Achieving effective traceability systems for the domestic fresh produce industry in New Zealand

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Abstract

A reliable and effective traceability system is important to the food industry especially when a foodborne illness outbreak occurs. In particular, fresh fruit and vegetables are highly perishable, fragile, seasonal, diverse products with relatively short shelf life, thereby making their value chain complex and fast-paced. Hence, the traceability system in the fresh produce industry becomes critical in the event of a food crisis where products need to be tracked and traced in a timely manner. The objective of this study was to investigate current traceability systems in the fresh produce industry in New Zealand and also to explore potential improvement in the traceability system along the domestic supply chains. There were four different methods applied in this study: observation of traceability information available on fresh produce products, interviews with industry participants using a questionnaire, survey strategy by means of a questionnaire that was sent to growers, and a pilot study using GS1 technology to examine a modelled traceability system in two supply chains of strawberries.

There were 336 fresh produce samples observed for traceability information analysis throughout the supply chain. Four growers, three wholesalers and one retailer from the fresh produce industry participated the face to face interviews. The questionnaire developed in the survey was sent to 578 growers with 40 of them responded and answered. Two pallets of strawberries were selected and GS1 (Global Standards One) barcodes and systems were used in the pilot study to track and trace each strawberry punnet throughout the supply chains. Qualitative and quantitative data were collected from produce traceability data samples, interviewed industry stakeholders, surveyed growers, and the pilot study to generate empirical information on traceability systems along fresh produce supply chains in New Zealand. Subsequently, data were analysed using quantitative tools such as frequency distributions, Chi-Square test (X^2) and Fisher's Exact test, and qualitative descriptions in this study.

The findings show that fragmentation of product traceability information, lack of standardisation in data format and information asymmetry exist in the domestic fresh produce industry. As only a 'one-up, one-down' traceability system for food businesses is required by regulators in New Zealand, industry players intend to solely focus on their own or internal needs without recognising the importance of an industry-wide traceability system in the fresh produce supply chain. The findings pose a question mark as to whether or not the 'one-up, one-down' traceability requirement is sufficient for the fresh produce industry. The findings also indicate that an effective and efficient external traceability system throughout the fresh produce value chain in New Zealand is feasible to implement by industry-wide cooperation from growers, packers, transporters and receivers/buyers.

This study fills the gap found in the literature where few academic papers focused attention on traceability systems in the fresh produce industry in New Zealand.

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Abbreviations

CDC	=	Centre of Disease Control and Prevention
EAN	=	European Article Number
FCP	=	Food Control Plan
FDA	=	Food and Drug Administration
Global GAP	=	Global Good Agricultural Practice
GS1	=	Global Standards One
GTIN	=	Global Trade Item Number
LITS	=	Livestock Identification and Traceability System
MPI	=	Ministry for Primary Industries
NFC	=	Near Field Communication
NP	=	National Programme
NZ GAP	=	New Zealand Good Agricultural Practice
PNs	=	Petri Nets
QR Code	=	Quick Response Code
RFID	=	Radio Frequency Identification
SSCC		Serial Shipping Container Code
TRU	=	Traceable Resource Unit
UCC	=	Uniform Code Council
1D Barcode	=	One-Dimensional Barcode
2D Barcode	=	Two-Dimensional Barcode

1.0 Introduction

Foodborne disease outbreaks have always been one of the biggest concerns for government agencies, food industry sectors, consumers and medical professionals (Arendt et al., 2013; Haleem, Khan & Khan, 2019; Hussain & Dawson, 2013; World Health Organization, 2008; Bosona & Gebresenbet, 2013; Wognum, Bremmers, Trienekens & Van der Vorst, 2011). In particular, fresh produce contributes significantly to foodborne illness outbreaks as they are often eaten raw, with minimal or no further processing such as heating to kill any potential pathogens (Bennett et al., 2018; Lynch, Tauxe & Hedberg, 2009; Sivapalasingam, Friedman, Cohen & Tauxe, 2004; Julien-Javaux, Gerard, Campagnoli & Zuber, 2019; Mahajan, Caleb, Singh, Watkins & Geyer, 2014; Prakash, 2016). For example, a *Yersinia pseudotuberculosis* outbreak linked to fresh produce was reported in New Zealand in 2014 and resulted in over 300 illnesses in the country (Ministry for Primary Industries, 2014). Another outbreak caused by *Escherichia coli* O104:H4 occurred in Germany and France in 2011 was associated with imported fenugreek seeds (De Henriette, 2016). Moreover, a *Listeria monocytogenes* outbreak caused by contaminated cantaloupe was reported in the United States and was blamed for at least 26 deaths (Claiborn, 2011). In such cases, a reliable traceability system plays a vital role and becomes an effective method when a food recall is required (Dzwolak, 2016; Porter, Baker & Agrawal, 2011; Fan et al., 2019; Mgonia, Luning & Van der Vorst, 2013; Rong & Grunow, 2010; Zhao & Nakano, 2018; Mainetti et al., 2013; Pouliot & Sumner, 2008; Dabbene, Gay & Tortia, 2014). According to Lindh and Olsson (2010), food traceability can be used to improve food safety management systems for food businesses and enhance customer confidence in their products. It was described as the ability to trace food products through the supply chain from farm or production to consumer (Charlebois & Haratifar, 2015). There are various elements and information included in a reliable traceability system throughout the produce value chain, ranging from grower name, grower contact details, product name, variety, colour, size, pack date, harvest date, field code, transport details, to wholesaler and retailer information (Kondo, 2010; Fresh Produce Safety Centre Australia & New Zealand, 2019). This type of information is vital in the event of a product recall (Pouliot & Sumner, 2008).

It is well-known that the meat and dairy industries have made huge efforts to ensure that product traceability procedures are implemented and a great deal of research has been undertaken to improve their traceability systems (Donnelly, Karlsen & Olsen, 2009; Mgonia et al., 2013; Mutua et al., 2018; Vulton, 2010). For instance, Mgonia et al. (2013) evaluated the traceability system of a fish processing company with a diagnostic tool. Mutua et al. (2018) conducted a livestock identification and traceability pilot with a beef supply chain between Tanzania and Kenya. On the other hand, there were also a number of studies carried out to investigate current traceability systems for fresh fruit and vegetables value chains worldwide (Manikas et al., 2010; Canavari et al., 2010; Gichure et al., 2017; Kondo, 2010; Kim, Hilton, Burks & Reyes, 2018). Manikas et al. (2010) studied different factors affecting the efficiency of traceability systems in the fresh produce industry in Greece. Canavari et al. (2010) investigated traceability systems as part of information management in the fruit value chain in Italy. Gichure et al. (2017) carried out a case study on product traceability system within the kale supply chain in Kenya and examined a variety of factors influencing the implementation of effective traceability systems.

However, very few studies have been conducted to explore the existing traceability systems in the fresh produce industry in New Zealand. Additionally, the challenges and limitations of food traceability system implementation throughout fresh horticultural products supply chain in New Zealand are not well understood. To date, there is no standardized industry-wide method used in New Zealand that allows traceability from the grower, through the supply chain to the consumer. In addition, the fresh produce supply chain is fragmented, and has fragmented information in terms of effective traceability due to the sheer number of products and the intricacies of each supply chain merging at various levels before reaching the consumer (Manos & Manikas, 2010; MacKenzie & Apte, 2017; Manikas et al., 2010). Furthermore, the fresh produce industry is fast-paced, with most products moving from farm to plate in as little as a few days (MacKenzie & Apte, 2017). This all contributes to produce traceability challenges. Therefore, there is a need to make headway in improving traceability systems for the sector.

1.1 Main Objective

The main objective of this study was to understand current traceability systems in the fresh produce industry in New Zealand and explore potential improvement in the traceability system along the domestic value chains.

1.2 Specific Objectives

Specific objectives were:

1. To explore the current traceability practices in the fresh produce industry in New Zealand;
2. To investigate barriers in the design and implementation of tracking and tracing systems;
3. To demonstrate perceptions and attitudes to the uptake of traceability within the fresh produce industry;
4. To propose a reliable traceability framework for the domestic fresh produce industry to achieve an effective traceability system.

2.0 Literature review

2.1 Introduction

Along with the high consumption of fresh fruit and vegetables due to healthy eating recommendations, the rate of foodborne illness outbreaks associated with fresh produce continues to increase worldwide (Callejon et al., 2015; Hanning, Nutt & Ricke, 2009; Harris et al., 2003; Prakash, 2016; Curtis, Yeager, Black, Drost & Ward, 2014). By implementing a reliable traceability system across the product value chain, food businesses can target the products affected by a food safety problem and therefore minimise any potential public health risks in a timely manner (Bertolini, Bevilacqua & Massini, 2006; Bello, Mirabella & Torrisi, 2005; Mainetti et al., 2013; Sun & Wang, 2019; Kim et al., 2018; Costa et al., 2013). Meanwhile, fresh produce is perishable, seasonal, fragile and has relatively short shelf life, thereby increasing the complexity and difficulty of traceability implementation in the fresh produce supply chain (Gokarn & Kuthambalayan, 2019; Wognum et al., 2011; Priyadarshani & Wickramasinghe, 2018).

However, information on the traceability system of the domestic fresh produce supply chain is limited and little research has been conducted in New Zealand. United Fresh NZ Inc., the pan-industry fresh produce trade association, proposed a framework to encourage comprehensive interaction among the produce industry towards establishing a traceability system in New Zealand (Maurer, Dolan & Arts, 2015). The proposed framework was introduced by Maurer et al. (2015) and all fresh produce stakeholders were encouraged to take responsibility and work together as an industry. This proposed framework required a huge involvement and co-operation from all produce stakeholders, including government and regulators (i.e. Ministry for Primary Industries), New Zealand industry bodies, retailer businesses, research bodies, training providers, system verifiers, and so on (Maurer et al., 2015). Maurer et al. (2015) also stated that the framework could be beneficial for the entire produce supply chain as a more structured approach to achieve a robust food safety culture. Nevertheless, details of the implementation of an effective traceability system for the horticultural industry in New Zealand were not well described in this study.

Effective traceability systems are important when the product has to move rapidly through the chain especially as a large number of products are consumed raw without further processing (Mainetti et al., 2013). This means that if the product is contaminated with a microbial organism at any point in the supply chain and there is no kill step, it could lead to illness. Outbreaks of Hepatitis A in late 2015 linked to frozen berries and *Yersinia pseudotuberculosis* in late 2014 potentially associated with fresh carrots and lettuce have been reported in New Zealand (Ministry for Primary Industries, 2014).

Therefore, the objective of this literature review was to understand the current traceability systems implemented in the fresh produce industry and identify any outcomes from previous research. Complexity and different roles of stakeholders of fresh produce supply chain in New Zealand were explored and discussed. Food traceability studies from other countries were also examined to assist with understanding of current systems and their application in the New Zealand domestic environment to improve fresh produce traceability system, both internally and externally. This review consists of six sections: foodborne illness outbreaks, characteristics of food traceability, food traceability technology, barriers of the implementation of traceability systems and their current shortcomings, fresh produce supply chain in New Zealand, and some stakeholders of fresh produce supply chain in New Zealand.

2.2 Foodborne illness outbreaks

There has been a great number of foodborne illness outbreaks associated with fresh produce consumption over the past decades and many people suffered or even died from this (Julien-Javaux et al., 2019; Ministry for Primary Industries, 2014; Pouliot & Sumner, 2008; Hanning et al., 2009; Kirezieva et al., 2013; Sun & Wang, 2019). Contaminated alfalfa sprouts were linked to two large *Salmonella* outbreaks in the United States, Finland and Canada between 1995 and 1996 with more than 700 illnesses and one death reported (Hanning et al., 2009; Mahon et al., 1997; Van Beneden et al., 1999). It was concluded that contaminated alfalfa seeds were the main reason causing *Salmonella* infections after investigations (Mahon et al., 1997; Van Beneden et al., 1999). Some examples of foodborne outbreaks related to contaminated produce within the last two decades were summarised in Table 2.1.

Table 2.1 Examples of foodborne outbreaks due to contaminated produce between 1999 and 2019.

Produce	Pathogen	Year	No. of illnesses	Reference
Mung sprouts	*Salmonella*	2000	45	Hanning et al., 2009; Mohle-Boetani et al., 2009
Tomatoes	*Salmonella*	2004	561	Gupta et al., 2007; Hanning et al., 2009
Watermelon	*Salmonella*	2006	20	Hanning et al., 2009
Bagged spinach	*Escherichia coli O157:H7*	2006	204 (3 deaths)	Pouliot & Sumner, 2008; Calvin, 2007
Alfalfa sprouts	*Salmonella*	2008	13	Hanning et al., 2009
Cantaloupe	*Salmonella*	2008	51	Hanning et al., 2009
Serrano peppers	*Salmonella*	2008	1442	Hanning et al., 2009
Cantaloupe	*Listeria monocytogenes*	2011	>130 (At least 26 deaths)	Claiborn, 2011
Fenugreek seeds	*Escherichia coli O104:H4*	2011	>3,000 (37 deaths)	Bilinski et al., 2012; De Henriette, 2016; Sun & Wang, 2019
Fresh produce (likely)	*Yersinia pseudotuberculosis*	2014	217	Ministry for Primary Industries, 2014
Cilantro	*Cyclosporiasis*	2015	546	Julien-Javaux et al., 2019
Strawberry	Hepatitis A virus	2016	143	Julien-Javaux et al., 2019
Romaine lettuce	*Escherichia coli O157:H7*	2018	210 (5 deaths)	Julien-Javaux et al., 2019

A huge number of studies were performed and investigations were undertaken to analyse the root cause and cross contamination. For instance, foodborne outbreaks associated with fresh fruit and vegetables were studied and reviewed to understand factors contributing to the incidences (Harris et al., 2003). It was indicated that various fresh produce has become a source of *Salmonella* outbreaks, such as watermelon, iceberg lettuce, orange, cantaloupe and strawberries (Harris et al., 2003). It was also mentioned that a hepatitis A virus outbreak linked to frozen berry fruits was investigated and infected workers and contaminated irrigation water were considered to be the potential causes of cross contamination (Harris et al., 2003). A number of foodborne illness outbreaks associated with fresh tomatoes contaminated by Salmonella were investigated and discussed by some researchers (Dev Kumar et al., 2018; Hanning et al., 2009). In addition, the involvement of *Salmonella* in tomato associated outbreaks and its growth in soil and water were examined and studied (Dev Kumar et al., 2018). Another *Salmonella* outbreak associated with serrano peppers from Mexico was confirmed by FDA in 2008 with over 1000 illnesses reported (Hanning et al., 2009). An investigation was undertaken to trace products back through their distribution channels to the origins of products and contaminated irrigation water from a farm in Mexico was identified as the source of causing this outbreak in the United States ("FDA extends consumer," 2008).

Nevertheless, the root cause of contamination from a foodborne illness outbreak could not always be confirmed in spite of numerous time and labour being spent on the investigation. For example, a *Yersinia pseudotuberculosis* outbreak likely associated with fresh produce was reported in New Zealand in 2014 and resulted in a total of 217 cases linked to infection by *Yersinia pseudotuberculosis* from 1 September to 7 October (Ministry for Primary Industries, 2014). However, the source of contamination was not clearly identified even though huge efforts have been made to undertake investigations throughout the product supply and distribution chains (Ministry for Primary Industries, 2014). A hepatitis A virus outbreak associated with frozen strawberries was reported in 2016 and the Food and Drug Administration (FDA) carried out investigations to trace back the contaminated strawberry products (Julien-Javaux et al., 2019). It was found out that the strawberries were imported from Egypt (Julien-Javaux et al., 2019). However, it was still unknown of the root cause of the contamination on the Egyptian strawberries from investigations (Julien-Javaux et al., 2019).

Furthermore, industry stakeholders such as produce growers could greatly be affected due to unexpected outbreaks linked to their fresh fruit and vegetables. For instance, the *Escherichia coli O104:H4* outbreak in 2011 which caused over 3,000 infections and 37 deaths was initially thought to be linked to cucumbers produced in Spain (Abend, 2011). The reputation of Spanish producers was therefore greatly damaged and it was estimated that Spanish agriculture sales lost 200 million euros in the first week of the crisis (Abend, 2011). According to Pouliot and Sumner (2008), a *Escherichia coli* outbreak in September 2006 was linked to bagged fresh spinach and caused at least 200 illnesses in the United States. The contaminated spinach was traced back to the original packer Natural Selection Foods and eventually tracked back to one of four farms in California from the investigation (Pouliot &

Sumner, 2008). After six months of the E. coli outbreak, the consumption of bagged spinach still kept decreasing and below the level from previous year whilst the consumption of bunched spinach has rebounded (Calvin, 2007).

2.3 Characteristics of food traceability

2.3.1 Defining food traceability

There were various definitions with regards to food traceability rather than a standardised definition applied in literatures, even though some of them were presenting very similar information (Bosona & Gebresenbet, 2013). For example, traceability was defined as the ability to trace and follow a food product through all stages of production, processing and distribution by European Parliament and Council (2002), whilst Souza-Monteiro and Caswell (2010) explained that traceability indicated an information flow amongst food companies and also involved interfirm coordination. The Codex Alimentarius Commission (1999) specified traceability as the ability to trace the history, application or location of an entity with recorded identifications. According to Olivier, Fourie and Evans (2006), food traceability was considered as a voluntary and regulative framework to bridge the information gaps among industry participants, including grower or farmer, food producer, retailer and consumer.

An effective traceability system in the fresh produce industry indicates that any movement of products could be traced backwards and forwards at any point within the supply chain (Haleem et al., 2019). It is the ability to track the history, application or location of fresh fruit and vegetables through all stages of growing, processing and distribution, ranging from growers, packhouses, wholesalers, distribution centres to retailers (Canavari et al., 2010). Similarly, Mainetti et al. (2013) indicated that traceability was the ability to capture, collect and store data associated with all process operations within the supply chain in terms of the origin, location and life history of a product, thereby providing guarantee to both industry participants and the consumer. Charlebois and Haratifar (2015) described traceability as the ability to trace products back throughout the supply chain from farm or production to the end user. Manos and Manikas (2010) explained that fresh produce traceability in the primary industry was referred to the ability to trace the produce product history through the entire supply chain, ranging from product identification to operations undertaken during the product life cycle. Overall, three key elements of food traceability were summarised by Bosona and Gebresenbet (2013) as tracing or backward follow-up of products, tracking or forward follow-up of products, and the history information of product along the supply chain. Bosona and Gebresenbet (2013) also presented the concept of food traceability with a schematic representation in Figure 2.1.

Figure 2.1 Conceptual representation of product and traceability information flow in a food supply chain.

(Bosona & Gebresenbet, 2013).

In addition, according to ISO 22005:2007 standards, all food businesses were required to establish a one-up, one-down traceability system and to know both their customers and suppliers (International Organization for Standardization, 2006). The concept of one-up, one-down approach was further illustrated by Bosona and Gebresenbet (2013), including two questions that food businesses should ask themselves:

1. Who is the supplier/s of ingredients and/or partially processed food?
2. Who is the receiver/s of food items?

Moreover, the European Parliament and the Council established the principles and requirements of general food law through regulation (EC) 178/2002 and created the European Food Safety Authority in 2002 (Souza-Monteiro & Caswell, 2010; Wognum et al., 2011).

General procedures in terms of food safety were provided and the implementation of traceability systems in the food supply chains in Europe was required by the European Parliament and the Council (Stranieri, Cavaliere & Banterle, 2017).

2.3.2 Advantages and disadvantages of food traceability

Food traceability has always been a focus by food businesses to improve their food safety management systems and also gain customer confidence on their food products (Lindh & Olsson, 2010; Olivier et al., 2006; Haleem et al., 2019; Costa et al., 2013). In addition, Souza-Monteiro and Caswell (2010) demonstrated that traceability could be utilised as a tool to obtain product information and manage food safety risks linked to these products. Traceability system was also considered as an important tool to control and optimise food production, obtain better industrial data and make better decisions, as well as profile desirable product characteristics (Storoy, Thakur & Olsen, 2013).

Furthermore, food traceability systems have also been widely applied in the food industry for meat and dairy products (Bennet, 2010; International Organization for Standardization, 2011; Mania, Delgado, Barone & Parisi, 2018). Traceability has emerged as a risk management tool that enables food companies or authorities to recall or withdrawal unsafe food products promptly (Mgonia et al., 2013).

A traceability system was considered as an effective and efficient tool to manage product information flow between different parties within a supply chain (Souza-Monteiro & Caswell, 2010; Dai, Ge & Zhou, 2015). Additionally, it could enhance logistics processes and minimise the impact of food safety risks (Hobbs, 2004: Meuwissen, Velthuis, Hogeveen & Huirne, 2003). Furthermore, Cozzolino (2012) highlighted that food adulteration could be reduced and minimised by tracing and authenticating agricultural products. Bosona and Gebresenbet (2013) identified and explained the benefits of food traceability implementation in their study, including increased customer satisfaction, enhanced food safety incidents management, improved food supply chain management, competence development for food businesses, technological and scientific contribution, and contribution to agricultural sustainability.

Traceability systems enable food businesses to track products effectively and efficiently in the event of a product recall due to food safety issues, thereby preventing consumers from any potential illness or injury caused by this product purchase (Bai & Li, 2014; Olivier et al., 2006). In addition, as traceability systems identify specific products to be recalled, the other products within the same category could potentially be avoided suffering the same destiny and disruption of trading will be reduced (Olivier et al., 2006). For instance, when a batch of fresh orange associated with foodborne illness is provided by a grower and needs to be recalled from a retailer, effective traceability system enables this retailer to target the batch of orange and track it back to a specific grower, or even a specific field block. Corrective and preventative actions will be taken to investigate the food safety issue with the affected orange grower and all affected orange products will be isolated from other products. Therefore, all other orange growers with the same variety of orange can still supply their produce to the retailer and disruption of trading is minimised. Olivier et al. (2006) stated that the advantage of product tracing was the ability to react quickly and demonstrated the procedures of tracing product in the event of a food safety crisis. Typically, the affected product and issue were identified at first, then the origin of the product and its problem were identified through the supply chain. Subsequently, other products at risk and their locations within the supply chain were detected. Finally, appropriate actions were taken and if necessary product withdrawal or recall was carried out to minimise their risks to the public (Olivier et al., 2006).

