the major suppliers of your fresh fruits and vegetables and related processed products?
- Who are the major customers of your fresh fruits and vegetables and related processed products?
- What do you understand about food traceability?
- To what extent do you apply traceability within and outside your establishment? Kindly explain your traceability process(s).
- In case you do not apply traceability in your establishment, why? What is the possibility of introducing traceability to your establishment?
- What traceability system(s) do you use in your establishment (paper based or electronic system)?
- What traceability software do you use in your establishment?
- What are the major benefits of traceability your establishment has enjoyed?
- What are the major challenges and limitations in your application of traceability in the horticulture supply chain.
- What possible recommendations would you give to both the government and the private sector to improve traceability in Zambia?

Appendix 3: Key informant's checklist for supermarkets

- What is your role/position in the establishment?
- What are the major fresh fruits and vegetables and related processed products you trade in?
- Who are the major suppliers of your fresh fruits and vegetables and related processed products?
- Who are the major customers of your fresh fruits and vegetables and related processed products?
- What do you understand about food traceability?
- To what extent do you apply traceability within and outside your establishment? Kindly explain your traceability process(s).
- In case you do not apply traceability in your establishment, why? What is the possibility of introducing traceability to your establishment?
- What traceability system(s) do you use in your establishment (paper based or electronic system)?
- What traceability software do you use in your establishment?
- What are the major benefits of traceability your establishment has enjoyed?
- What are the major challenges and limitations in your application of traceability in the horticulture supply chain.
- What possible recommendations would you give to both the government and the private sector to improve traceability in Zambia?

Appendix 4: Key informant's checklist for Market Representative

- What is your role/position in the establishment?
- What are the major fresh fruits and vegetables and related processed products you trade in?
- Who are the major suppliers of your fresh fruits and vegetables and related processed products?
- Who are the major customers of your fresh fruits and vegetables and related processed products?
- What do you understand about food traceability?
- To what extent do you apply traceability within and outside your establishment? Kindly explain your traceability process(s).
- In case you do not apply traceability in your establishment, why? What is the possibility of introducing traceability to your establishment?
- What traceability system(s) do you use in your establishment (paper based or electronic system)?
- What traceability software do you use in your establishment?
- What are the major benefits of traceability your establishment has enjoyed?
- What are the major challenges and limitations in your application of traceability in the horticulture supply chain.

- What recommendations would you give to improve traceability in Zambia?

Appendix 5: Focus Group Discussion checklist for Smallholder farmers

- What are the major horticultural crops you produce?
- What is the major market for your products?
- Who are the major buyers of your products?
- What do you understand about food traceability?
- To what extent do you apply traceability within and outside your farms?
- In case you do not apply traceability in your farms, why? What is the possibility of introducing traceability to your farms?
- What traceability system(s) do you use in your farms (paper based or electronic system)?
- What traceability software do you use on your farms?
- What are the major benefits of traceability your farm has enjoyed?
- What are the major challenges and limitations in your application of traceability in the horticulture supply chain.