Costa et al. (2013) implied that food traceability in the agri-food sector was an efficient tool to share information and was potentially capable of providing more information for industry actors through the production and distribution chain. In addition, the time needed to intervene in the event of a food crisis was reduced in terms of recalling a whole stock from the market and individuating the real origin of the problem by applying an effective traceability system (Costa et al., 2013).

Olivier et al. (2006) considered that it was important to maintain effective traceability in the food chain not only due to food safety risks but also because it may result in painful consequences from food scandals for both industry participants and those in positions of authority such as government. In addition, it was stated that a better fresh produce traceability system was needed to avoid loss of sales through food safety recalls due to illness outbreaks (Food & Drug Administration, 2007; Olivier et al., 2006). More importantly, a robust traceability system could help the Food and Drug Administration (FDA) to narrow its search quickly and the costs caused by foodborne illness could be reduced to a minimum (Food & Drug Administration, 2007).

It was stated that traceability could be used for food crisis management such as distinguishing product identity and food fraud prevention (Badia-Melis, Mishra & Ruiz-Garcia, 2015). Lower cost distribution systems and reduced product recall expenses could also be achieved by the application of a reliable traceability system (Golan, Krissoff & Kuchler, 2004).

An effective traceability system could also promote food product sales as part of decision-making factors from buyers (Sun & Wang, 2019). Sun and Wang (2019) studied the preference of buyers such as retails in terms of sourcing products from suppliers such as food producers in a food supply chain. It was indicated that the buyer would prefer to source food products from the supplier who had a high-level traceability (Sun & Wang, 2019).

In addition, Hobbs, Bailey, Dickinson and Haghiri (2005) used experimental auctions to examine consumer willingness in terms of paying for traceability in beef and pork products in the United States and Canada in their study. It was pointed out that American and Canadian consumers were willing to pay a premium for beef and pork traceability (Hobbs et al., 2005). However, Wognum et al. (2011) discussed challenges in food supply chains and explored factors influencing the buying decisions of consumers. It was concluded that consumers appeared not to be willing to pay more for better traceability (Wognum et al., 2011).

However, there were also disadvantages of food traceability identified and discussed in previous research (Bosona & Gebresenbet, 2013; Souza-Monteiro & Caswell, 2010). Barriers and limitations to achieve effective food traceability implementation were discussed by Bosona and Gebresenbet (2013). There were five key limitations identified during their study from different directions, covering resource, information, standard, capacity and awareness (Bosona & Gebresenbet, 2013). Firstly, extra effort and cost were required for food businesses to develop and implement traceability systems and could potentially lead to financial issues. Secondly, traceability in the agricultural industry was linked to inherent uncertainty and sometimes it was difficult to obtain detailed information in a timely manner throughout all steps within the food supply chain. Thirdly, lack of sufficient and standardised information and methods of data exchange also became one of the main obstacles in terms of food traceability improvement and implementation. Fourthly, there was no adequately skilled employees that able to develop, implement and manage the traceability due to the complex nature of food traceability system in the supply chain. Finally, traceability implementation was considered as extra burden by industry partners and there was a lack of clarity information to understand traceability and its advantages, leading to concerns of the investment cost over its benefits and causing lack of awareness as well as less willingness to achieve traceability implementation (Bosona & Gebresenbet, 2013).

On the other hand, Souza-Monteiro and Caswell (2010) stated that food traceability was costly because it required obtaining, storing and sharing information. Furthermore, the benefits of a food traceability system may not be evenly distributed throughout the supply chain (Souza-Monteiro & Caswell, 2010).

Bosona and Gebresenbet (2013) undertook a comprehensive literature review on food traceability systems along different supply chains and indicated five main factors or concerns influencing the development and implementation of food traceability: regulatory concern, concerns of food safety and quality, social concern, economic and technological concerns.

2.3.3 Internal and external traceability

According to GS1 (2010), there are two different types of traceability: internal and external. Whilst, food traceability could also be categorised into internal traceability and chain traceability (Moe, 1998; Souza-Monteiro & Caswell, 2010). Similarly, Lindh and Olsson (2010) named external traceability as chain traceability and explained that participation and co-ordination of all actors from the supply chain were important to chain traceability. Good co-operation within all actors of the supply chain was required for an effective chain traceability system to ensure that it could be implemented successfully (Lindh & Olsson 2010). However, Olivier et al. (2006) emphasized that the supply chain co-operation was very difficult to achieve since it involved traceability information synchronisation through the supply chain and required a high level of transparency and collaboration between industry players.

Both internal and external traceability systems play important roles in the fresh fruit and vegetables supply chain. Internal traceability was considered as the proprietary data that a company used within its operations, but external traceability was the information exchange between trading partners (GS1, 2010; Souza-Monteiro & Caswell, 2010). Internal traceability allows people to track fresh produce through all steps of process flow within the business, while external traceability is associated with tracking fruit and vegetables outside of the business but within the supply chain (Rong & Grunow, 2010). According to Mgonia et al. (2013), internal traceability focuses on product activities within one company and it relates to traceability information of raw materials and processes to the final product prior to delivery. On the other hand, external or chain traceability is associated with data from one level to the next across the supply chain (Rong & Grunow, 2010). Souza-Monteiro and Caswell (2010) explained that chain traceability tracked the history of a batch within the value chain, including production, transport, storage, processing, distribution and sales. For example, a produce wholesaler is able to track its produce products from product arrival, quality checks, temporary storage, dispatch to delivery within the wholesaler through its internal traceability system. However, external traceability becomes vital when a product recall occurs and fresh produce purchased by consumers needs to be traced back to where it was grown and when it was packed.

A slightly different description was stated by Bello et al. (2005) in terms of internal and external traceability but still with fundamentally the same principles. Bello et al. (2005) indicated that two monitoring systems were required to achieve a full traceability: one system operated at production level and recorded product and process data from each stage of production; the other system operated at factory level and coordinated traceability information received from the first one for logistics (Bello et al., 2005).

2.3.4 Components of food traceability systems

Recently, Olsen and Borit (2018) defined Traceable Resource Unit (TRU) and described different components of a traceability system. According to Olsen and Borit (2018), a TRU in a traceability system was considered as a traceable object or product along a supply chain. The same concept of TRU was also proposed by Fan et al. (2019) and used to test a food traceability system and equipment in their study. In addition, Dabbene and Gay (2011) considered TRU as the foundation to implement an effective traceability system and stated that TRUs must be defined in the traceability system. A TRU was a uniquely identifiable unit and it needed to be consistent with traceability information recorded along the supply chain (Fan et al., 2019; Olsen & Borit, 2013).

There were three different types of TRUs identified in a traceability system (Olsen & Borit, 2018; Aung & Chang, 2014). A TRU could be a trade unit such as a box or a crate, a logistic unit such as a pallet or a production unit such as a batch (Olsen & Borit, 2018). Nevertheless, Aung and Chang (2014) proposed three types of TRUs which were slightly different compared to Olsen and Borit (2018). Batch, trade unit and logistical unit were considered as three types of TRUs by Aung and Chang (2014). A batch was a quantity or a number of products that went through the same processes. A trade unit was described as a unit delivered from one company to the next within a supply chain while a logistical unit was referred to a type of trade unit created as a group by a company prior to its transport or storage (Karlsen, Donnelly & Olsen, 2011).

Olsen and Borit (2018) analysed and discussed different components of a food traceability system. It was concluded that there were three main components of a traceability system, including a mechanism for identifying each TRU throughout its entire life cycle, the way of recording TRU relationships (e.g. connections between TRUs as they move through the supply chain), and the way of documenting all information relating to TRU attributes (Olsen & Borit, 2018). Firstly, a traceability system has to be able to identify the unit traced and therefore each unit must be unique and identifiable from the others. Secondly, the joining and splitting of units in the entire supply chain need to be recorded and documented in the traceability system to clearly show the product movements. Finally, the traceability system should also capture data of unit attributes such as product weight, location and temperature (Olsen & Borit, 2018).

The transformation of TRUs was commonly manifested by package splitting and aggregation (Fan et al., 2019). Fan et al. (2019) illustrated the joining and splitting of TRUs within a typical supply chain in current food traceability systems in Figure 2.2.

Figure 2.2 Process flow of traceable resource units (TRUs) aggregation and splitting through a typical supply chain in current food traceability systems.

(Fan et al., 2019).

However, Opara (2003) considered that an integrated agricultural and food value chain traceability system consisted of six important elements: product traceability, process traceability, genetic traceability, inputs traceability, disease and pest traceability, and measurement traceability. Product traceability determines physical locations of products at any stage within the supply chain while process traceability ascertains the type and sequence of activities applied on products. Genetic traceability covers genetic formation of products and inputs traceability determines type and origin of inputs such as fertilizer, chemical sprays and irrigation water. Disease and pest traceability traces the epidemiology of pests and biological hazards. Measurement traceability relates individual measurement results to accepted reference standards (Opara, 2003).

Olivier et al. (2006) pointed out that there were three main types of traceability for fresh produce. Firstly, the origin of a fresh produce was identified and subsequently the relevant product records was linked to the farm. Secondly, a product was tracked within a facility or internal processes such as packing or palletising. Thirdly, fresh produce products were tracked and traced through the value chain, commonly with a ‘one step forward and one step back’ approach (Olivier et al., 2006).

2.4 Food traceability technology

In order to establish an efficient and effective traceability system along the supply chain, innovative technologies were required for product identification, process characterization, system integration and dealing with relevant data such as capture, analysis, storage and transmission (Mainetti et al., 2013; Borrero, 2019; Dabbene & Gay, 2011). These technologies involved in both hardware and software solutions (Mainetti et al., 2013). The hardware solutions included identification tags and labels for products, logistic units and locations while software solutions covered computer programs and information systems (Mainetti et al., 2013).

In particular, a wide range of technologies were applied in food traceability to identify and trace products along their value chains (Abdullah, Nurilmala & Sitaresmi, 2019; Fan et al., 2019; Foster, Buskirk, Schweihofer, Grooms & Clarke, 2018; Institute of Food Technologists, 2019; Ishiyama, Kudo & Takahashi, 2016; Qiao, Wei & Yang, 2013; Costa et al., 2013; Dandage, Badia-Melis & Ruiz-Garcia, 2017). Specifically, barcodes, radio frequency identification (RFID), near field communication (NFC) and other technologies such as blockchain were examined and discussed in many studies in the past years (Abdullah et al., 2019; Alfian et al., 2017; Bai et al., 2017; Bello et al., 2005; Feng, Fu, Wang, Xu & Zhang, 2013; Ghaani, Cozzolino, Castelli & Farris, 2016; Luvisi et al., 2012; Mainetti et al., 2013; Sermpinis & Sermpinis, 2018; Kim et al., 2018; Bibi, Guillaume, Gontard & Sorli, 2017; Galvez, Mejuto & Simal-Gandara, 2018). The different technologies applied in the food industry and their benefits were summarised in Table 2.2 below.

Table 2.2 Application of different food traceability technologies in the food industry.

Technology	Advantage	Application	Reference
DNA mini-barcodes	As a molecular marker to prevent food fraud and to improve traceability system	Hairtail fish products authentication	Abdullah et al., 2019
Barcodes	Cost-effective; Ease of use	Animal identification	Bai et al., 2017; Ghaani et al., 2016
RFID	Real-time; Accurate data acquisition and transmission;	Environmental monitoring in a kimchi supply chain;	Alfian et al., 2017; Feng et al., 2013; Luvisi et al., 2012;

	High efficiency	Product tracking in the beef industry; Grapevines	Bibi et al., 2017
NFC	Derived from the RFID family; Inherit basic features of RFID but could also share data across active devices	Piloted in a vegetable supply chain for location identification	Mainetti et al., 2013
Blockchain	Tamperproof; Transparent; Real-time; High efficiency and security	Theoretical study and pilot only so far	Sermpinis & Sermpinis, 2018; Kim et al., 2018; Galvez et al., 2018

Barcodes have been widely applied in retail over the last three decades to facilitate their inventory control and stock recording as a low cost and easy to use technology (Ghaani et al., 2016; Bibi et al., 2017). Barcodes were classified as one-dimensional (1D) barcode and two-dimensional (2D) barcode (Fan et al., 2019). 1D barcode was also named as linear barcode (Bello et al., 2005). It was a pattern of parallel spaces and bars arranged to represent a series of digits and its encoded information was read by an optical barcode scanner (Bibi et al., 2017; Fan et al., 2019). Subsequently, the relevant information was sent to a system to be stored and processed during the scanning stage (Fan et al., 2019). 2D barcode was associated with composite codes and contained multi-row bars in a matrix (Bello et al., 2005). Compared to 1D barcodes, 2D barcodes were able to store more information by combining dots and spaces arranged in an array or a matrix rather than bars and spaces (Fan et al., 2019; Liang et al., 2013). In particular, the quick response (QR) code was a typical 2D barcode used widely in product identification and traceability on labels (Fan et al., 2019). QR code technology was very similar to 1D barcode but it could only become readable by a QR code reader or scanner (Seino et al., 2004).

RFID has drawn attention from the public since it was implemented by Wal-Mart in its supply chain in 2003 with publicly announced initiative (Singh, Singh, Desautels, Saha & Olsen, 2010). Recently, RFID has increasingly been adopted in the food industry for product traceability systems due to its superiority of automated and highly precise data recording (Bai et al., 2017; Bello et al., 2005; Mainetti et al., 2013; Bibi et al., 2017). It was a flow control technology which enabled traceability of products along all stages of the supply chain to be captured (Costa et al., 2013; Kelepouris, Pramatari & Doukidis, 2007; Ngai, Moon, Riggins & Yi, 2008). Additionally, RFID became an important technology applied in traceability due to its advantages such as eliminating the manual control, improving versatility of operational and logistical contexts, long service life and miniaturisation of equipment and devices (Sarac, Absi & Dauzere-Peres, 2010). RFID was composed by three different elements: an RFID tag, an interrogator and a database system (Costa et al., 2013; Bibi et al., 2017). The tag was generally applied on the displacing product directly and the interrogator was a device such as a reader to capture data from the tag, while the database system or a host computer was to store the data obtained through the interrogation process (Costa et al., 2013; Bibi et al., 2017). The RFID tag normally had an identification code and a microchip unit containing memory storage. The tags were classified as read-only and read-write tags (Costa et al., 2013). The former could be read in multiple times but could not be modified, while the latter could be both read and modified for several times (Costa et al., 2013).

RFID technology allowed contactless identification of products and effective information sharing with customisation and handling (Bosona & Gebresenbet, 2013; Fan et al., 2019). Olivier et al. (2006) implied that RFID enabled food products to be tracked and monitored across the supply chain without human intervention. RFID was also considered as a technology that could be used to enhance the information flow management through the food supply chain and improve security in the agri-food industry (Costa et al., 2013). RFID technology was more convenient to identify products compared to barcode systems because visual contact was not required by RFID tags and therefore they could be placed into product containers, injected into animals or embedded into an object (Bibi et al., 2017). However, barcodes were still widely used and dominated on the market because the cost of barcode systems was less than RFID technology (Bibi et al., 2017).

The differences between barcodes and RFID technology discussed in literatures were summarised in Table 2.3.

Table 2.3 Comparison between barcodes and RFID technology.

(Fan et al., 2019; Ghaani et al., 2016).

Attribute/feature	**1D barcode**	**2D barcode**	**RFID**
Technology	Optical (laser)	Optical (laser)	RF (radio frequency)
Environment condition	Sensitive to environment, dirt, scratches	Sensitive to environment, dirt, scratches	Durable, waterproof
Security	Low	Higher	Highest

	(non-encryption)	(simple encryption)	(deep encryption)
Reading distance	Near	Near	Far
Storage capacity	Very small (only express numbers)	Small (can express alphabet or other characters)	Big (can store data around 32-128Bit)
Reading/writing	Cannot be updated	Cannot be updated	New information can be over-written
Price	Cheap	Cheap	Expensive

A RFID based traceability system applied in beef production was examined and explored (Feng et al., 2013). In particular, it was concluded that real-time and accurate data acquisition and transmission were achieved by applying the RFID-enabled system. Furthermore, it was highly efficient to track traceability information throughout the beef production supply chain with the application of RFID based traceability system (Feng et al., 2013).

Recently, a barcode-RFID bidirectional transformation equipment was used by Fan et al. (2019) to enhance continuous traceability systems in the food industry. Apart from this, NFC was demonstrated as a short-range wireless technology derived from RFID but it was distinguished by the ability to share information through active and powered devices (Mainetti et al., 2013).

It was illustrated that blockchain technology could have great applications across a number of areas in the food industry especially for traceability (Institute of Food Technologists, 2019). Borrero (2019) also considered that the implementation of blockchain technology and cooperation of industry participants could be beneficial to the horticultural industry by providing more transparency and reducing the risk of food fraud and adulteration.

Blockchain technology used hash-based cryptology to ensure security and trust and it had three essential parts of data: transaction details, the transaction timestamp and a new hash connecting the hash and details from previous transaction (Institute of Food Technologists, 2019; Pierro, 2017). A hash was described as an encrypted type of a string or sequence of characters and it was considered as computationally impossible to derive the original without a key (Institute of Food Technologists, 2019). Subsequently, each transaction was distributed throughout the network and therefore a continuous encrypted record of the transaction was kept and became immutable once added to the blockchain (Institute of Food Technologists, 2019; Pierro, 2017). Transactional and distributed ledger functionality were provided via blockchain to allow different industry parties to operate without the requirement of a centralised and trusted authority (Galvez et al., 2018).

Blockchain technology enabled a more transparent and decentralised system across companies within the supply chain and allowed businesses to add information into the system with a level of anonymity and control (Institute of Food Technologists, 2019). Every computer or node within the network stored a copy of the blockchain and the nodes were periodically synchronised to ensure that all were sharing the same database (Galvez et al., 2018). In addition, different companies throughout the food supply chain could potentially add data into a shared ledger and the shared ledger could reach both ends of the value chain from grower to consumer (Institute of Food Technologists, 2019; Tian, 2017; Galvez et al., 2018). Digital product data such as grower details, batch numbers and logistical information were connected to food products and relevant information was added into the blockchain at each stage of the process along the supply chain with the application of blockchain technology (Galvez et al., 2018). Furthermore, industry participants could add traceability data while keeping important proprietary information hidden (Institute of Food Technologists, 2019).

However, Galvez et al. (2018) pointed out some challenges in implementing a blockchain technology on food traceability within the value chains. Its complexity made it difficult to be adopted and all industry participants in the supply chain had to collaborate to implement (Iansiti & Lakhani, 2017). Additionally, there was a lack of understanding and standards for the implementation of blockchain since it was still at an early stage of development (Galvez et al., 2018). Moreover, all involved parties needed to operate on an agreed type of blockchain, which made them under pressure (Galvez et al., 2018).

Noticeably, costs of technologies related to food traceability systems was still considered as high and therefore blocked their wide adoption in the fresh produce industry especially for low cost products (Mainetti et al., 2013).

2.5 Barriers of the implementation of traceability systems and their current shortcomings

A variety of studies have explored the implementation of traceability systems and discussed its barriers in the food industry (Donnelly et al., 2009; Feng et al., 2013; Mania et al., 2018; Mgonia et al., 2013; Mutua et al., 2018; Manikas et al., 2010; Olivier et al., 2006). For example, in the meat, dairy and seafood industry, Mgonia et al. (2013) introduced a diagnostic tool to assess company traceability systems internally for fish processing businesses. They pointed out that traceability systems were generally developed at company level and therefore only limited traceability data were provided. In addition, these data were fragmented and uncoordinated in approach through the entire supply chain (Mgonia et al., 2013). A RFID based traceability system in beef production was developed and assessed by Feng et al. (2013). The process flow for beef production along the supply chain and key information from the beef products traceability system were identified via a survey (Feng et al., 2013).

Recently, a livestock identification and traceability system (LITS) was designed and piloted by Mutua et al. (2018) within the northern Tanzania-Narok-Nairobi beef value chain. Traceability data from identified animals along with the value chain were collected and added into an online database and meat samples were also analysed for tetracycline and diminazene residues. In addition, a questionnaire survey was carried out and stakeholders from the beef value chain such as traders, producers and transporters were interviewed at the end of the pilot to understand their perceptions and level of acceptance on the LITS. Cui et al. (2018) introduced a systematic modelling approach to capture relevant critical traceability information from the sheep meat supply chain in China. A process modelling tool named petri nets (PNs) was proposed and used in this study. Advantages of PNs based information traceability model were also explained and illustrated by Cui et al. (2018).

Some studies were also undertaken to determine the implementation of traceability systems in the fresh produce industry worldwide. However, there was limited research carried out to explore the implementation of traceability system in the fresh produce industry in New Zealand and challenges of its implementation were not well understood in detail. A case study was conducted in Greece to examine a variety of factors affecting the efficiency of traceability with regards to fresh produce supply chain. Semi-structured in-depth interviews with key personnel from each company were employed and multi fragmentation and lack of vertical integration were observed in this fresh produce supply chain (Manikas et al., 2010).

Traceability as part of information management in the fruit supply chain was also explored by Canavari et al. (2010) through semi-structured in-depth interviews with key personnel from the Italian fresh produce supply chain. There were 17 key informants interviewed from the fruit supply chain, including producers, co-operatives, wholesalers, major and small retailers, and a catering company. Furthermore, interviews were carried out at decision-making level with six topics covered in the interview questions, including information about the company, product management, information management, purchasing needs versus company capabilities, co-ordination issues, and compliance with other management systems and voluntary certifications (Canavari et al., 2010). It was considered that data and information were managed and transferred in different ways by fruit businesses within the Italian supply chain, depending on their positions in the fruit supply chain and their mission as well as resources (Canavari et al., 2010).

Additionally, Canavari et al. (2010) stated that poor co-ordination with food business operators among different stages of the fruit supply chain caused transaction costs and resource wastage, especially at the control stages. Specifically, control costs were created by quality controllers in the field, warehouse, or retailers to control produce quality and verify the correspondence to their signed agreements. However, control of the same product in various ways by different produce companies caused inefficiency and unnecessary costs in the entire supply chain system. The costs for physical samples, laboratory tests, labour cost, instruments and transport costs could potentially be minimised with a better co-ordination system.

Olivier et al. (2006) carried out a traceability study in the fruit export industry in South Africa and semi-structured interviews were conducted with 27 key stakeholders and experts from the industry. It was highlighted that information fragmentation and the demand of managing costs carefully in a highly competitive market resulted in the need for effective traceability system within the entire supply chain (Olivier et al., 2006).

A specific study with regards to fresh produce traceability implementation was undertaken and its drivers and constraints were examined by Manos and Manikas (2010) in the Greek supply chain. Interviews of key representatives from the Greek agricultural businesses were carried out and qualitative data were collected using a questionnaire in this study. It was concluded that tight profit margins from the agricultural businesses and inadequate knowledge of understanding potential benefits from a reliable traceability system have become challenges in terms of the traceability implementation (Manos & Manikas, 2010).

Gichure et al. (2017) performed a case study on traceability systems along organic kale supply chain in Kenya to understand the factors influencing its implementation and maintenance. Interviews were carried out with organic kale farmers, traders and farmers' market officials using semi-structured questionnaires in this study. According to Gichure et al. (2017), it was suggested that the there was a need to increase the awareness of industry stakeholders on traceability through organisational activities and enhanced information flow to achieve safer products.

Mainetti et al. (2013) investigated food traceability system through the fresh vegetables supply chain using RFID technology and implemented a pilot project in one of the largest fresh vegetables producers in Italy. A gapless traceability system using RFID technology in both greenhouses and the processing factory was proposed by Mainetti et al. (2013).

Kim et al. (2018) introduced an integrated 'farm to fork' food traceability system using blockchain technology and illustrated this theoretical system in detail. The proposed traceability system for the agricultural value chain applied blockchain distributed ledgers to streamline data sharing across the network and allowed all industry participants to have access to a trustless source of data (Kim et al., 2018; Miller, 2018). The blockchain ledger was updated accordingly with process information and delivery trucks were tracked while in transit as products moved through facilities and loaded onto trucks. Product traceability information such as temperature and other logistic data were transmitted into the blockchain ledger at the same time. When products arrived at the destination and accepted by the buyer, contractual payment for products was executed through triggering blockchain smart contract by electronic notification. Therefore, the growers were able to monitor their products for when it reached the consumer through the blockchain enabled supply chain. Meanwhile, the consumer could scan a product at a retailer store and find relevant information related to the product, including where the product was from, how long it was in the store and other logistic details (Kim et al., 2018).

Borrero (2019) developed a proof of concept for agri-food supply chain traceability to explore the possible implication of blockchain application in the berries value chain in Spain recently. It showed that the adoption of blockchain technology in terms of traceability provided added value in the agri-food supply chain. In addition, it was feasible to combine all data from the field, processing factory, packaging and transporting into a chain of blocks using an authorised ledger and a smart contract (Borrero, 2019). Compared to traditional methods with centralised databases in different companies knowing different stages of product information through its value chain, the same level of relevant information from industry participants could be shared using blockchain technology within the whole industry (Borrero, 2019).

According to Wognum et al. (2011), an international benchmark study was carried out in Australia, The Netherlands, Germany, Spain, Sweden and the United Kingdom as well as the United States of America. It was indicated that traceability performance levels between food supply chains differed while the differences among the countries were not very large (Wognum et al., 2011). Legislation was considered as an important motivation for food businesses to meet requirements of traceability standards (Wognum et al., 2011). However, there was no clear requirement or standard identified from current legislation to provide details for food companies to implement full traceability and most legislations focused on in-company traceability instead of full supply chain traceability (Wognum et al., 2011). One of the consequences was that most food companies placed emphasis on their own business rather than the entire supply chain in terms of traceability implementation and the majority had developed certain traceability across company borders (Wognum et al., 2011; Luning, Devlieghee & Verhe, 2006; Van der Vorst, 2006). In addition, most food businesses were focusing on the prevention of product recall rather than traceability implementation because they could not always obtain benefits from traceability especially when the traceability outcomes were not very precise. It was common that retailers removed all batches of the food products from the shelf rather than only the specific batch concerned in the event of a food safety crisis (Wognum et al., 2011; Luning et al., 2006; Van der Vorst, 2006).

Remarkably, vulnerabilities of produce supply chain were discussed intensively and traceability was identified as a key issue by the government and industry due to the food tampering incidents which occurred in Australia and New Zealand, involving sewing needles inserted into fresh strawberries in September 2018 (Food Standards Australia New Zealand, 2018). It was concluded that some factors affecting an effective traceability system included:

- Lack of regulatory requirements in the horticulture sector;

- The fragmented nature of the sector, with many small companies and no regulatory or industry oversight;
- The current practice of mixing and combining produce from more than one grower or supplier;
- The complexity of the supply chain;
- Loosely sold produce without any packaging (where product traceability information could be present);
- The seasonal nature of labour hiring practices resulted in difficulties in monitoring workers.

Furthermore, it was indicated that the 'one step forward, one step backward' approach to traceability was not sufficient and traceability along the supply chain was suggested to be better understood to improve supply chain integrity (Food Standards Australia New Zealand, 2018).

2.6 Fresh produce supply chain in New Zealand

2.6.1 Characteristics of fresh produce and its supply chain

Fresh fruit and vegetables are considered as foods from plant origin with limited shelf life (Gokarn & Kuthambalayan, 2019; Hospido et al., 2009; Clements, Lazo & Martin, 2008). In addition, there are many uncertainties in the fresh produce supply chain due to their intrinsic properties, including seasonality, perishability and quality variation (Gokarn & Kuthambalayan, 2019). The high level of perishability and fragility of fresh produce can result in high wastage levels and therefore make it very difficult for retailers to manage when consumers require fresh and high-quality produce (Clements et al., 2008). Horticultural products are highly perishable due to their nature that fresh fruit and vegetables continue metabolic processes after harvesting, which lead to their ripening or senescence and eventually unmarketable state (Falagan & Terry, 2018; Mahajan et al., 2017; Kramer, Wunderlich & Muranyi, 2018; Song, He & Xu, 2019; Mahajan et al., 2014). The perishable nature of fresh produce and variability in quantity and quality due to weather conditions, seasonality and biological variation increases the difficulty and complexity of traceability implementation in food supply chains (Wognum et al., 2011; Priyadarshani & Wickramasinghe, 2018). Clements et al. (2008) also indicated that the biological nature of horticultural products posed further challenges to maintain product quality and continuous supply, including seasonal production, unpredictable weather, pest of disease outbreaks. Hence, in order to maintain the quality of fresh produce and reduce product losses caused by its perishability, industry coordination from all participants such as growers, storage operators, processors, shippers and retailers are required (Mahajan et al., 2017; Ali, 2016).

Furthermore, fresh fruit and vegetables have short deterioration time and are easily contaminated, making the management of their value chains especially important (Gokarn & Kuthambalayan, 2019). For instance, Codron et al. (2014) explained that fresh produce growers in the supply chain were considered as one of the sources of product loss caused by chemical contamination from pesticides. Additionally, it was stated that produce spoilage and postharvest loss caused by deterioration and contamination could occur at any stage across the fresh produce supply chain (Mahajan et al., 2017). Blackburn and Scudder (2009) also implied that fresh produce deteriorated rapidly and their value decreased significantly over time along the supply chain at rates which were highly temperature and humidity dependent. The characteristics of fresh produce supply chain were summarised by Gokarn and Kuthambalayan (2019) in Table 2.4 below:

Table 2.4 Characteristics of fresh produce supply chain.

(Gokarn & Kuthambalayan, 2019).

No.	**Element**	**Characteristics**
1	Nature of product	Perishable
2	Nature of supply chain	Complex, inefficient
3	Nature of demand	Fluctuating
4	Wastage	High
5	Cost pressure	High
6	Product range	Diverse
7	Dependencies over climate	High
8	Sector	Agriculture, unorganised

According to Mahajan et al. (2017), there were many factors influencing the perishability and deterioration of fresh fruit and vegetables since each individual produce had inherent physiologies and biochemistries. For example, different skins of fresh produce are associated with different gas exchange, water loss and rates of metabolism especially respiration, which are linked to various storage potentials (Mahajan et al., 2017). Additionally, the harvested part from plants could vary depending on different developmental stages of products, including sprouts, stems, leaves, inflorescences, partially developed fruit, fully developed fruit, roots and tubers (Mahajan et al., 2017). Furthermore, even for the same fresh produce, the harvest time and physiological characteristics such as shape, size, colour, and sugar level vary depending on different varieties, which extends the diversity of the fresh produce products (Mehdi, Ahmad, Yaseen, Adeel & Sayyed, 2016).

There have always been fluctuations in the supply of agricultural produce as fresh fruit and vegetables are seasonal products and they are only available in a short period of time during the year (Van Walbeek, 1996; Mehdi et al., 2016; Ge, Canning, Goetz & Perez, 2018). A typical example is that mango produced in Pakistan is only available during summer as a type of seasonal fruit (Mehdi et al., 2016). The period for apples harvesting in Hawkes Bay in New Zealand was estimated to be from February to May depending on the cultivar (Goossens, 2019). Van Walbeek (1996) stated that climatic and weather conditions largely influenced the production of fresh produce, thereby leading to the seasonal variation in the quantity and quality of produce. For instance, Hospido et al. (2009) pointed out that some north European countries were not able to grow fresh produce all year round because of their climatic constraints. Furthermore, Ge et al. (2018) explained that each variety of fresh produce was harvested in a given range of weeks within the harvest period and the products had to be consolidated quickly and carefully. Noticeably, the fluctuation and seasonality of fresh produce supply could also be influenced by extreme climate events such as heavy rainfalls and floods. For example, contamination of irrigation water sources due to heavy rainfalls or floods would potentially result in food safety issues and product loss in the agricultural produce industry (Kirezieva, Jacxsens, Van Boekel & Luning, 2015).

2.6.2 Relationship in fresh produce supply chain in New Zealand

Fresh produce supply chain involved a great deal of different industry actors, including farmers or growers, manufacturers or processors, wholesalers, logistics, retailers, supermarkets, and others (Borrero, 2019; Codron et al., 2014; Jadav, Leua & Darji, 2011; Givens & Dunning, 2019). Hardesty et al. (2015) categorised produce suppliers into different groups by the type of retail outlet and the number of stores they own: farmers market, independent vendor representing single store, neighbourhood store meaning 2 to 6 stores, and chain store for retailers owning more than 7 stores. Fouayzi, Caswell and Hooker (2006) illustrated the produce supply chain and considered that it covered growers, packers, processors, shippers, wholesalers, retailers, food service operations and consumers.

According to Worinu (2007), industry actors along the fresh produce supply chain included supermarkets, hotels, restaurants, fast food outlets, urban and roadside markets and others. These could be generally categorised into two main systems: formal and informal ones (Worinu, 2007). Formal supply channel or market is also named as direct market and refers to when fresh produce is delivered from growers or packhouses through wholesalers to retailers such as supermarkets, the relationships between different parties within the supply channel are generally characterised by company agreements and products are supplied on an ongoing basis (Trienekens, Van Velzen, Lees, Saunders & Pascucci, 2017). There are some relationships built up between the suppliers and buyers (Worinu, 2007). Whilst, informal supply channel or market is commonly referred to open market and is related to purely trust and commitment developed between industry actors such as farmers and buyers and products are provided occasionally or periodically without agreed contracts (Givens & Dunning, 2019; Timsina & Shivakoti, 2018). For example, fresh fruit and vegetables sold via roadside stalls and farmers markets by growers are considered as informal supply channel and there is no long-term relationship between farmers and buyers as products are supplied occasionally (Worinu, 2007). Curtis et al. (2014) interpreted that farmers markets provided local growers a great opportunity to eliminate costs of the middle man and it was easier for small producers to participate in with relatively lower vendor fees and limited contractual obligations. It was indicated that the number of industry participants with formal and informal relationships across a food supply chain could be large (Wognum et al., 2011).

Relationships in fresh produce supply chains have been changing over the past few decades due to demand conditions, new technologies, private supply chain requirements and public regulatory standards (Fouayzi et al., 2006). An adversarial relationship with multiple suppliers has gradually become a closer and on-going relationship with a few selected suppliers or even exclusive supplier (Clements et al., 2008; Kalwani & Narayandas, 1995). This trend could be driven by various reasons (White, 2000; Fearne & Hughes, 2000; Hingley & Lindgreen, 2002). White (2000) indicated that on-going relationship allowed retailers to have access to adequate fresh produce products and maintain the continuity of supply. In addition, a competitive advantage over other retailers was obtained through exclusive access to the best raw material producers (Fearne & Hughes, 2000; Hingley & Lindgreen, 2002). Furthermore, search time and cost were reduced and therefore productivity was improved through the integration of retailer and supplier systems (Hingley & Lindgreen, 2002; Brookes, 1995). Meanwhile, this on-going relationship would also benefit producers from selected suppliers through increased security and reduced risk (Hingley, 2001).

Lee and Nuthall (2015) carried out a case study on supplier commitment to agri-food supply chains in New Zealand and factors attracting suppliers to be committed to long-term relationships were examined. According to Lee and Nuthall (2015), increased price certainty, premium prices and related quality were considered as three main factors.

Clements et al. (2008) investigated fresh produce supply chains in New Zealand focusing on relationship connectors, supply chain functions and product characteristics. In addition, two case studies of fresh produce supply chains in the South Island of New Zealand were undertaken under this research. Clements et al. (2008) stated that many factors in the fresh produce supply chain could impact on relationships within a supply chain for both between chain partners and within companies themselves, such as difficulties of guaranteeing continuity of supply due to seasonal and unexpected shortage or oversupply, logistics and quality management, information exchange and process alignment along the chain.

2.6.3 Fresh produce supply channels in New Zealand

There are several studies undertaken to understand the fresh produce supply channels in New Zealand over the past two decades (Maurer, 1999; Clements et al., 2008; Ministry for Primary Industries, 2014). Maurer (1999) introduced a framework to describe a typical produce supply chain in New Zealand in Figure 2.3 as below.

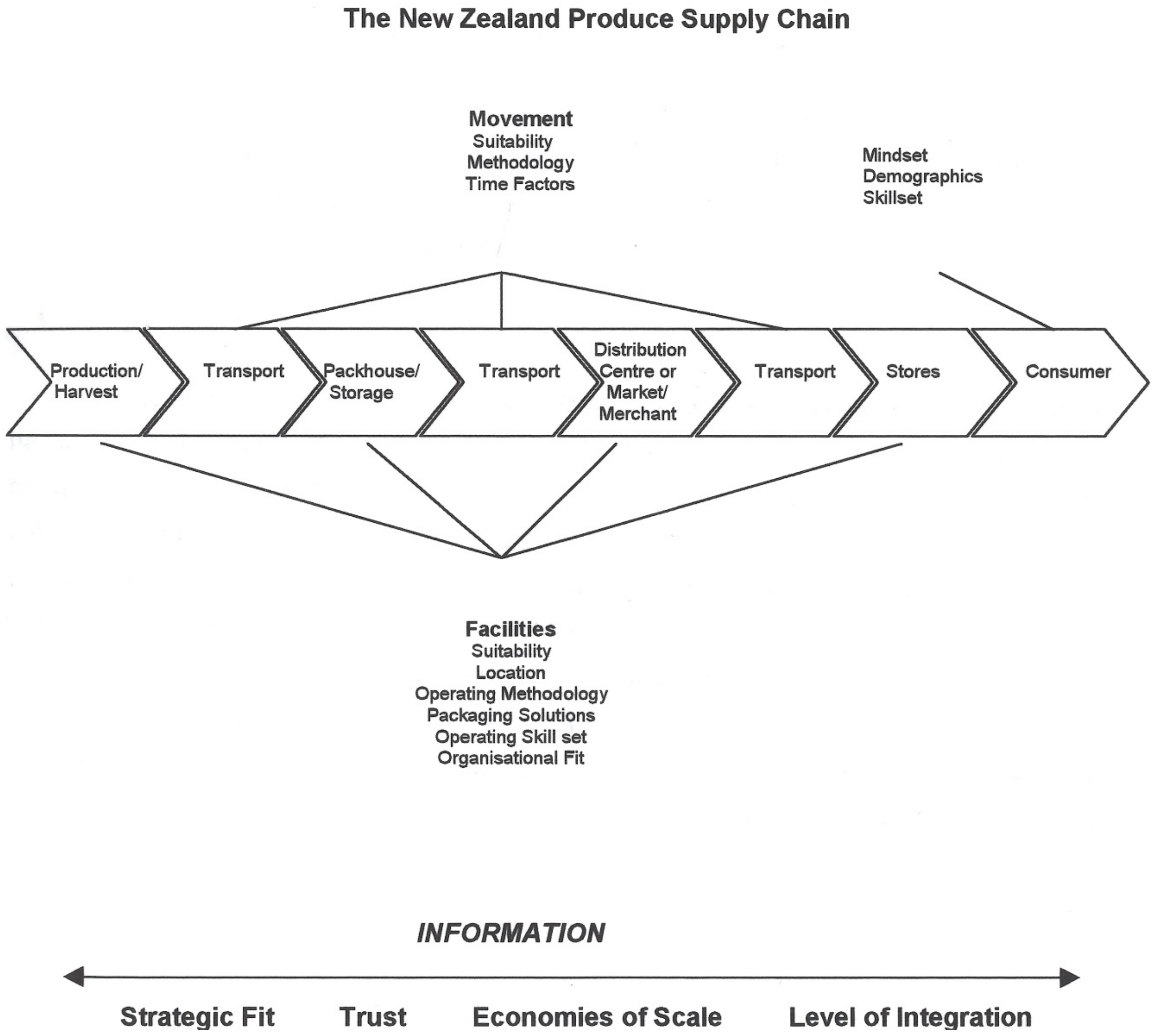


Figure 2.3 A typical fresh produce supply chain in New Zealand.

(Maurer, 1999).

Fresh produce was initially harvested and transported to packhouse or storage facility, through distribution centre or market and subsequently delivered to stores for consumer purchasing (Maurer, 1999). Noticeably, Maurer (1999) explained that the all possible supply chain variations for New Zealand produce were incorporated in the framework, however, not all produce products moving along the supply chain necessarily passed through all stages.

However, the fresh produce supply chain is not always linear (Ministry for Primary Industries, 2014). Products could reach the consumer through a number of different routes (Ministry for Primary Industries, 2014). For instance, fresh produce may be purchased by consumers via farmers markets or online sales from the grower directly. In addition, products could also be supplied by growers and transported to retail stores nationally (Ministry for

Primary Industries, 2014). Givens and Dunning (2019) demonstrated that fresh fruit and vegetables could be delivered by farmers directly to restaurants as a short supply channel to avoid extra expense via intermediary distributors.

Moreover, a food supply chain was also considered as a network since industry participants in the supply chain commonly had several or many suppliers and customers which made the whole chain more complex (Wognum et al., 2011). The network of fresh produce supply channels in New Zealand was illustrated in Figure 2.4 (Ministry for Primary Industries, 2014; Clements et al., 2008; Maurer, 1999).

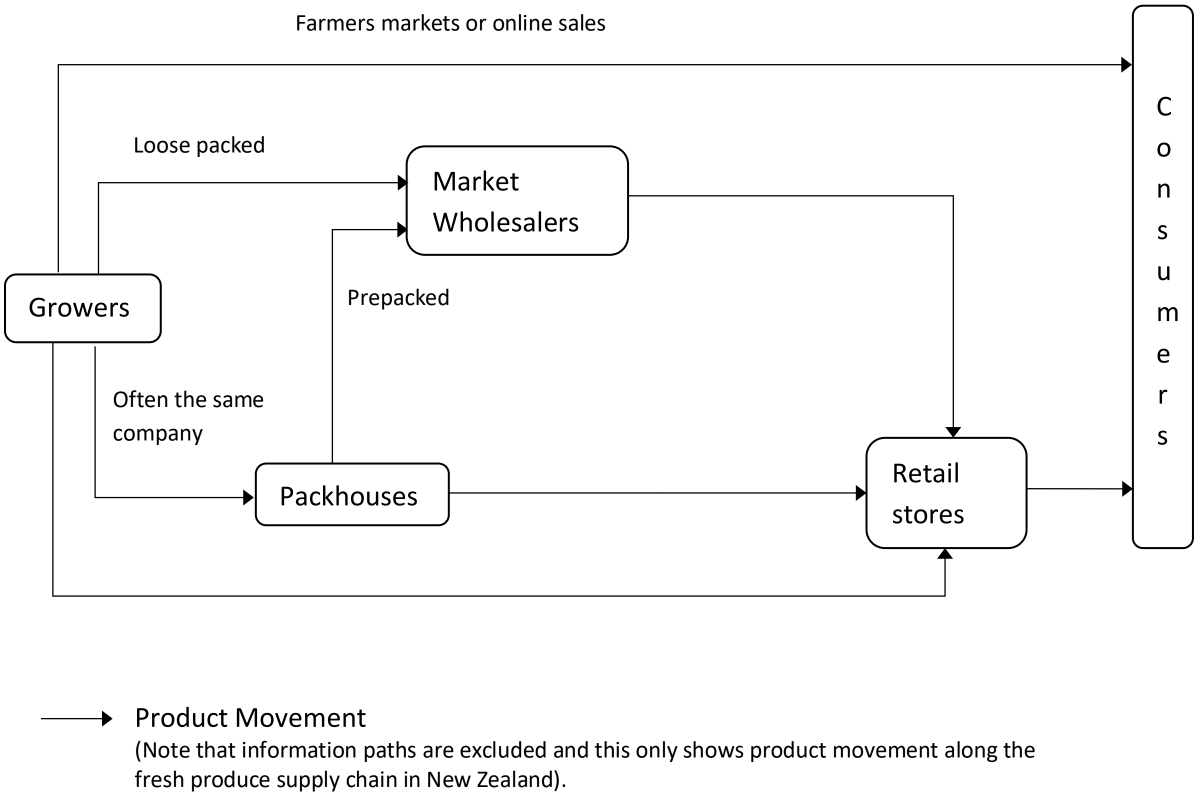


Figure 2.4 Complexity of fresh produce supply channels in New Zealand.

(Ministry for Primary Industries, 2014; Clements et al., 2008; Maurer, 1999).

According to Clements et al. (2008), some retail stores throughout New Zealand were individually owned but managed by one organisation who had a cooperative buying structure to source most of fresh fruit and vegetables for stores, whereas the other retail outlets were owned by one company who had a corporate business structure around the country. Products sourced by organisations for retail stores could be from market wholesalers or directly from their own preferred growers (Clements et al., 2008). In addition, market wholesalers also had their own preferred and non-preferred growers where they purchased fresh produce from (Clements et al., 2008).

2.6.4 The scale of the fresh produce industry in New Zealand

It was indicated that New Zealand was a major agricultural producer as an island nation and free from many diseases and pests around the world (Webb, Strutt & Rae, 2016). The geographical restriction impeded both importing and exporting of fresh fruit and vegetables to certain extent in the country (Webb et al., 2016). As a relatively small country in the world, the total population of New Zealand was 4.762 million in 2017 and was expected to grow steadily (Horticulture New Zealand, 2017). It was reported that there were approximately 5,000 growers in total in New Zealand and around 121,413 hectares land were used for the horticultural industry across the country to provide fresh fruit and vegetables (Horticulture New Zealand, 2018). The entire industry value was estimated at 5.68 billion dollars by Horticulture New Zealand (2018).

In total, there were two major retail organisations associated with the fresh produce supply chain in New Zealand, namely Foodstuffs New Zealand and Woolworths Australia (Progressive Enterprises) (Catley, 2010). T&G Global Limited (T&G Global), formerly Turners and Growers, was one of the larger wholesalers in New Zealand for horticultural products (Clements et al., 2008; MarketLine, 2017).

2.6.5 Export and domestic markets in New Zealand

The fresh produce industry has been rapidly growing in recent years in New Zealand for both local and export markets, with the industry value of 5.68 billion dollars reported in 2018 (Horticulture New Zealand, 2018). Specifically, different proportions of export and domestic markets in New Zealand in 2018 are illustrated by Horticulture New Zealand (2018) in Figure 2.5 as below.

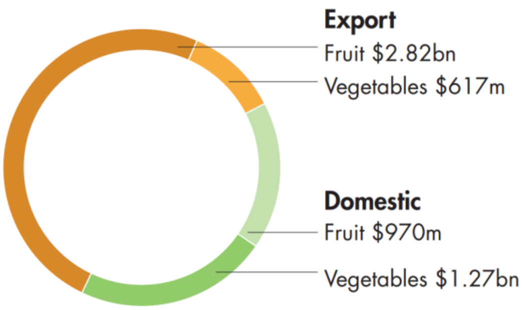


Figure 2.5 Different proportions of export and domestic markets in New Zealand in 2018.

(Horticulture New Zealand, 2018).

In particular, New Zealand's fruit exporting has been well positioned in terms of average growth in export volumes and has become one of the largest fruit export countries in the world with competitors from South Africa, Argentina, Chile and Australia (Olivier et al., 2006). Export was referred to global value chains for food products and the production took place in a different country from where the products were being sold (Trienekens et al., 2017). Fresh fruit and vegetables from New Zealand were transported to 128 export markets in 2018 and the total export value was 3.44 billion dollars, with kiwifruit (1.6 billion dollars), apple (691.1 million dollars) and avocado (147.5 million dollars) being the top three produce products for exporting (Horticulture New Zealand, 2018).

Meanwhile, food safety risks have drawn more attention from the public as more fruit and vegetables are grown and consumed, and serious outbreaks have occurred in association with produce consumption (Bennett et al., 2018; Sivapalasingam et al., 2004). In export markets, some brands have developed a reliable food safety and traceability system to provide consumer confidence and protect their own reputation. For example, the largest exporter of green and Zespri™ gold kiwifruit in the world, Zespri International Limited, has worked with Global Standards One (GS1) to achieve a full traceability of fruit from orchard to final customer (GS1, 2004). However, due to the complexity and diversity of the domestic fresh produce industry, food safety and traceability levels could vary from one food sector to another and between businesses within the same fresh produce supply chain (Clements et al., 2008).

2.6.6 Current traceability regulations in New Zealand

Food safety and traceability was considered as a major requirement in many countries and in particular food traceability was mandatory by law (Costa et al., 2013). Similarly, the requirements of traceability for food products in New Zealand were mandatory by law. Specifically, there were a number of food safety standards used in the fresh fruit and vegetable industry within New Zealand, including New Zealand Good Agricultural Practice (NZ GAP), Global GAP, Food Control Plan (FCP) and National Programmes (NP) under the Food Act 2014 of New Zealand, and private schemes (Horticulture New Zealand, 2018). For example, NZ GAP certification ensured the safe production of fresh fruit and vegetables in New Zealand and certified growers were able to meet both market certification demands and regional council requirements (Horticulture New Zealand, 2018). The food safety and traceability requirements among these standards varied depending on product type, product characteristics, intended use / potential consumer, destination market such as supermarkets, farmers markets, and so on.

The Food Act 2014 became effective on 1 March 2016 in New Zealand which replaced the Food Act 1981. The new Food Act recognised that each food business was different and it was a new approach to managing food safety risks within businesses. Under the Food Act 2014, all food businesses were required to have procedures for tracing and recalling food. Furthermore, both the Food Act 2014 and Food Safety Law Reform Bill 2018 required effective ‘one-up, one-down’ traceability to be implemented by food businesses (The Parliament of New Zealand, 2018).

A guideline document for fresh produce in terms of food safety has recently been released by Fresh Produce Safety Centre Australia and New Zealand (2019) and it was suggested that each organisation in the supply chain should record sufficient and accurate product information for traceability. An example of this is illustrated in Figure 2.6.

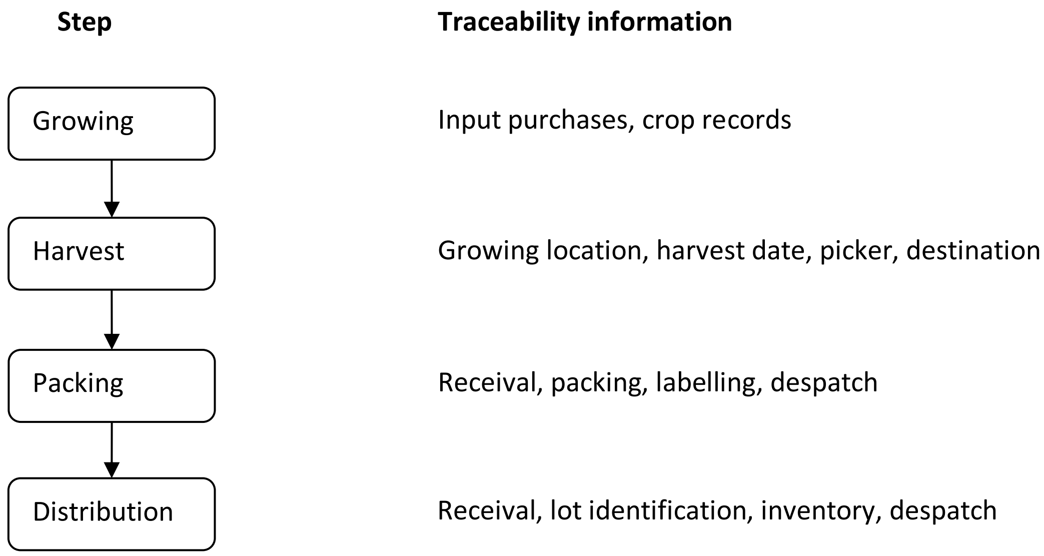


Figure 2.6 Traceability information needed at different steps in the supply chain.

(Fresh Produce Safety Centre Australia & New Zealand, 2019).

2.7 Some stakeholders of fresh produce supply chain in New Zealand

Perceptions and attitudes from industry stakeholders play an important role in the implementation and maintenance of traceability systems for fresh produce (Gawron & Theuvsen, 2009; Gichure et al., 2017; Heyder, Theuvsen & Hollmann-Hespos, 2012). The effectiveness of a traceability system implemented is always associated with personnel perceptions from all stakeholders along the fresh produce value chain (Gichure et al., 2017). According to Heyder et al. (2012), it was found that increased uptake of tracking and tracing systems could be achieved with higher personnel's positive perceptions on their traceability.

Apart from typical industry players such as growers, wholesalers, retailers and transporters along with the fresh produce supply chain, there were many groups and organisations developed within the horticultural industry in New Zealand, ranging from government agencies, industry organisations representing a group of growers or horticultural businesses, to consultancy companies providing technical and value-adding advices (Horticulture New Zealand, 2018; Webb et al., 2016; NZ Grower, 2015). For example, industry organisations representing the interests of growers included Horticultural New Zealand, Tomatoes New Zealand, Potatoes New Zealand Incorporated, Vegetables New Zealand Incorporated, and Process Vegetables New Zealand (Horticulture New Zealand, 2018).

2.7.1 Role of Ministry for Primary Industries (MPI)

The Ministry for Primary Industries (MPI) was established in April 2012 as a unified entity and was merged from the Ministry of Agriculture and Forestry (MAF), the New Zealand Food Safety Authority (NZFSA) and the Ministry of Fisheries (State Services Commission, the Treasury and the Department of the Prime Minister and Cabinet, 2016). MPI was a large and complex government agency charged with pivotal work and essential regulatory systems for New Zealand, covering biosecurity, food safety, fisheries and forestry (State Services Commission et al., 2016; Webb et al., 2016). In addition, MPI is responsible for the development of standards and regulations for primary industries in New Zealand (Lynch & Nalder, 2015). The purpose of MPI is about growing and protecting New Zealand, with the two dimensions supporting each other fundamentally (State Services Commission et al., 2016).

2.7.2 Roles of United Fresh New Zealand Incorporated and The AgriChain Centre

As the only pan-industry organisation for fresh produce in New Zealand, United Fresh New Zealand Incorporated (United Fresh) has over 90 members including growers, retailers, wholesalers, research organisations and service providers. Its Mission is to connect the fresh fruit and vegetable value chain by providing services and representation to industry. It also brings together the interests of all parties involved in the fresh produce supply chain. To date, United Fresh has worked with the entire value chain to provide technical advice to support and promote the fresh produce industry for over 28 years (United Fresh New Zealand Incorporated, 2019).

The AgriChain Centre Limited (The AgriChain Centre) is a food safety and biosecurity consultancy company and specialised in the fresh produce industry. It offers value adding solutions in terms of food safety, post-harvest, biosecurity, phytosanitary certification and knowledge services to businesses and organisations throughout the entire food supply chain. It is also a member of United Fresh and provides services and technical advice to United Fresh.

2.7.3 Role of GS1

Barcoding and scanning system were initially used in the grocery sector and were then adopted by some companies in the food industry in the late 1960's when they were seeking a way to have a standardised inter-industry product code for each product (Sargent, 2012). The new barcoding and scanning system helped the food industry to address food safety and low profit issues through improving the efficiency and accuracy of information capture and reporting (Sargent, 2012). In addition, the early adoption and efforts eventually led to the establishment of Global Standard One (GS1) which was an international organisation and also a global standard system to identify products, businesses and relevant locations (Cierpiszewski, Korzeniowski & Niemczyk, 2019; Sargent, 2012). GS1 organisation managed barcode systems in approximately 150 countries and the system has been implemented in over two million companies in the world (Cierpiszewski et al., 2019).

On the other hand, EAN and UCC stand for European Article Number and Uniform Code Council respectively. The EAN.UCC numbering system is used to identify product items and services at all stages of production and distribution through assigning a unique number to each (Olivier et al., 2006). The barcode is the most visible part of the numbering system and all users of the system are required to follow the same coding rules to eliminate confusion, duplication and misinterpretation (Olivier et al., 2006).

GS1 standards were globally adopted supply chain standards and provided unique identification for products, resources and their locations (Kim et al., 2018; Cierpiszewski et al., 2019). In particular, Global Location Number (GLN) was used for all locations of every company in the world while Global Trade Item Number (GTIN) was applied on all products (Sargent, 2012). The GTIN was described as a 14-digit global item number in the EAN.UCC system used for globally unique identification on product items (Olivier et al., 2006). According to Olivier et al. (2006), the GTIN was an umbrella term for a variety of product identification descriptions, including a single item, different sizes of an item and combinations of an item. However, Sargent (2012) considered GTIN as a globally unique 8, 12, 13 or 14-digit number used to identify products worldwide and it could be encoded as a GS1-128 barcode, GS1 DataMatrix or GS1 Databar. The components of GTIN generally contained an indicator for packaging, a company prefix, an item number for a specific product and a check digit (Sargent, 2012). Other information such as expiry date, lot number or serial number could also be added and contained in the GTIN if appropriate (Sargent, 2012).

A serial shipping container code (SSCC) was described as a unique code and used to identify each pallet or logistic unit of products (GS1 Australia, 2011; Cierpiszewski et al., 2019). Lopes-Martinez et al. (2018) discussed GS1 standards application in the drugs traceability system and illustrated the coding system of GS1 used to identify products or logistic units in different level of packaging in Figure 2.7 below.

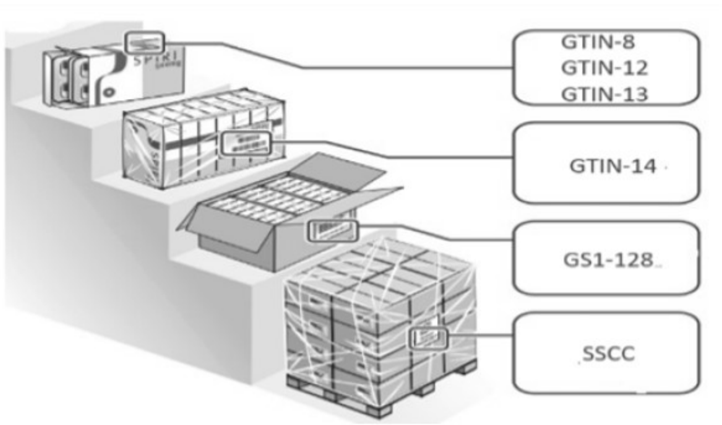


Figure 2.7 Identification in each level of packaging using GS1 standards.

(Lopes-Martinez et al., 2018).

According to Lopes-Martinez et al. (2018), GTIN with 8, 12, 13 or 14 digit numbers (GTIN-8, GTIN-12, GTIN-13, GTIN-14) were generally used on the inner packaging of products or for each individual product, whist GS1-128 coding was commonly applied on the outer packaging of products such as boxes or cartons. SSCC was used on logistic units such as pallets to uniquely identify each individual pallet of products (Lopes-Martinez et al., 2018).

3.0 Materials and methods

The information described and images inserted in this section were provided by The AgriChain Centre Limited for use in this study and permission of access to company information, data and images was obtained (Appendix 9.3).

3.1 Study design

This was a cross sectional study designed to understand current traceability systems in the domestic fresh produce industry and explore their potential improvements along the value chain in New Zealand, based on previously applied methods in other studies (Hewitt & Rivas, 2015; Wong, 2003; Canavari et al., 2010; Codron et al., 2014; Fouayzi et al., 2006; Mutua et al., 2018; Mattevi & Jones, 2016). There were several methods used in this research. In order to achieve each specific objective, research methods such as sampling and observation, carrying out interviews with industry participants, conducting a questionnaire survey and performing a pilot study were used.

In order to explore the current domestic traceability practices for fresh fruit and vegetables, various fresh produce products across New Zealand were inspected and traceability information were observed and analysed (Hewitt & Rivas, 2015; Wong, 2003). In addition, face to face interviews were carried out with organisation representatives from the fresh produce industry in New Zealand using a semi-structured questionnaire to investigate barriers in the implementation of tracking and tracing systems (Canavari et al., 2010; Codron et al., 2014). Apart from this, a questionnaire survey was designed, developed and sent to domestic fresh produce growers to examine their perceptions and attitudes towards traceability within the domestic produce industry (Fouayzi et al., 2006; Mattevi & Jones, 2016; Jin & Zhou, 2014). Moreover, a strawberry pilot was conducted as an industry trial to track strawberry punnets from packhouse through supply chain to consumer using GS1 technology (Mutua et al., 2018). The strawberry pilot was performed to propose a reliable traceability framework for the domestic fresh produce industry to achieve an effective traceability system.

Qualitative and quantitative data were collected from produce traceability data samples, interviewed industry stakeholders, produce growers, and the pilot study to generate empirical information on traceability systems along fresh produce supply chains in New Zealand. Subsequently, data were analysed using descriptive statistics and factor analysis in this study.

3.2 Limitations and Constraints

There were some limitations and constraints in this traceability study especially during the industry stakeholder interviews. Firstly, the number of fresh produce growers interviewed was very limited due to difficulties of contacting growers and unwillingness of participating in the interview. In particular, there were challenges in terms of approaching growers as many of them did not have a company website where their phone numbers and addresses could be shared to the public. Moreover, face to face interviews were relatively time-consuming to some growers due to their busy season workload. Secondly, industry participants such as independent stores and farmers markets were not included in this industry stakeholder interview and further research could be carried out in this field.

3.3 Current fresh produce traceability observation

Traceability data of products are traditionally conveyed by the means of labelling (Jin & Zhou, 2014). Product labels of the New Zealand's fresh produce from various sources were observed and inspected in this study to explore the current traceability practices in the domestic fresh produce industry. Data collected from fresh produce samples for traceability were analysed and quantified in a meaningful way to assist with understanding of the current traceability system in New Zealand.

3.3.1 Fresh produce selection

Fresh fruit and vegetables were selected from a number of sources along supply chains across New Zealand between June 2018 and March 2019, including packhouses, wholesalers, and retailers such as supermarkets and independent stores. In particular, supermarkets were considered as large self-service retailers supplied by central distribution centres, such as Foodstuffs and Progressive Enterprises in New Zealand, whilst independent stores were considered as individual stores which source their own produce products.

A sampling plan was developed and ten groups of fresh fruit and vegetables were used to select various fresh produce samples on traceability information in this study, based on the classification principles of Codex Classification of Foods and Animal Feeds (FAO/WHO, 2006). The sampling plan covered crop products from different growers and were generally available in New Zealand. In addition, produce samples were selected and sourced during visits to packhouses, wholesalers, supermarkets and independent stores from both South Island and North Island areas in New Zealand, including Christchurch and Auckland (Table 3.1).

Table 3.1 Fresh produce selection.

Group Number	Group	Produce Selected	Sample Source Along Supply Chain
1	berries and other small fruits	Blackberry, Blueberry, Boysenberry, Strawberry, Raspberry	Packhouse Wholesaler Supermarket Independent Store
2	brassica vegetables	Brussel Sprouts, Cabbage, Kalian	
3	citrus fruits	Grapefruit, Lemon, Lime, Mandarin, Orange, Tangelo	
4	fruiting vegetables	Capsicum, Chilli, Mushroom, Okra, Sweet Corn	
5	leafy vegetables	Choisum, Endive, Mustard Greens, Pak Choi, Puha, Spinach, Spinach Beet, Watercress	
6	legume vegetables	Green beans	
7	pome fruits	Apple, Pear, Quince	
8	root and tuber vegetables	Carrot, Kumara, Potato, Swede, Turnip	
9	stalk and stem vegetables	Asparagus, Rhubard	
10	stone fruits	Apricot, Cherry, Nectarine, Peach, Plum	

The intention of fresh produce samples selection was to capture a big picture of current traceability information in the domestic fresh produce industry in New Zealand and to achieve the greatest diversity of domestic growers and fresh produce products in the sampling plan. Hence, the sample selection was planned to obtain as many different crops as possible. Noticeably, fresh fruit and vegetables were also selected with different varieties or from different growers if it was the same crop. Different varieties of fresh crops were considered as different fresh produce samples and same crops from different growers were considered as different supply lines, therefore these fresh crops were selected in this study.

3.3.2 Inspection of fresh produce traceability

All fresh crops selected were inspected to determine their traceability data availability and any traceability information identified with each crop was photographed using a smart phone camera (iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.). As the purpose of photographing was to obtain all traceability information identified on each fresh produce for data analysis, the focus of pictures taken was on places where product traceability was clearly shown rather than product itself. For instance, the emphasis was placed on product packaging, grower or packhouse card, wholesaler stickers and retailer labels to capture any product traceability data while taking pictures. Therefore, the aesthetic perception of taking pictures could be ignored and the integrity of product or product packaging in a picture could not be guaranteed.

3.3.2.1 Identification of sources of traceability

There were three different levels of source to capture produce product traceability information, including the information attached to product packaging from growers or packhouses, wholesalers and retailers. Therefore, the fresh produce supply chain traceability sources were divided into three categories:

1. Outer Packaging
2. Market Packaging
3. Retail Packaging

Outer packaging indicates that a grower card or packhouse card is attached to a crate or container that growers or packhouses used to pack produce items and provide to market wholesalers (Figure 3.1). Similarly, market packaging means the sticker or label is attached to a crate or outer packaging for tracking of stock by market wholesalers (Figure 3.2). Retail packaging is the retail pack or unit that contains any traceability information at the consumer level (Figure 3.3).

Figure 3.1 Product traceability information on outer packaging from growers.

(Image captured by iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.).

Figure 3.2 Product traceability information on market packaging from wholesalers.

(Image captured by iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.).

Figure 3.3 Product traceability information on retail packaging (at retailers).

(Image captured by iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.).

As these fresh produce products were selected from various stages within the supply chain, they may contain traceability information from single source or multiple sources (Figure 3.4). For instance, a punnet of strawberries obtained from a supermarket may only have traceability information on its labelling from growers or packhouses, whilst a bag of apples photographed from a supermarket distribution centre could have grower card, wholesaler label and supermarket distribution centre sticker attached to its crate on the same time. Furthermore, the traceability information from strawberry punnet label was considered as one unit while these from apples were determined as three units in terms of traceability information. Namely, units one, two and three of traceability information were from grower card, wholesaler label and supermarket distribution centre respectively. All traceability information of produce items inspected were collected and analysed.

Figure 3.4 A typical product container with traceability information from two sources (left: a card from a packhouse; right: a sticker from a wholesaler).

(Image captured by iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.).

However, nearly half of fresh fruit and vegetables available on the market were found that either there was no traceability data at all or only the product name was displayed during the product information collection stage. For example, fresh produce sold loosely in supermarkets had no packaging or stickers and only the product name could be identified. In addition, some loosely sold produce in independent stores had a product name shown in a different language rather than English so not everyone could understand and language barrier became a challenge. In these cases, product traceability data collection was extremely limited and could provide little information in terms of data analysis. Therefore, these produce items that had no traceability information at all or only had a product name were not collected or photographed in this study and they were excluded prior to data collection and analysis. Nevertheless, it was noted that more product traceability data were collected from wholesalers or packhouses than from independent stores.

3.3.2.2 Identification of approaches of presenting traceability

There were a number of different methods to present traceability data on product labels, including simple hand-written, machine printed and machine-readable identification such as barcodes (Jin & Zhou, 2014). Two ways of presenting traceability information from each source or unit were identified in this study with both being machine-printed. Specifically, the information to the traceability was either present in text such as written format, or present within GS1 traceability barcode format.

3.3.2.3 Identification of components of traceability

The components of each selected and inspected traceability information source or unit included:

1. "ID" – Identification. This was subcategorised into Product ID and Grower ID (Figure 3.5).
2. "Batch/Run/Lot" – The identifying number of the shipment.
3. "Serial" – The identifying serial number of the box/crate.
4. "Pack Date" – The date the product was packed.
5. "Harvest Date" – The date the product was harvested.

Figure 3.5 A typical product traceability information with Product ID and Grower ID (Product ID means product identification; Grower ID means grower identification).

(Image captured by iPhone 6, Version iOS 11.2.5, Apple Inc., CA, USA.)

Notably, for each fresh produce sample collected and photographed, it may contain certain traceability components but not all of them, which was commonly found during data collection. For example, a produce sample could have product ID and grower ID only as its traceability data on outer packaging and these two traceability components were present in written format. In this case, there were no batch number, serial number, pack date or harvest date identified from the sample in terms of traceability information. In addition, data collection for its product ID and grower ID present in GS1 barcode format was none. However, when a product containing product ID in both written and GS1 barcode format was collected, the two different ways of presenting product ID would both be analysed and shown in result figure diagram. In another word, for each traceability component identified from produce samples, it could be none, or only present in written or GS1 format, or could have both.

3.3.3 Analysis of data on fresh produce traceability

3.3.3.1 Sampling and sample size

A sample size (n) of 300 fresh produce was planned for this observational study, with 30 samples being randomly selected from each group. All planned samples were selected from various sources along the supply chain in New Zealand.

3.3.3.2 Prevalence rate of traceability information components

Fresh produce photos showing traceability information were firstly inspected and analysed. Subsequently, commodity name and variety of the product were recorded and entered for each fresh produce sample selected, followed by various traceability information components from different sources under different displaying formats.

The presence of each traceability information component was indicated via number: "1" indicates the information was present; "2" indicates the information was not present; "3" indicates the appropriate sticker/label/packaging was not observed and therefore the information was not applicable.

The prevalence rate of each traceability information component and its presenting formats (text/written format and GS1 barcode format) were analysed respectively from three sources (outer packaging, market packaging and retail packaging) along the supply chain.

3.3.3.3 Data analysis

Column graphs showing the data on prevalence rate of information on traceability components from different sources were summarised using Microsoft® Excel 2016 (Microsoft®, Washington, USA).

3.4 Industry stakeholder interview

In-depth interviews with key personnel from the fresh produce supply chain were used by Canavari et al. (2010) in their study and this approach has been followed for this research. Face to face interviews with company representatives from four growers, three wholesalers and one retailer in New Zealand were undertaken for traceability assessment to investigate barriers in the design and implementation of fresh produce traceability systems, to understand how they align with internationally accepted traceability systems, and also to identify any challenges to help the domestic fresh fruit and vegetables industry.

3.4.1 Development of questionnaire

GS1 Global Traceability Compliance Criteria for Food Application Standard Release 4.0.1 Dec 2016 was used as a consistent reference to construct and develop the questionnaire in this assessment (GS1, 2016). In total, there were 11 sections developed in the questionnaire to explore and investigate current traceability systems within domestic fresh produce value chains (Appendix 9.1). These 11 sections were: objectives, product definitions, internal traceability, establishment of procedures, flow of materials, information requirements, documentation requirements, structure and responsibilities, training, external traceability, and internal assessments. The questionnaire was modified and simplified further to suit the situation of the interviewee.

The scope of the assessment covered all operations within the interviewed organisations, generally ranging from seeds/produce receipt, temporary storage and/or processing to dispatch and transport. All fresh fruit and vegetables handled within the company were included in this assessment and produce process flows were discussed during the face to face interviews.

3.4.2 Conducting interviews

The traceability assessment research commenced on 1 August 2018 and finished on 19 July 2019. It was comprised of approximately two months of making appointments, travelling, conducting interviews with key personnel from different fresh produce organisations, and summarising notes taken from interviews. Interviews with three wholesalers were conducted on 27th August, 28th August and 6th September in 2018 respectively. The interview with one retailer was carried out on 22nd January 2019. Interviews with the first two growers were both performed on 7th May 2019 due to the close distance between the two grower premises. The other two growers were interviewed on 16th and 17th July in 2019 separately.

The interviewees were selected through their contacts with The AgriChain Centre. The AgriChain Centre has a network with fresh produce growers, wholesalers, retailers, logistic providers, and other key players in the industry in New Zealand. Interviewees were contacted by email or telephone in advance to invite them to participate and an explanation of the research was given during the email or telephone conversations. An appointment for the interview was then planned and negotiated if the interviewee was willing to cooperate and participate. The scope defined for the interview and the questionnaire developed were sent to the interviewee via email for their preparation prior to the actual interview commenced.

In addition, a brief description of the study was provided and an indication of topics to be discussed was given at the beginning of each interview. Subsequently, face to face interviews with key personnel from fresh produce organisations in New Zealand were conducted at each organisation premise and the developed questionnaire was used for these interviews. Each face to face interview took approximately 90-120 minutes. Semi-structured interviews were used in this study. Therefore, there was room for additional questions and obtaining more details based on responses from the interviewee in addition to questions prepared in advance.

3.4.3 Sample size

There were four fresh produce growers, three wholesalers and one retailer selected and confirmed for face to face interviews in this study. For confidentiality reasons the interviewed organisations were named as grower one, grower two, grower three, grower four, wholesaler one, wholesaler two, wholesaler three and the retailer. The selected companies were proved to be highly representative for the majority of growers, wholesalers and retailers in the fresh produce industry in New Zealand, considering the small scale of this country.

The four growers participated in this interview had very different attitudes and situations, with grower one believed that they had an effective traceability system and would be willing to show it during the interview, while grower two admitted that there were improvements needed in their traceability practices and would like to learn from our interview. Grower three and grower four stated that their traceability systems met regulatory requirements. Grower one is a fourth-generation family-based business which has become one of the largest green vegetable growing operations in New Zealand. Products from grower one are provided to local supermarkets including Foodstuffs and Woolworths, and other customers nationwide. Grower two operates on a family-owned farm since 1948 and supplies fresh produce to local supermarket chains such as Foodstuffs and Woolworths, specialised stores including Farro Fresh Food and Fruit World, and independent stores directly or via wholesalers. Grower three and grower four are also both family-orientated businesses and have been operating for a few generations in New Zealand. Their products are supplied to local customers such as supermarkets, wholesalers and independent stores nationwide.

Supermarkets in New Zealand receiving fresh fruit and vegetables from the three wholesalers included Countdown, New World, Pak'nSave, Four Square and others. Wholesaler one had more than 13 branches nationwide including 9 depots and had their own transport operation. Wholesaler two had 9 sites and their fresh produce was sourced from approximately 700 growers to supply supermarkets, independent retailers and food service companies across New Zealand. In addition, almost 90% of the growers from wholesaler two were NZGAP or equivalence approved. Wholesaler three played a role in supplying fresh produce direct to retail, wholesale and food services in New Zealand and handled over 36 million boxes of fresh produce annually. Wholesaler three had premises in Auckland, Palmerston North and Christchurch.

There are two major retailer organisations in New Zealand and both were contacted and invited to attend this interview with only one accepted. The accepted retailer organisation is a 100% New Zealand owned business with over 30,000 staff nationwide. It occupies approximately 57% market share and has about 2 million customers in New Zealand.

3.4.4 Data collection and analysis

A pre-printed questionnaire was used to record answers and take notes from the interviewee at each interview for data collection. Data collected from all eight interviews were then carefully labelled with the name of interviewee, company name and interview date and stored for analysis.

Data collected from the industry stakeholders' interviews were analysed using qualitative descriptions to assess traceability systems of the six fresh produce organisations, covering the 11 themes from questionnaire: objectives, product definitions, internal traceability, establishment of procedures, flow of materials, information requirements, documentation requirements, structure and responsibilities, training, external traceability, and internal assessments.

3.5 Grower survey

Internal attitudes and motivations from organisations were considered as a key element in terms of a traceability system implementation (Mattevi & Jones, 2016). A structured survey was carried out in this study to gain understanding of the attitudes, perceptions and barriers to traceability held by fresh produce growers in New Zealand using a questionnaire (Mattevi & Jones, 2016).

3.5.1 Development of questionnaire

An online survey software SurveyMonkey (SurveyMonkey Inc., San Mateo, California, USA., www.surveymonkey.com) was used to design and develop a questionnaire for growers.

The questionnaire was divided into data on respondent profiles, perceptions on traceability, and current practices in relation to traceability, including product recall (Appendix 9.2). In total, there were 21 questions created in the questionnaire, with 17 of them relating to perception and attitude of growers as well as their current operations associated with traceability systems. The other 4 questions were developed to obtain responded grower details, including grower location, main crop they grow, estimated costs on product labelling and if they are GS1 members or not.

3.5.2 Conducting survey

The questionnaire was initially sent to a range of industry participants (n=7) by email for testing and seeking feedbacks. It was then refined and finalised prior to formal survey commences. Subsequently, the survey was sent out to a list of domestic fresh produce growers (n=578) by email and the list of recipients was drawn from mailing lists of United Fresh New Zealand Incorporated and The AgriChain Centre Limited where the produce growers registered themselves as members. This list represents approximately 11.6% of the total 5,000 fresh fruit and vegetable growers in New Zealand as reported by Horticulture New Zealand (2018). In addition, all ten fresh produce groups used for product traceability information observation were covered in the survey growers list, including berries and other small fruits, brassica vegetables, citrus fruits, fruiting vegetables, leafy vegetables, legume vegetables, pome fruits, root and tuber vegetables, stalk and stem vegetables, and stone fruits.

The questionnaire-based survey was sent out to growers on 19 October 2018 and finished on 28 February 2019. A reminder email was sent to the same growers after approximately three months on 7 January 2019.

3.5.3 Data collection and statistical analysis

Online survey data were collected between 19 October 2018 and 28 February 2019 using SurveyMonkey software (SurveyMonkey Inc., San Mateo, California, USA., www.surveymonkey.com). All online data collected from the grower survey via SurveyMonkey were then exported into Microsoft® Excel 2016 (Microsoft®, Washington, USA) for statistical analysis.

Graphs showing the data of survey results from fresh produce growers in New Zealand were generated using Microsoft® Excel 2016 (Microsoft®, Washington, USA). In addition, exported data from each questionnaire were analysed using SPSS Version 23.0 software

(IBM Corporation, New York, USA). Categorical variables were analysed using frequency distributions. Pearson Chi-Square test (X^2) was used to determine the relationships between the following variables (Snedecor & Cochran, 1989; Mattevi & Jones, 2016):

- Different perceptions of traceability systems from growers
- Different current practices of product labelling
- Different distribution channels of product supplies
- Different packaging formats of fresh produce sold at retail outlets
- Different notification methods of product delivery
- Participants who had experienced product recalls compared to those who did not
- Different challenges encountered in product recalls

The Chi-Square test (X^2) was chosen as the data from questionnaire survey was categorical and descriptive (Mattevi & Jones, 2016). Fisher's Exact test was used when the overall total of the table was less than twenty or between twenty and forty, and the smallest of the four values was less than five (Sharma, 2011). Statistical significance was determined at $P<0.05$.

Any determined relationships between the variables with significance of less than 0.05 were listed and discussed. The outputs of statistical analysis are shown in Appendix 9.4.

3.6 Pilot study

3.6.1 Selection of pilot sample

Pilot study can provide valuable preliminary information in terms of reliability of the measurement instrument and the pilot sample is commonly a small group of the target population. In order to gain better understanding of the fresh produce supply chain traceability system and also to explore the feasibility of using barcodes and scanning technology in New Zealand, a pilot study using strawberry samples was designed and carried out in this study between September 2018 and November 2018.

Strawberry was selected to undertake this traceability study for two reasons. Firstly, as pre-packed fresh produce, the packaging of strawberries could potentially carry traceability data from the grower through the supply chain to retailers or even consumers, while it may be difficult to loosely sold items such as lettuce or watermelon. Compared to other fresh fruit and vegetables in New Zealand, loose strawberries are typically packed in transparent plastic punnets by growers with labels attached to each single punnet, subsequently moved through the entire supply chain, and eventually sold to consumers with the same plastic packaging and labels attached. Therefore, it is literally practical to track any single strawberry punnet from the grower through the supply chain to the consumer by adding product traceability information onto the strawberry packaging with advanced technology, such as barcodes and scanning system.

Secondly, there has been hugely increased food safety concerns in terms of strawberry products in New Zealand and Australia since the sewing needle incidents occurred in both countries in 2018 (Meyer, 2018; Quackenbush, 2018; The Guardian, 2018). The entire strawberry industry especially growers in Australia suffered numerously economic loss and New Zealand strawberry growers were inevitably influenced by the needle incidents. Hence, an effective and efficient external traceability system for the strawberry industry was urgently required to track targeted products throughout the supply chain and narrow any negative effect to other product lines or growers.

3.6.2 Design of pilot study

As an industry trail, the strawberry pilot was designed to track strawberry punnets from growers/packhouses through supply chain to customers using GS1 technology. The designed pilot was considered as providing high-precision data as the unit of sampling was each punnet of strawberries rather than a whole batch of strawberries. United Fresh, GS1, and strawberry supply chain participants including two growers/packhouses, one wholesaler, one distribution centre (DC) and five retail stores were incorporated in this study to conduct the strawberry pilot. Two different strawberry supply chains from two growers/packhouses were selected to conduct the pilot. Packaging labels including punnet label, crate label and pallet label were specifically designed by GS1 in advance to contain GS1 barcodes where product identification and traceability information could be easily scanned. A software was developed by GS1 and installed in laptops in advance to store strawberry traceability data along with its value chains. Meanwhile, a hand-held scanner was Bluetooth connected with each laptop to scan product barcode and capture relevant traceability information. The scanned product traceability data was then automatically stored into the software in laptops.

There were ten pre-determined locations throughout the strawberry supply chain created by GS1 in the software system. Any product traceability information from the strawberry punnet scanning was associated with these ten pre-set locations and subsequently stored in the software system. The two strawberry growers/packhouses involved in this pilot had similar but slightly different supply channels for product distribution. The selected strawberry growers and packhouses were the same companies in this pilot. For confidentiality reasons the two growers/packhouses were named A and B, and the two retail stores received strawberries through distribution centre from grower/packhouse A were named A1 and A2. Similarly, the three independent stores received products via the wholesaler from grower/packhouse B were named B1, B2 and B3 respectively.

3.6.2.1 Scope of pilot study

A brief introduction and study design workshop were held at the start within each company involved in to define the scope of the pilot and to identify a value chain to use. The scope of the pilot was defined by determining the expected precision and depth of the traceability system, which were composed of the range of data to be collected.

Data collected in this pilot included date, time, product name, product location or truck details for transport, process step within the supply chain, and identification codes on punnets, crates and pallets where products were packed in or onto. This implied that all strawberry products in the pilot could reliably be traced back to the packhouse, and where possible, to the field. Each strawberry punnet was identified as the key identification unit to use in this pilot with other identification methods such as crate and pallet identification codes could also be allowed.

3.6.2.2 Selection of supply channels

Two pallets of strawberries from two different growers/packhouses were selected to carry out the trial, with one pallet from each grower/packhouse to indicate two different strawberry supply chains in New Zealand. In particular, one pallet of fresh strawberries was packed at packhouse A, transported directly to a distribution centre, and then moved to its retail outlets (Figure 3.6). Whilst the other pallet was packed at packhouse B, transported to a wholesaler, and subsequently delivered to independent stores (Figure 3.7).

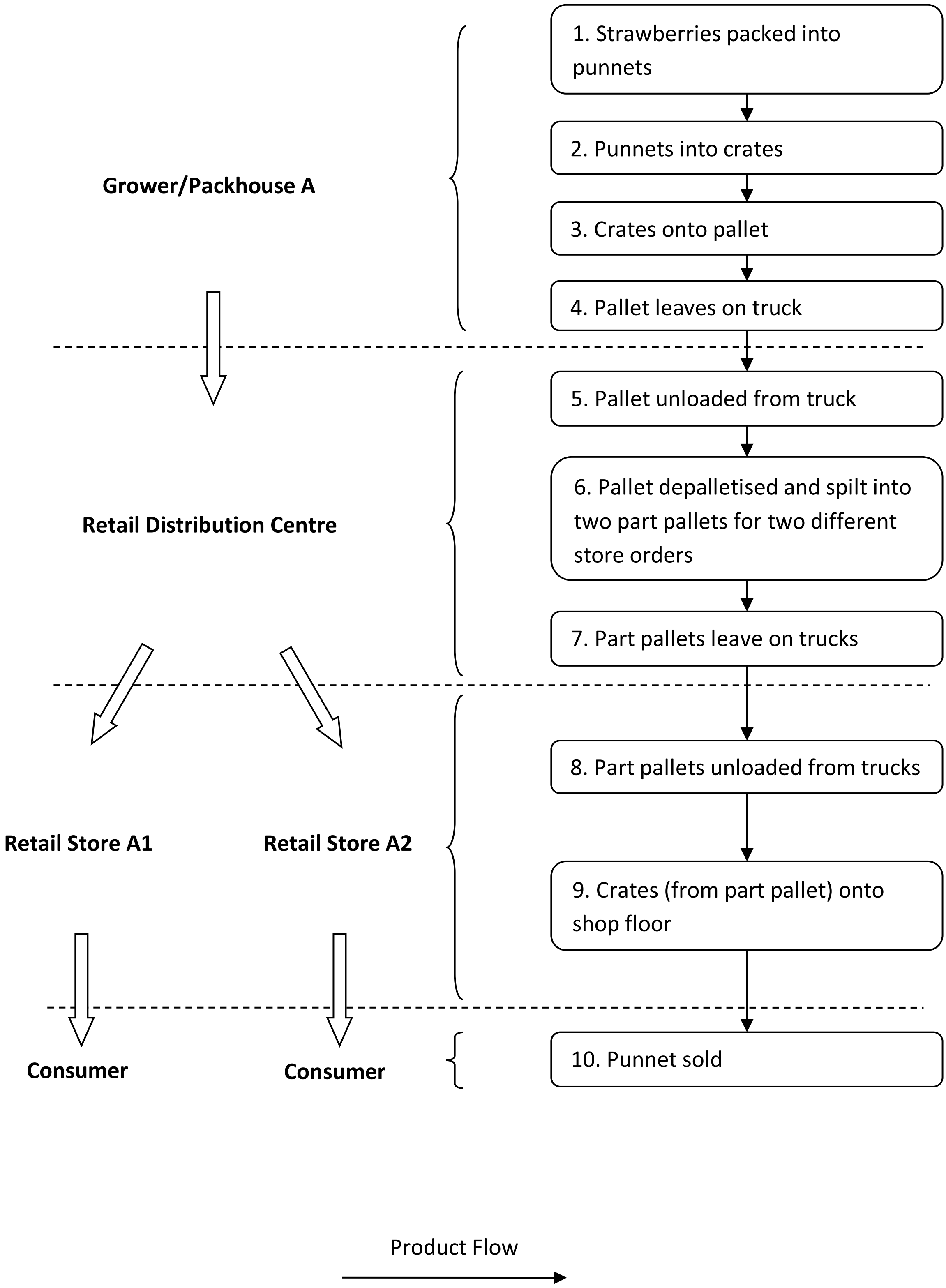


Figure 3.6 Selection of supply channels in the pilot study for strawberries at packhouse A.

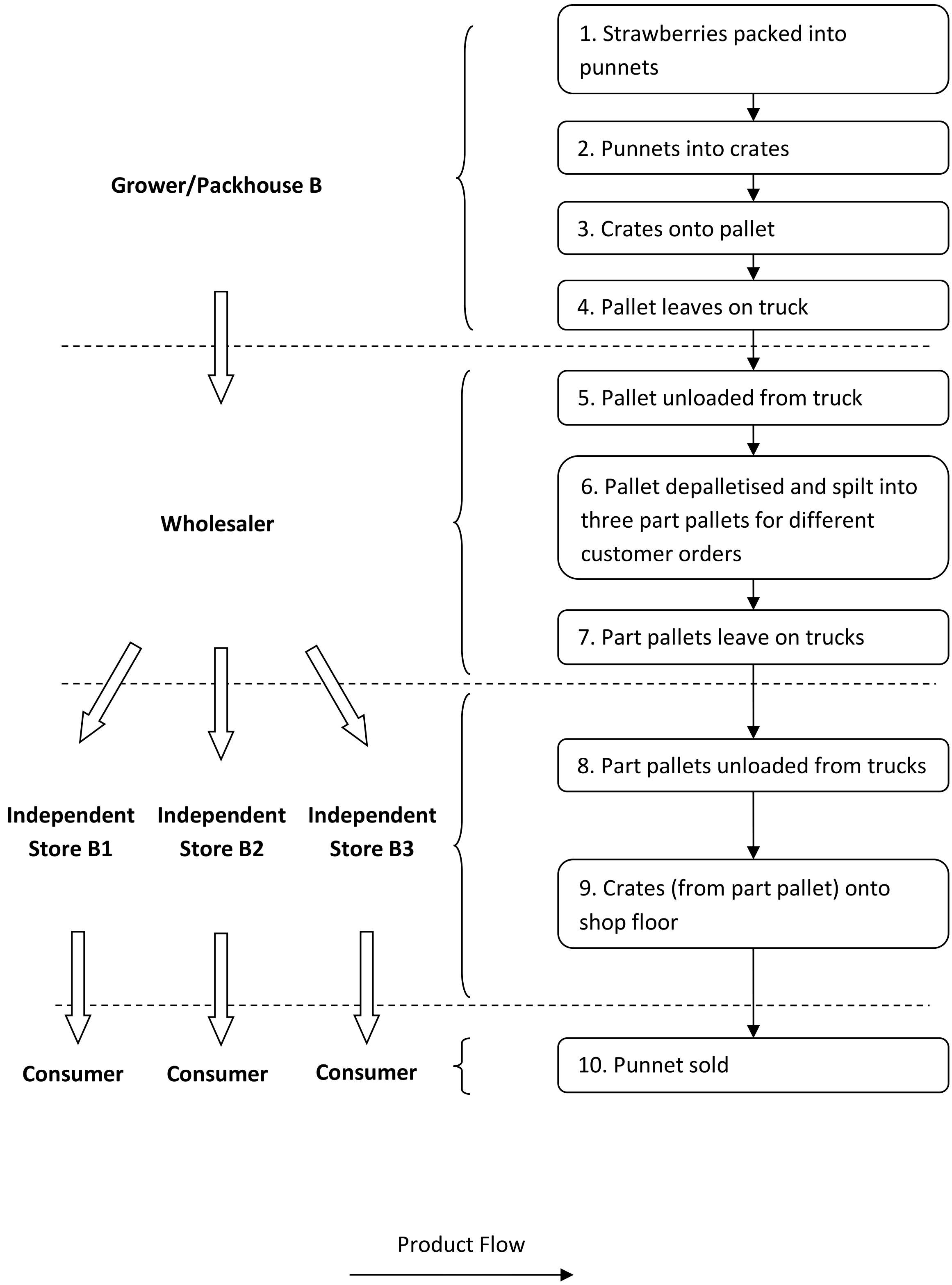


Figure 3.7 Selection of supply channels in the pilot study for strawberries at packhouse B.

Two strawberry punnets were purchased at each retail outlet to simulate consumer purchase and to scan the punnet barcodes at the retailer point of sale (POS). Barcodes of the two punnets were scanned and recorded into the software system. As there were five retail stores involved in this study, ten strawberry punnets were purchased from these stores in total.

3.6.2.3 Design of packaging label

There were three different types of packaging labels used in the strawberry trail: punnet label, crate label and pallet label (Figures 3.8 – 3.10). The dimension of strawberry punnet label was 4 x 6 centimetres so it was small and could be easily attached to each strawberry punnet. The crate label dimension was 6 x 9.5 centimetres and it was placed on the side of each crate. Pallet label was relatively larger and its dimension was 21 x 29.6 centimetres. All three different types of strawberry packaging labels were pre-designed, pre-printed and distributed to the two packhouses in advance with instructions on use. Labels for punnets and crates were provided by GS1 with 14-digit GTIN numbers and barcodes. Additionally, SSCC labels for pallets were also provided by GS1 with 18-digit GTIN numbers and barcodes. All three different types of strawberry packaging labels contained product name, grower/packhouse name, grower/packhouse address, and GTIN with both a numerical sequence number and a barcode for scanning. Moreover, the "picked on date" was printed on each pallet label, whilst this was not printed on strawberry punnet and crate labels as they were too small to add it on. However, this information could potentially be captured in GS1 barcodes and therefore it was not a concern in this pilot.

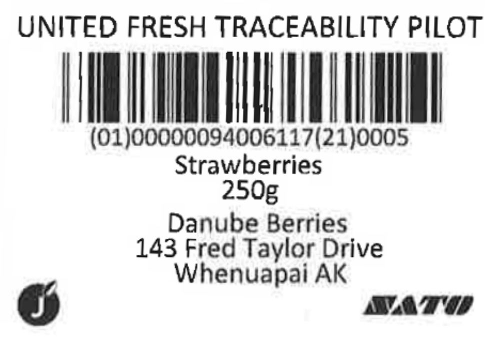


Figure 3.8 An example of strawberry punnet label used in the pilot study.

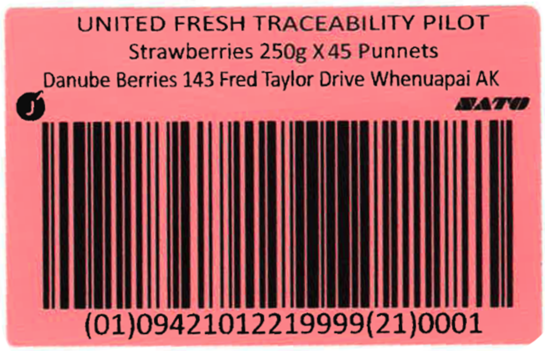


Figure 3.9 An example of strawberry crate label used in the pilot study.

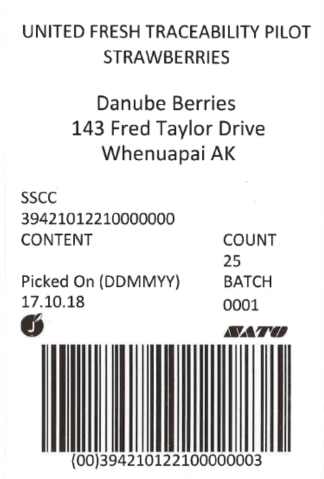


Figure 3.10 An example of strawberry pallet label used in the pilot study.

3.6.2.4 Model development

Pocket 2-dimensional (2D) barcode scanners (Eyoyo BT 2D Barcode Scanner Model: EY-002S) were used for barcode scanning in this pilot study (Figure 3.11). Tracking software GEM (GS1 EPCIS Event Manager, Version 5.0) was created and provided by GS1 to store product traceability data scanned and captured by the scanner. This software GEM was developed by GS1 and was purposely built to enable a simple data load process into a platform for the pilot requirements. The software was subsequently installed in a laptop which was blue-tooth connected to the barcode scanners. All scanned data was recorded in the software system on the laptop.

Figure 3.11 Pocket 2-dimensional (2D) barcode scanner.

Locations of premises through which strawberries would pass in the pilot were pre-determined and relevant information including addresses and contact details were entered into the software GEM in advance. Life history of a punnet, crate and pallet for strawberries was modelled into the software GEM system. Points at which selected strawberries passed through were scanned with scanners connected to the GEM software. Vehicles used to transport strawberry pallets from packhouse through wholesaler or distribution centre to retailers were also tracked and relevant information was scanned into the software system.

The GEM software was modelled to cover all ten process steps involved in the strawberry pilot (Figure 3.12). These ten process steps involved were from loading punnets into tray, loading trays onto pallet, pallets depart from grower, pallets arrive at DC/wholesaler, removing trays from pallet, loading trays onto pallet, pallets depart from DC/wholesaler, pallets arrive at store, move trays onto sales floor, to sell punnets at store POS. These ten process steps were also ten scanning points for the strawberry supply channels as identified in the pilot.

The GEM software system installed in laptops and associated scanners were pre-tested with pre-printed labels for strawberry punnets, crates and pallets prior to being applied in packhouses to make sure that these devices could work functionally and properly. In particular, it was important that scanners were able to scan the barcodes on pre-printed labels and all captured information could be uploaded into the software in real time.

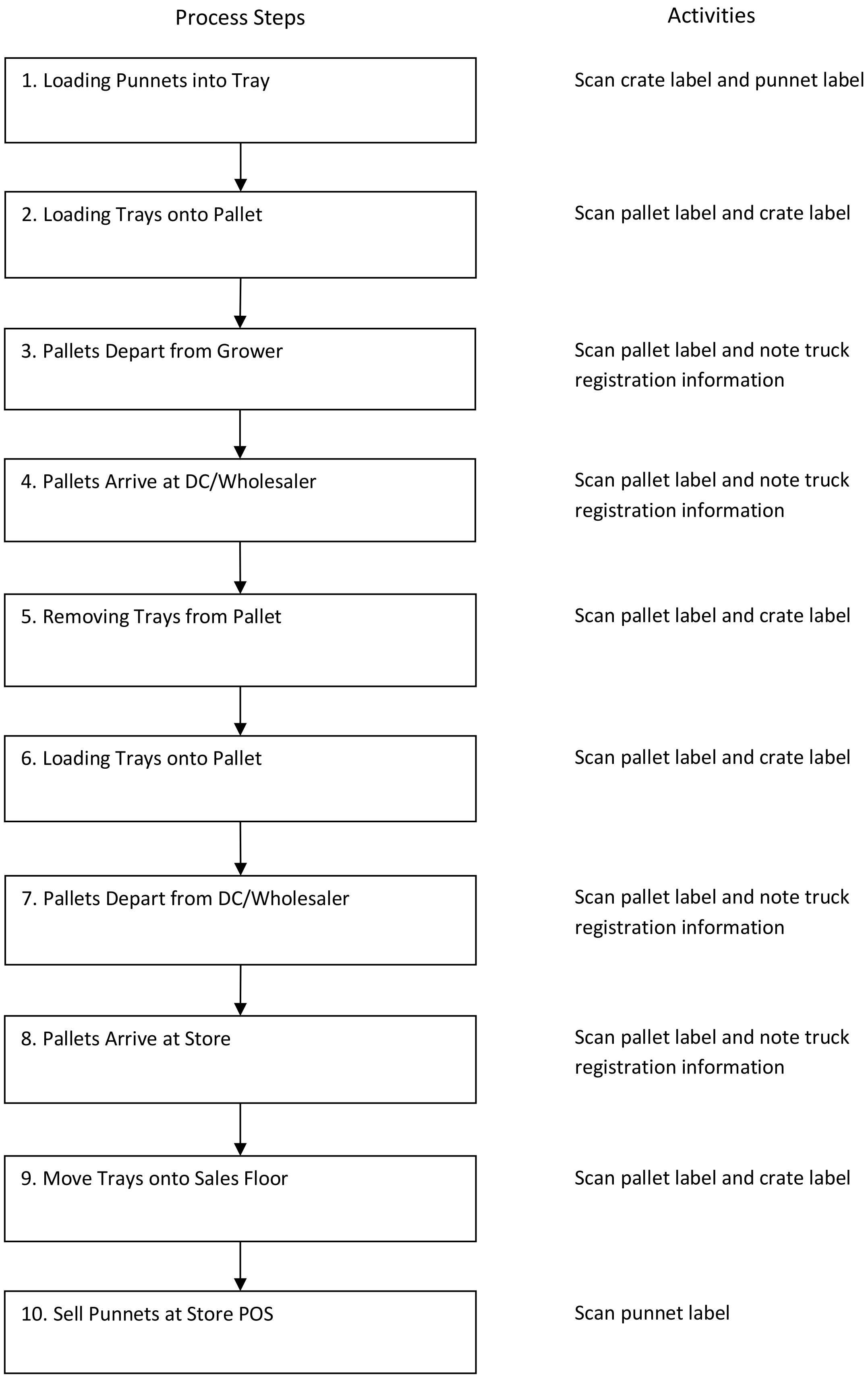


Figure 3.12 Ten process steps involved in the strawberry pilot were modelled into the GEM software system.

3.6.3 Field trial

Pre-printed punnet labels containing GS1 barcodes were manually applied to each packed strawberry punnet at the end of strawberry packline prior to placing into a returnable plastic crate. As the strawberry punnets were loaded into the crate, a crate label carrying GS1 barcode was attached to the crate. Subsequently, both the punnet and crate labels were scanned with a barcode scanner connected to the GEM software system (Figure 3.13). Meanwhile, all strawberry punnets in the crate were associated with this specific crate during the scanning process and relevant traceability data including scanning date and time were recorded by the GEM software system. The strawberry crates were then stacked onto a wooden pallet where a pallet label was attached to the pallet. Similarly, both the crate and pallet labels were scanned with the barcode scanner and all crates on the pallet were associated with this specific pallet. In addition, relevant traceability information including scanning date and time were recorded into the GEM software.

The similar scanning, associating and recording procedures were repeated at each process step along with the selected strawberry supply channels in the pilot study. For instance, as the strawberry pallet was loaded onto a truck and the pallet label was scanned, relevant information including loading date, time and vehicle registration number associated with this strawberry pallet transporting were recorded by the GEM software. When the truck arrived at wholesaler or distribution centre premise and the strawberry pallet was unloaded from the truck, the pallet label was scanned and the truck registration number was noted to record traceability data into the tracking and tracing software.

The crate and pallet labels were scanned as the pallet was depalletised and some crates were removed from the pallet. When pallets were loaded onto trucks and sent to retailers from wholesaler or distribution centre, the same scanning processes for labels and truck information recording were repeated.

As part of the pilot study, two punnets of strawberries from each retail outlet were purchased and barcodes on the punnet labels were scanned to simulate consumer purchase process at the POS in process step 10.

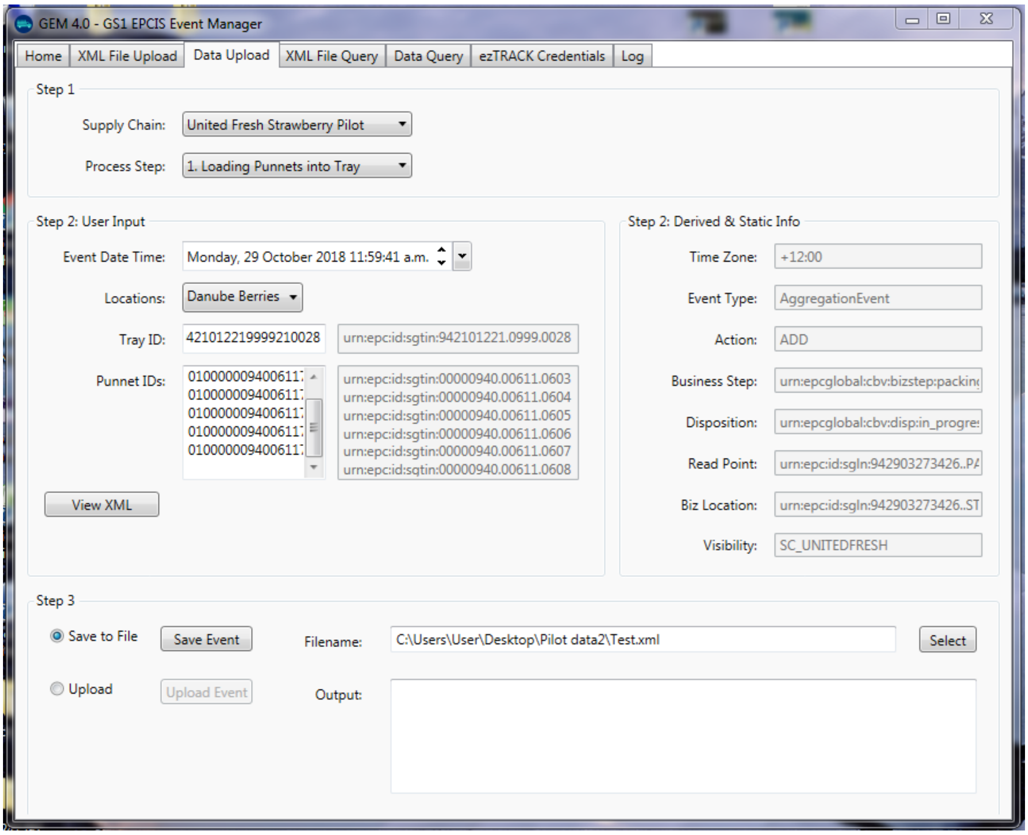


Figure 3.13 Screenshot showing GEM software system during process step 1 loading punnets into tray/crate.

Ten points for scanning of strawberries throughout the supply chain were created in the GEM software to cover all possible scanning points that may occur during the strawberry movement. This monitoring software associated each scanning point with strawberry punnets, crates or pallets.

All information related to these scanning points were recorded and stored in the tracking software which was installed in a computer.

3.6.4 Data collection and analysis

Traceability data including product identification codes of strawberry punnet, crate and pallet, grower/packhouse, retail distribution centre or wholesaler, retail store or independent store, destination and transported truck were collected as strawberries moved along the supply chains until being purchased at the retailer outlet (Table 3.2).

Table 3.2 Traceability data collected in the strawberry pilot study.

Subject	Traceability data collected
Strawberry punnet	Punnet identification code Source (grower/packhouse) Pack size Identification code of associated crate Date and time of loading punnets into crate Date and time of unloading punnets from crate
Strawberry crate	Crate identification code Source (grower/packhouse) Pack size Identification codes of associated punnets and pallet Date and time of loading crates onto pallet Date and time of unloading crates from pallet
Strawberry pallet	Pallet identification code Source (grower/packhouse) Pack size Identification codes of associated crates Date and time of pallet departing from grower/packhouse Date and time of pallet arriving at next destination
Grower/packhouse	Name Location Contact details Date and time of products exiting
Retail distribution centre or wholesaler	Name Location Contact details Date and time of products entering Date and time of products exiting
Retail store or independent store	Name Location Contact details Date and time of products entering Date and time of products on shelf Date and time of products being purchased
Truck (for transporting)	Registration number

Data stored in the GEM software system were retrieved and analysed. Descriptive analyses were carried out and results were summarised using tables and figures.

4.0 Results and discussion

4.1 Current fresh produce traceability

As the number of fresh produce samples selected in each group was based on the availability and seasonality of crops, time limit for selection, and any adverse weather events, there were in total 336 samples selected for analysis in this study (Table 4.1).

Table 4.1 Selected fresh produce sample details.

Group Number	Group	Produce Selected	Number of Produce Selected in Each Group	Sample Source Along Supply Chain
1	berries and other small fruits	Blackberry Blueberry Boysenberry Strawberry Raspberry	24	Wholesaler = 8; Supermarket = 12; Independent Store = 4.
2	brassica vegetables	Brussel Sprouts Cabbage Kalian	4	Wholesaler = 3; Independent Store = 1.
3	citrus fruits	Grapefruit Lemon Lime Mandarin Orange Tangelo	60	Wholesaler = 43; Supermarket = 12; Independent Store = 5.
4	fruiting vegetables	Capsicum Chilli Mushroom Okra Sweet Corn	54	Wholesaler = 33; Supermarket = 10; Independent Store = 11.
5	leafy vegetables	Choisum Endive Mustard Greens Pak Choi Puha Spinach Spinach Beet Watercress	10	Wholesaler = 6; Supermarket = 1; Independent Store = 3.
6	legume vegetables	Green beans	3	Supermarket = 2; Independent Store = 1.
7	pome fruits	Apple Pear Quince	62	Wholesaler = 29; Supermarket = 21; Independent Store = 12.
8	root and tuber vegetables	Carrot Kumara	58	Packhouse = 2; Wholesaler = 21;

		Potato Swede Turnip		Supermarket = 25; Independent Store = 10.
9	stalk and stem vegetables	Asparagus Rhubard	37	Packhouse = 1; Wholesaler = 26; Supermarket = 5; Independent Store = 5.
10	stone fruits	Apricot Cherry Nectarine Peach Plum	24	Wholesaler = 18; Supermarket = 6.
Total			336	

In total, over three hundred units of fresh fruit and vegetables (n=336) were randomly selected from different stages within the produce supply chain and photos were taken to capture product traceability information for analysis.

A total of 462 units of product traceability information were collected and analysed across the 336 fresh produce products as some products were determined that they contained traceability data from more than one sources. The total 462 units of product traceability information consisted of 193 units from grower / packhouse cards, 135 units from wholesaler stickers, and 134 units from retailer labels attached onto fresh produce or its packaging.

Product ID and grower ID were observed more prevalent than other traceability information components on product outer packaging provided by growers or packhouses (Figure 4.1). In contrast, harvest date was almost never present in either written or GS1 format compared to all other traceability information units identified from outer packaging. Additionally, the prevalence rate of most traceability information components present in written format was higher than these present in GS1 format, except serial number. Serial number present in GS1 format was slightly more prevalent than this present in written format on product outer packaging.

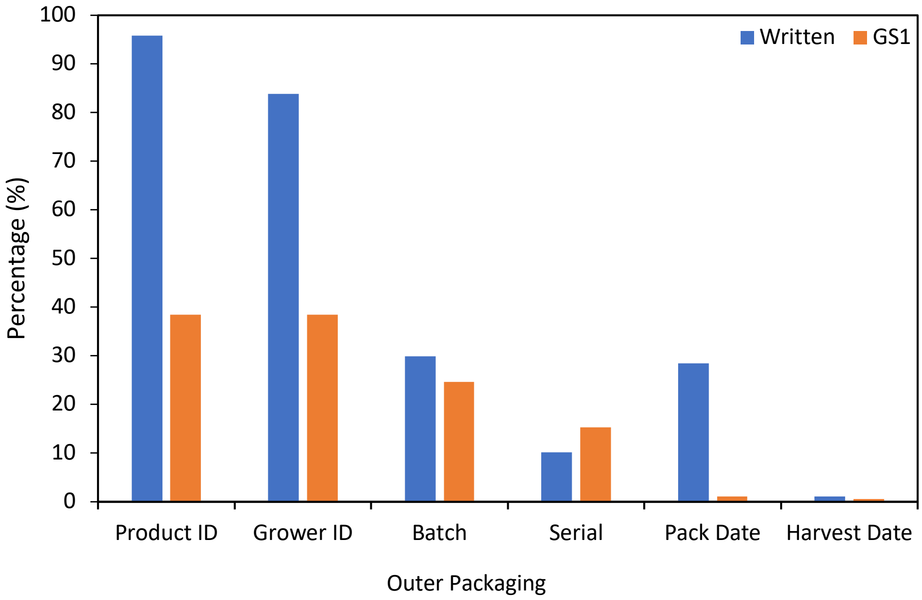


Figure 4.1 Prevalence rate of different traceability components on product outer packaging in written and GS1 format.

(Notes: written format means traceability information is present in text and readable to consumers; GS1 format means traceability information is present in GS1 barcode and not readable to consumers but can be scanned and recognised by GS1 scanner.)

Within different traceability information components present in written format identified on product market packaging, product ID and grower ID were consistently more prevalent than other traceability units in written format, including batch number, serial number, pack date and harvest date (Figure 4.2). In comparison, there was very limited traceability information observed from pack date and harvest date on product market packaging. In addition, written traceability information identified the product and grower more frequently than GS1 formatted traceability information from wholesaler packaging.

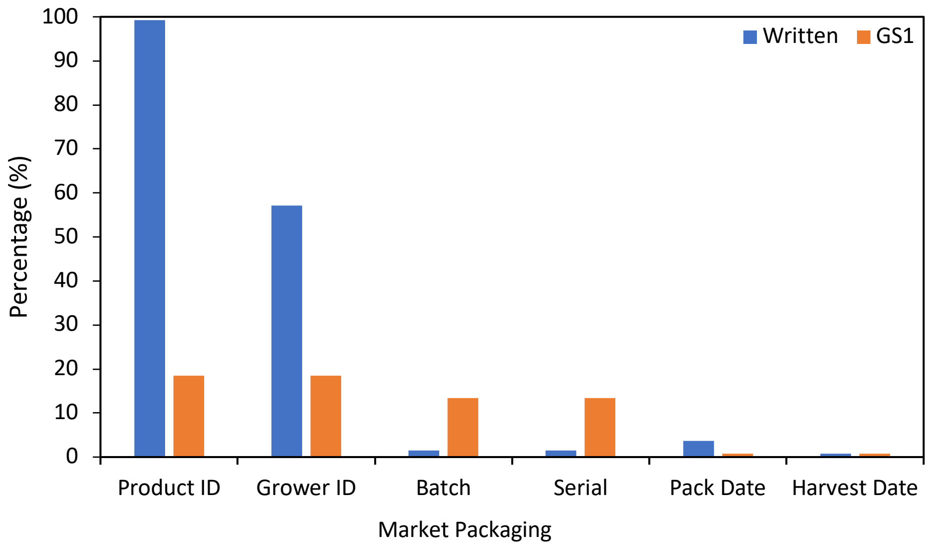


Figure 4.2 Prevalence rate of different traceability components on product market packaging in written and GS1 format.

(Notes: written format means traceability information is present in text and readable to consumers; GS1 format means traceability information is present in GS1 barcode and not readable to consumers but can be scanned and recognised by GS1 scanner.)

Product ID and grower ID showed higher prevalence rates in both written and GS1 format than other traceability components on product retail packaging (Figure 4.3). In contrast, the prevalence rates of batch number, serial number and harvest date in both written and GS1 format were extremely low from traceability information identified on retail packaging. Noticeably, pack date present on product retail packaging in written format was observed with the prevalence rate of 33.9%, whilst it was never identified in GS1 format. This phenomenon could be understood easily as information at retail level was expected to be available and readable to consumers. Therefore, pack date in written format rather than GS1 code would be preferred by the public, even if the GS1 format is more and more common.

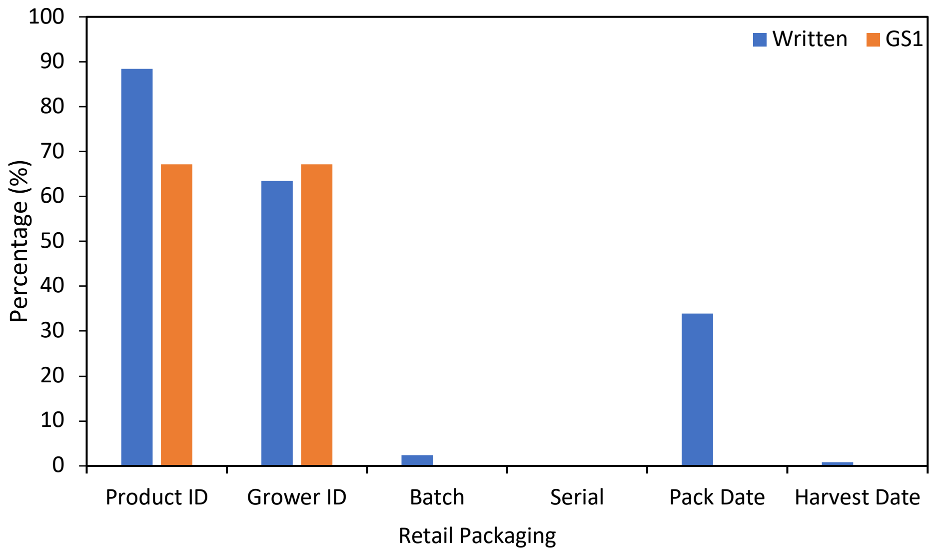


Figure 4.3 Prevalence rate of different traceability components on product retail packaging in written and GS1 format.

(Notes: written format means traceability information is present in text and readable to consumers; GS1 format means traceability information is present in GS1 barcode and not readable to consumers but can be scanned and recognised by GS1 scanner.)

Overall, GS1 formatted traceability information was less prevalent than these present in written format on product outer packaging, market packaging and retail packaging. Product ID and grower ID were most consistently identified traceability information on different sources of product packaging compared to other traceability components, including batch number, serial number, pack date and harvest date. It can be assumed that product ID and grower ID were considered as the most important product information attached to product packaging throughout the fresh produce supply chain. However, missing of some more specific product information such as batch number, serial number, pack date, and harvest date may not affect fresh fruit and vegetables delivered from growers or packhouses, to wholesalers and retailers as these product information were not required by their customers. In addition, as the fresh produce industry is fast paced and products could go from farm to fork in as little as three days, the quality of fresh produce would not be hugely affected especially with visual inspection carried out all the way through produce movement in the supply chain. However, from a food safety view point, pack date should always be attached to fresh fruit and vegetables especially for high risk produce products such as bean sprouts and berry fruits. Moreover, Dabbene and Gay (2011) indicated that it was pivotal to have all the information associated with products along the supply chain in a traceability system especially in the event of a food safety crisis.

The prevalent rates of product ID and grower ID present in GS1 format were dramatically increased on product retail packaging. As most retailers including supermarkets use GS1 system, this could be the drive behind this phenomenon. In addition, it indicated that retailers placed their emphasis on product ID and grower ID instead of batch number, serial number, pack date or harvest date.

Batch number and serial number were relatively prevalent on product outer packaging from growers or packhouses. However, they were identified less frequently on market packaging from wholesalers and were rarely recorded on retail packaging. Obviously, these types of traceability information became fragmented and were not fully carried through the supply chain and most information was lost during product transition from growers or packhouses, to wholesalers and retailers.

Pack date present in written format on product outer packaging and retail packaging was moderately displayed but was rarely identified on market packaging from wholesalers. Pack date is not only a good indicator to show the product freshness but can also be used for traceability purposes. It is not always required by wholesalers, but some major retailers require their suppliers to provide pack date along with products.

Harvest date was consistently rarely displayed on all three types of product packaging throughout the produce supply chain, showing that this traceability information was either not recorded in the field by growers or never required by customers in the supply chain.

4.2 Industry stakeholder interview

4.2.1 Objectives and product definitions

Key personnel from all interviewed organisations were aware of their traceability regulations, standards and customers' requirements to which their produce products were sold within New Zealand, including requirements from Food Act 2014, NZ GAP and Woolworths Supplier Excellence Programme (WSE). In addition, all interviewed organisations except for one grower had documented traceability systems defining objectives, methodology and their scope, and also had product recall / withdrawal plans in place, with designated persons responsible for them. For most interviewed organisations, the company traceability system was reviewed by management team regularly or at least annually within each organisation. Whilst, objectives and scope of traceability system were not fully documented by a minority of the interviewed companies who had an internal traceability system to certain extent but some improvements were needed to make sure a traceability plan is fully documented and reviewed by company management team.

In general, all produce products or plant seeds received by the eight companies were assigned with unique identification numbers at inwards goods stage. Either a paper based or electronically based traceability system was used at each company premise to record unique product identification numbers and other relevant traceability information, including product name, date of product received, product quantity, and supplier name or code. Moreover, a unique identification number was also generated for each consignment or delivery at product dispatch stage and relevant traceability data were described in company traceability system. Remarkably, all produce from the interviewed organisations could be identified to product crate or carton level only and wooden pallets used for produce transport were not traceable or identifiable.

It was noted that most interviewed companies were GS1 members. In addition, the retailer and some wholesalers had GS1 traceability system in place and each produce product was identified with a Global Trade Item Number (GTIN) at receival. However, GS1 system was not used by all interviewed growers and the other wholesalers.

4.2.2 Internal traceability, establishment of procedures and flow of materials

Most of the organisations had a robust internal traceability system in place. A few had an internal traceability recording procedure within their company, however, its effectiveness and implementation were yet to be confirmed.

Within all the interviewed companies, only a minority could identify and recognize which staff member had physically handled a produce product in the operation and distribution areas. However, all fresh produce suppliers and customers were assigned with unique identification numbers or codes and their contact details were documented in company systems. For example, grower code, customer code and their contact details were stored in the wholesaler traceability systems, while seeds supplier name, customer name and relevant contact details were recorded by all of the growers.

Furthermore, it was pointed out by all interviewed companies that temporary storage areas in the chiller or warehouse were determined by crop physiology needs. Crops requiring different storage conditions were stored in different chillers or areas that were set up at different temperature ranges. Therefore, it seems that it is unnecessary to trace or identify internal locations within a fresh produce company. Nevertheless, some of the companies being interviewed could formally track the location of each fresh produce within their electronic traceability system. In addition, one of the growers used their own paddock codes to identify internal locations and the other growers could use field or block codes for internal location identification.

The process flow of fresh produce at growers' premises were demonstrated in Figure 4.4 as below. For crops grown from seeds such as lettuce and carrot, traceability data starts from seeding in nursery where seeding date, seed name and variety were recorded by growers. Subsequently, plant date, block code, harvest date, batch code and pack date were also stored in company traceability system (either paper based or electronically based). Similarly, for produce products harvested from existing trees or vines such as apple and strawberry, plants located in each block or paddock were identified and the block or paddock was coded as part of traceability. In addition, harvest date, batch number and pack date were recorded by growers.

Generally, a grower card or sticker was generated by growers and attached to each crate or container of produce prior to product dispatch and delivery. Product labels containing product traceability information were either printed on site and attached to each crate or inkjet printed on each pre-packed product packaging. Product traceability information contained in the grower card or sticker may vary depending on different systems owned by growers and also upon customers' requirements. For instance, grower one recorded plant date, batch code, harvest date and paddock code in a coded way created by themselves and printed on grower cards, and product name, pack date and grower details were also included in the grower card attached to each crate of products. However, grower two and grower three only had product name, grower name and details on each grower sticker on product crates. Moreover, for a specific customer who was a retailer ordering products directly from growers, a GS1 barcode was pre-provided by the customer and was required to print on each grower card or sticker attached to produce crates.

A product traceability harvest notebook was completed by grower one to record product traceability information and a harvest delivery docket was completed for each product delivery. Information including grower name, grower contact details, reference number, date, driver name, delivery time, delivery temperature, crop name, variety, batch code, paddock code, pack code, quantity, count and plant date were recorded on the harvest delivery docket. Electronic systems were used by grower three and grower four to record traceability data similar to grower one. However, information of product details such as seeding date and block code may be recorded by grower two, but record keeping was not always completed.

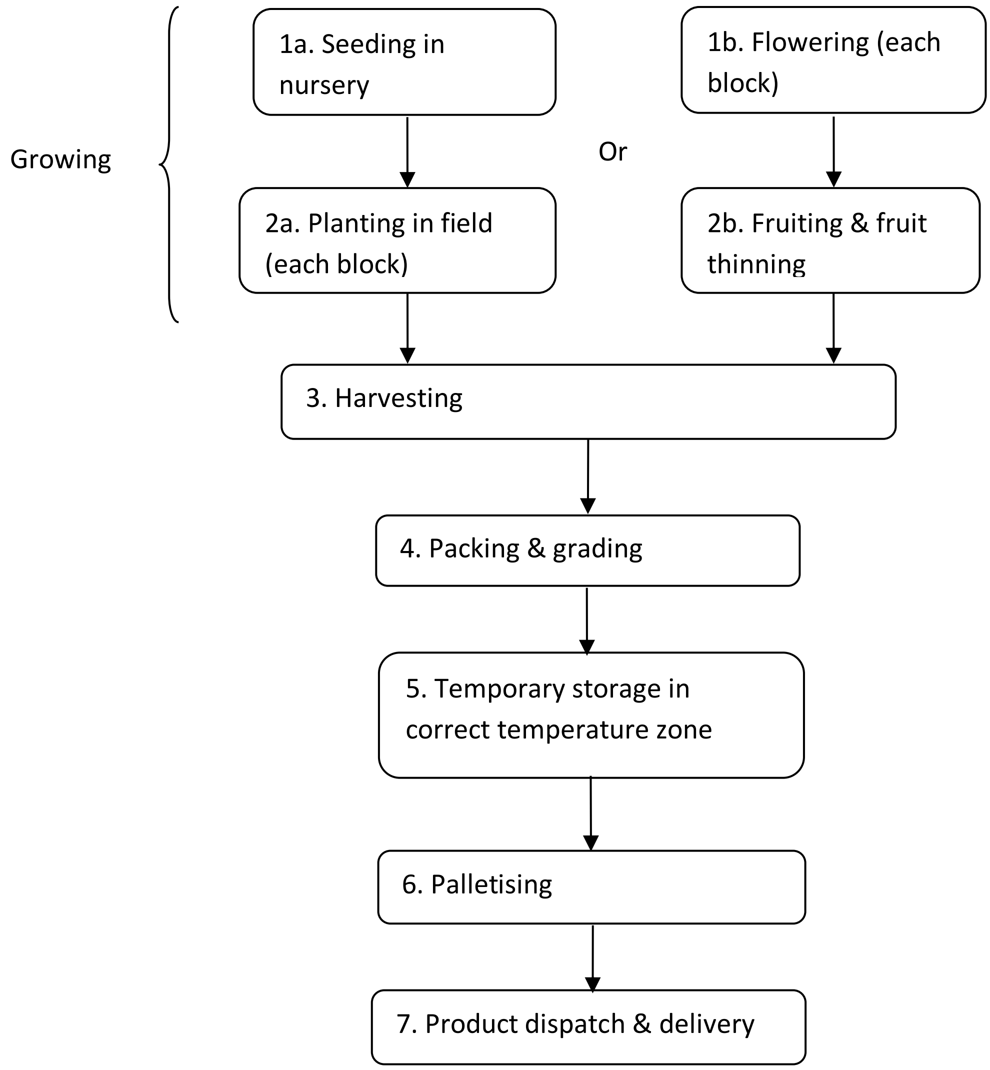


Figure 4.4 Fresh produce process flow at growers' premises.

The same process flow was followed when fresh fruit and vegetables were received, stored and dispatched at the three wholesaler sites as illustrated in Figure 4.5. When fresh produce was received at a wholesaler site, a product check was conducted and a label carrying traceability data was generated and attached to each crate or carton of fresh produce. This label was also called market packaging as referring to section 3.3 (Current fresh produce traceability observation). Traceability data carried in the label normally included product name and grower name or code. Pack date could also be included in the label depending on their customer requirements. However, there were very limited information on the label for batch number, serial number and harvest date in terms of product traceability. Coincidently, this finding was the same as the result of market packaging data analysis from section 4.1 (Current fresh produce traceability).

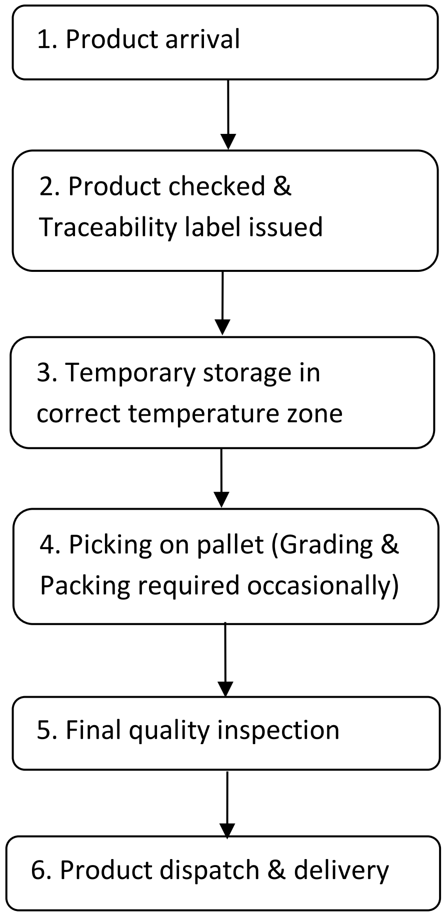


Figure 4.5 Fresh produce process flow in the three wholesalers.

(Notes: This process flow shows processes of fresh produce product arrival, through to dispatch and delivery at wholesaler sites).

The process flow of fresh produce at the retailer distribution centre (DC) was illustrated in Figure 4.6. Inwards goods were received and checked, and then a unique pallet label was generated for each pallet of products. Product labels containing item codes were printed and attached to each pallet. Products were subsequently moved to allocated areas for temporary storage and the allocated storage location was dependent on the cool chain requirements of each crop. Meanwhile, each location within the retailer DC was barcoded and a scanner was used by operators to scan the location barcode against the barcode on product label, in which way the product storage location was associated with the product in company traceability system electronically.

When a store order was generated, the required items were picked, collected and moved by forklifts to be ready to be checked and dispatched. A dispatch label was then generated for each pallet, containing description of product name, quantity, and other traceability information. The dispatch label was attached to each pallet of product prior to delivery.

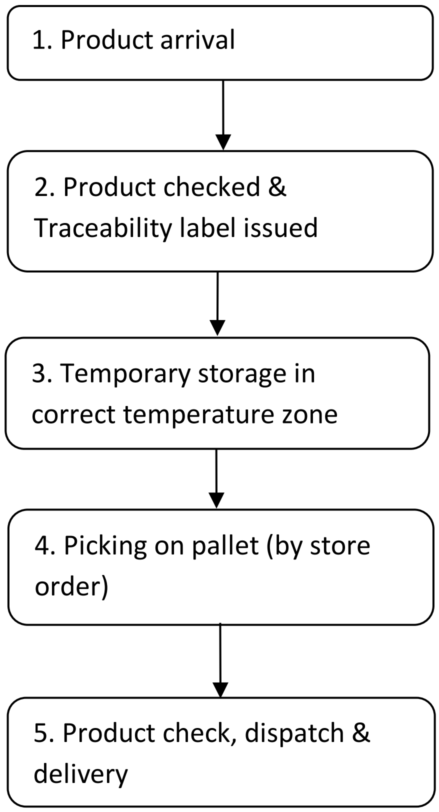


Figure 4.6 Fresh produce process flow at the retailer Distribution Centre (DC)

There were procedures and systems in place to record product traceability information in most of the interviewed companies. It was found that different electronic software systems were used among the interviewed companies where there was a traceability system in place. However, these systems appeared to be selected because of administration or logistic requirements rather than traceability objectives.

All three wholesale organisations were able to demonstrate their resorting processes and show relevant traceability records. As resorting process happens occasionally and only when there is a quality issue that products need to be resorted, it therefore is difficult to observe a resorting process at the time of traceability assessment on site. However, it was noted that there were difficulties in terms of tracking resorted produce back to where it was from when two or more batches of products under the same category were used and mixed for resorting. For example, when orange labelled as batch A and orange coded with batch B were used for resorting and resorted products were relabelled as batch C and batch D. According to resorting records, batch C and batch D were from batch A and batch B, whilst it was unknown that batch C was exactly from batch A or batch B. In particular, even though the two batches of orange may be from the same grower, they could be harvested from different blocks in the orchard or picked on different dates.

Documented procedures of aligning critical traceability data with business partners existed in all interviewed companies with very similar processes. For instance, a consignment check was carried out by all organisations at inwards goods area when products arrived onsite. Similarly, fresh produce products and picking slip were also checked against customer order at dispatch area prior to product dispatch and delivery. Products can only be received or dispatched when these documents and relevant information match to each other.

The majority of the interviewed companies established plans and procedures for crisis management, including food recall and withdrawal. Key contact personnel within each organisation was clearly identified and communication procedures to key stakeholders in an event of a product recall or withdrawal were also documented as part of the plan.

It was noted that all fresh crops received by these wholesalers and retailer were physically labelled with unique identification numbers at inwards good areas and also assigned with unique identification numbers prior to dispatch. However, fresh produce products can only be tracked back to crate or carton level but not individual product, according to the interviewed companies. In another word, loosely packed fresh produce can only be identified to crate or carton level, therefore tracing back to growers from consumers becomes very difficult to impossible. Specifically, when a full pallet of orange carrying twenty crates from one grower were received at a wholesale site, a unique identification number was generated and attached to each crate of the pallet. Subsequently, all twenty crates of orange were given exactly the same identification number in this way. Therefore, the traceability system could only trace back to the twenty crates of orange in the event of a product recall or withdrawal, while it could not distinguish one crate of orange from the other within the twenty crates.

Nevertheless, as "one-up, one-down" traceability system was required from customers and regulators in New Zealand currently, these traceability systems of interviewed organisations somehow met their requirements in spite of the limited information captured by these traceability systems. Specifically, all the interviewed wholesalers and retailer were able to trace their fresh produce back to their growers in case of a food recall event. However, to what extent the traceback process could be and how long it takes to achieve this are questionable.

4.2.3 Information and documentation requirements

Seven different software systems were used to record relevant information of product received and dispatched by most of the interviewed organisations respectively, while the principles of these different software systems were fundamentally the same. In particular, product information including product name, product quantity, dispatch date, supplier name or code, customer name, supplier and customer contact details were all recorded in these software systems and managed by authorised persons at these companies. Additionally, hard copies of relevant paper work were also kept on file for four to seven years. Hence, in the event of a food recall or withdrawal, most of the organisations would be able to trace their products from customer to supplier through the software systems. However, a few growers may or may not be able to trace their produce products from limited information provided on their product retailer packaging and available records kept on file.

It was confirmed that all relevant documents from product/seed receipt to dispatch were reviewed and signed off by supervisors or line managers within the eight companies. Moreover, administration of product traceability information such as organisational structure, operational responsibilities and traceability system capabilities were developed and documented as part of the food safety and quality management systems in three wholesalers, one retailer and three grower businesses. In addition, the food safety and quality management systems were reviewed and updated by nominated people at least annually to make sure that all relevant information were kept up to date and reflecting current processes within the seven organisations.

All documents related to traceability information were kept in restricted locations by all eight organisations with only authorized persons have access to them. Traceability data at interviewed companies were maintained and held between 4 and 7 years, which were complying with current regulations as at least four years for traceability records keeping was required in the Food Act 2014 (The Parliament of New Zealand, 2018).

4.2.4 Structure and responsibilities

An operational traceability team was assembled and established as part of the traceability plan for most interviewed organisations. Their roles and responsibilities were also defined and documented in the company traceability plan. Necessary resources such as Human Resources (HR), Information Technology (IT) and budget were provided to the traceability team at most of the companies to maintain the traceability system. Furthermore, the traceability team members of each organisation were aware of the company traceability procedures and instructions, and they were also able to demonstrate where to find them and how to use them.

4.2.5 Training and external traceability

It was noted that there was no formal traceability training developed or provided to personnel at all interviewed organisations, with only one company stated that verbal traceability training was provided but no records were kept and a documented training session on their company traceability system was working in progress.

All three wholesalers and one retailer were able to obtain traceability information of received fresh produce from suppliers and also to provide detailed traceability information to parties requesting it. However, according to the interviewed companies, there may be difficulties to obtain traceability information such as harvest date or paddock code and it may take minutes to days to approach this information from growers. For example, it was mentioned by a few companies that in some cases language barrier and access to technology can be an issue, especially for people speaking English as their second language and companies lacking email facilities. However, as the speed of data transmission between companies can determine the effectiveness of traceability, a real time data capturing and recording system is needed to provide solutions and enhance the current fresh produce traceability (Olivier et al., 2006). In addition, it was noted that barcode systems applied across the produce companies were not consistent along the supply chains. Specifically, all three interviewed wholesale and one retail organisations had different barcode systems in place for product traceability within the fresh produce supply chain. Additionally, only part of the product traceability information generated by growers was passed onto the buyer and resulted in information loss during product transport across the produce value chain. For example, produce harvest date and block code recorded by growers may not pass down to wholesalers since the information was not required by customers or regulators, thereby causing some traceability challenges in the fresh produce industry. Similarly, Trienekens and Beulens (2001) implied that only partial information created by a supplier linking to its products and processes was carried through to the buyer during their food traceability system study.

A crisis management plan was documented as part of their food safety and quality management programmes for the majority of the interviewed companies, including product recall and withdrawal. In addition, a crisis management team was established and their roles and responsibilities were assigned within the plan at each company.

According to most of the interviewed companies, they were able to carry out product recall or withdrawal process at any time as their key contact personnel listed on the crisis management team could be contacted 24/7. A few of the interviewed businesses could also perform product recall to an extent but its success will depend on the completion of relevant product traceability data on certain days required.

4.2.6 Internal assessment

An internal audit was conducted at least annually by the majority of interviewed organisations to ensure compliance with food safety and quality management requirements, including traceability standard. A mock recall exercise was also undertaken annually by them and all relevant records were kept on file. Any non-conforming issue identified from the internal audit or mock recall exercise was addressed and corrective actions were taken by nominated staff at each facility. Subsequently all relevant records were maintained and kept by each organisation.

4.2.7 Summary of the industry stakeholder interview

Most of the interviewed organisations were GS1 members and there was some use of barcodes for all of them. However, the barcode application was not consistent across the companies. It was noted that some growers had GS1 systems in place, while the labels and relevant information were not carried through to market level since the wholesalers had different systems and the grower crates were relabelled at wholesaler sites using their own systems. Mainetti et al. (2013) also pointed out that one of the challenges to achieve an effective traceability system in the fresh vegetables supply chain was the integration of management systems from all industry participants. The majority of fresh produce growers were generally small local farms and packhouses without a proper information system and their communications with customers or suppliers were still via traditional channels such as phone calls and text messages (Mainetti et al., 2013).

There were seven different electronic systems in use between the seven companies with the other one still using paper based document. These systems appeared to be selected because of administration requirements rather than traceability objectives. In addition, there was no consistent way in which data were shared across the supply chain in the event of an identified issue such as product recall or withdrawal. Any data sharing was based on the request received according to the company representatives, which means time-consuming could potentially be a concern in the event of a food crisis. Coincidentally, Storoy et al. (2013) stated that many food businesses had good electronic traceability systems internally but data exchange between companies within the supply chain was difficult or time-consuming. It was suggested by Storoy et al. (2013) that an international and non-proprietary standard was needed to facilitate electronic information interchange between different companies in the food value chain.

Crops grown at grower premises and products received at wholesaler or retailer inwards goods areas were tracked and checked in by all companies using paper and electronic based systems, while only one wholesaler and one retailer could identify which staff member had physically handled a product.

Internal locations for product temporary storage in chillers or warehouses were predominantly determined by crop physiology needs rather than systematically designated areas. A few companies being interviewed were able to formally track the location of each product within their electronic systems.

Surprisingly, at least one customer from retailer level requires their suppliers to relabel product crates prior to dispatch. The new label after relabelling consists of certain data carried over from previous one and also have new information required specifically by the retailer. For example, product name and grower details from the previous label stayed on and a reference number from the retailer was specifically required and added onto the new label to become the new label during the relabelling process. It was noted that this was the second relabelling since the product left the grower (first relabelling occurs at wholesaler inward goods where products are received from growers). According to discussions with industry stakeholders during interviews, the relabelling process involves in a significant amount of rework and cost, which has the potential to compromise effective external traceability. This appears to be an industry wide issue rather than specific to any one company. According to Kim et al. (2018), an integrated and more transparent traceability system in the food supply chain was able to create more efficiency and reduce relevant costs.

The majority of fresh produce organisations had documented product recall plans, including recall team, procedures and external contact list. However, products could only be tracked back to crate level but not to pallet level or individual product item such as a retail trading unit.

Internal audits and mock recall exercises were conducted by most organisations periodically, but staff training with regards to traceability was only undertaken by one company. This was not entirely satisfactory but there was no compulsory requirements so far since the current regulations and standards in New Zealand only required a ‘one-up, one-down’ traceability system for food businesses (The Parliament of New Zealand, 2018).

Aside from company specific details, three traceability systems were observed which appeared to work in parallel but within the same fresh produce supply chain: grower traceability system, wholesaler traceability system and retailer traceability system. The first traceability system involved in processes and operations at growers' premises. A typical example of this was crate cards or labels which were generally created by growers and attached to products. Product traceability data was generated via grower's system and passed onto wholesaler site on their products. Furthermore, some growers were not labelling each single crate but one or two on a whole pallet in some cases.

However, the traceability data on crate cards or labels from growers were not carried through to wholesalers as wholesalers had their own systems, which was the second traceability system within the same supply chain. The second traceability system was created by wholesalers and facilitated their operations across the wholesaler floor. For instance, fresh produce was labelled at wholesaler inwards goods area when received from growers using their own coding and systems.

In some situations, products were labelled again by wholesalers prior to dispatch as per additional customer specific labelling requirements. Certain information such as reference number required by customers was added onto the new label to facilitate customers' operations and this was the third traceability system used within the same supply chain.

As the three different traceability systems existed within the same supply chain, it has resulted in information fragmentation throughout the value chain as a whole and no standardised traceability information format was used by all industry stakeholders.

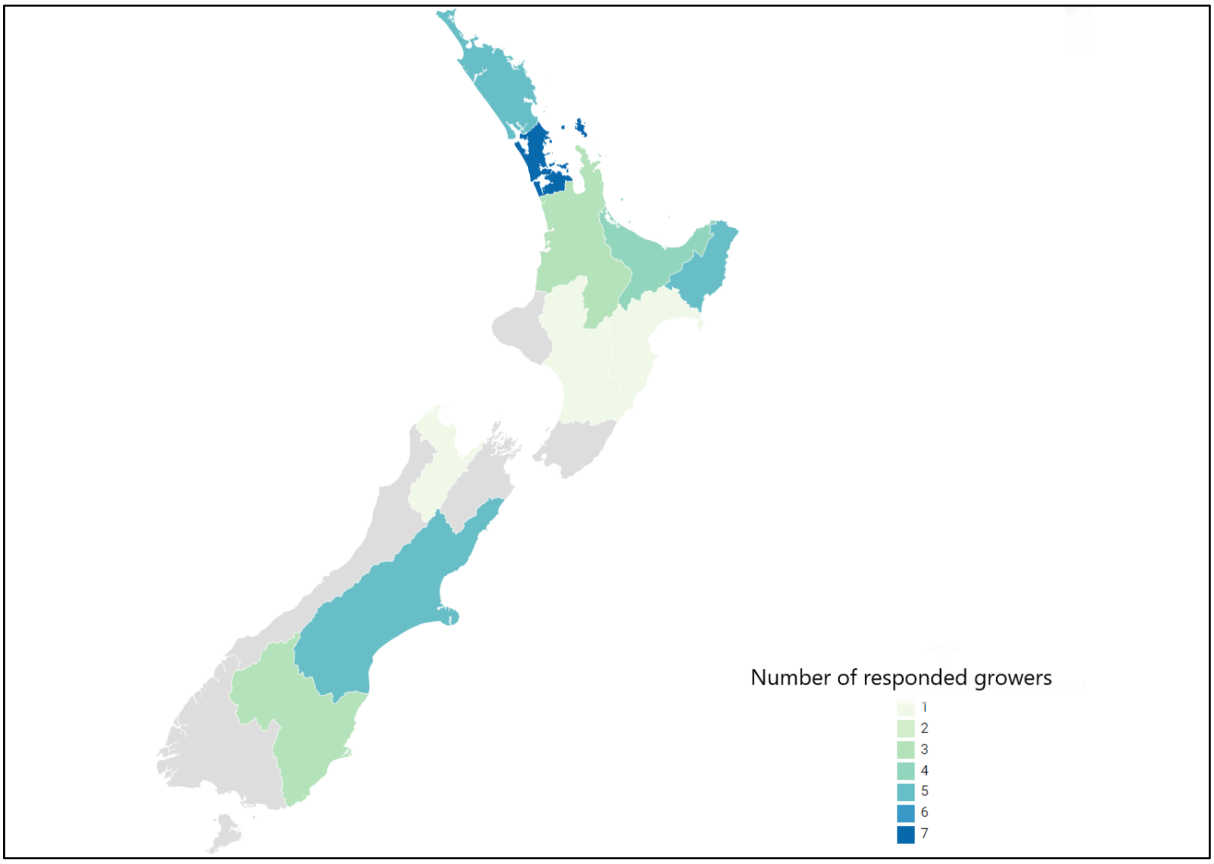
Similarly, Kim et al. (2018) examined traceability systems in the US and pointed out that there were some challenges to achieve efficient food traceability in the agricultural supply chain, including information asymmetry between industry participants and lack of standardisation in data format. Moreover, Gokarn and Kuthambalayan (2019) implied that information asymmetry existed in the fresh produce supply chain where the buyer had difficulty to identify good products while the supplier understood the history and condition of the product.

4.3 Grower survey

4.3.1 Profile analysis of growers

In total, forty out of 578 growers surveyed completed and returned the questionnaire for a response rate of 6.9%. It is common that low response rates are frequently observed in these types of studies (Fouayzi et al., 2006). Furthermore, it was noted that questions were sometimes skipped by respondents during the survey and therefore not all 40 received responses were with fully completed questionnaires. It implied that growers may not appreciate the importance of traceability system in the domestic fresh produce industry in certain extent.

Of the 40 responded growers, only 35 of them indicated their locations as shown in Figure 4.7. There were 26 growers from North Island (7 in Auckland, 5 in Northland, 5 in Gisborne, 4 in Bay of Plenty, 3 in Waikato, 1 in Hawkes Bay and 1 in Manawatu) in New Zealand. The other 9 growers were based in regions of South Island (5 in Canterbury, 3 in Otago and 1 in Tasman/Nelson).



Note: n=35.

Figure 4.7 Choropleth map of responded growers.

Types of crops that respondents mainly grow included categories of berries and other small fruits (n=2), brassica vegetables (n=2), citrus fruits (n=5), fruiting vegetables (n=4), leafy vegetables (n=2), pome fruits (n=2), root and tuber vegetables (n=2), stalk and stem vegetables (n=3), stone fruits (n=2), bulb vegetables (n=1) such as onion, assorted tropical and sub-tropical fruits (n=6) such as tamarillo, kiwifruit, passion fruit and avocado, based on the classification principles of Codex Classification of Foods and Animal Feeds (Food and Agriculture Organization of The United Nations World Health Organization, 2006). The other responded growers (n=9) only indicated that their main crops were vegetables or fresh fruit, but did not specify the crop type.

Some respondents (n=7) did not indicate that they were a GS1 member or not. Of the other responded growers (n=33), nearly half (48.5%; n=16) were GS1 members while the other half (51.5%; n=17) are not.

Investment in product labelling and traceability system was considered as extra burden by food businesses because additional costs were required and it may cause financial issues in some companies (Bosona & Gebresenbet, 2013). The estimated costs of responded growers on product labelling each year including labelling, printing, artwork and machinery were provided in Table 4.2. The estimated costs may be related to different sizes of growers. For example, bigger growers may spend higher costs on product labelling each year compared to smaller growers. However, as the size of responded growers was not determined during the survey, this assumption could not be confirmed.

Table 4.2 Estimated (%) costs of growers on product labelling each year.

	n	**%**
Estimated costs on product labelling each year		
< $1,000	13	33.3
$1,000 - $5,000	3	7.7
$5,000 - $10,000	6	15.4
> $10,000	17	43.6
Total	39[a]	100

[a] One respondent skipped and did not respond to this question therefore the total number is 39.

4.3.2 Perception of growers on traceability

Among the 40 responses received from the survey, the majority of fresh produce growers (92.1%) thinks that traceability is important, with only a few (7.9%) considers it is less important or not important (Figure 4.8). It indicates that these growers in New Zealand recognise the importance of traceability to a high level. These findings are similar to the results of a study conducted by Mattevi & Jones (2016) that found 95% of the UK companies in the food industry regarded traceability as important, however, there is space for improvement and grower education in terms of fresh produce traceability.

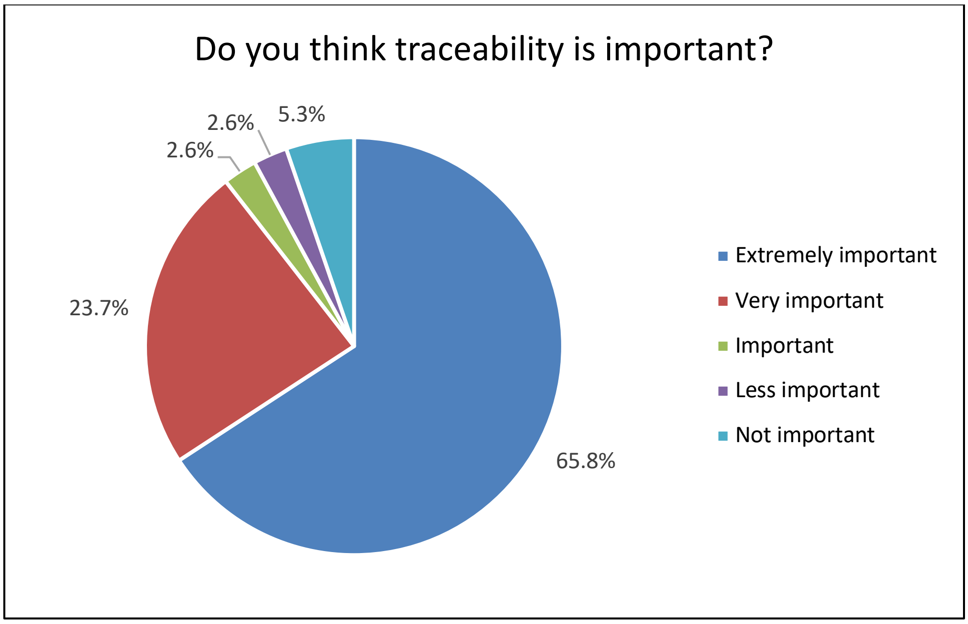


Figure 4.8 Perceptions (%) of importance on traceability from fresh produce growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

Most of respondents (>80%) believe that traceability along supply chains matter with two main reasons: it can help with product recalls when there are problems (82.5%) and also for food safety purposes (80.0%) (Figure 4.9). Less common reasons are to meet customer requirements (62.5%) and for record keeping purposes (37.5%). A minority (17.5%) think that traceability matters so they can get paid for their products. Similarly, Mattevi and Jones (2016) found that 75% respondents believed that traceability system could help with product recalls and also in the safety of products when they investigated attitudes and awareness of food companies towards traceability in the UK.

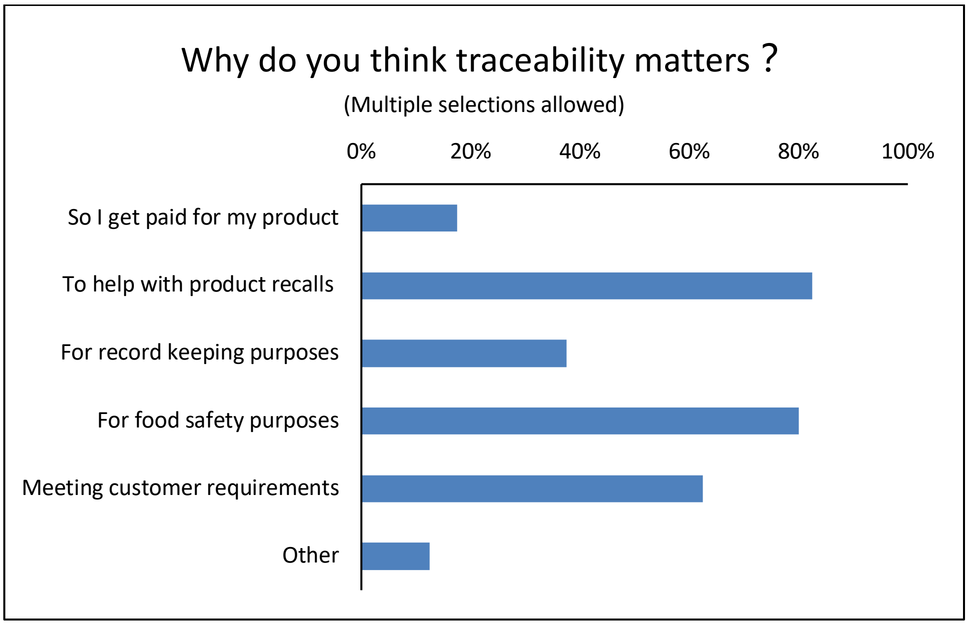


Figure 4.9 Reasons of perception (%) on traceability importance from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

The majority of growers record traceability data such as batch number and harvest date primarily due to customer requirements (59.0%) (Figure 4.10). In addition, many respondents consider that it is important to record traceability data because of legislative requirements (38.5%) and also for stock management purposes (48.7%). However, a few says they do not record any traceability data (10.3%).

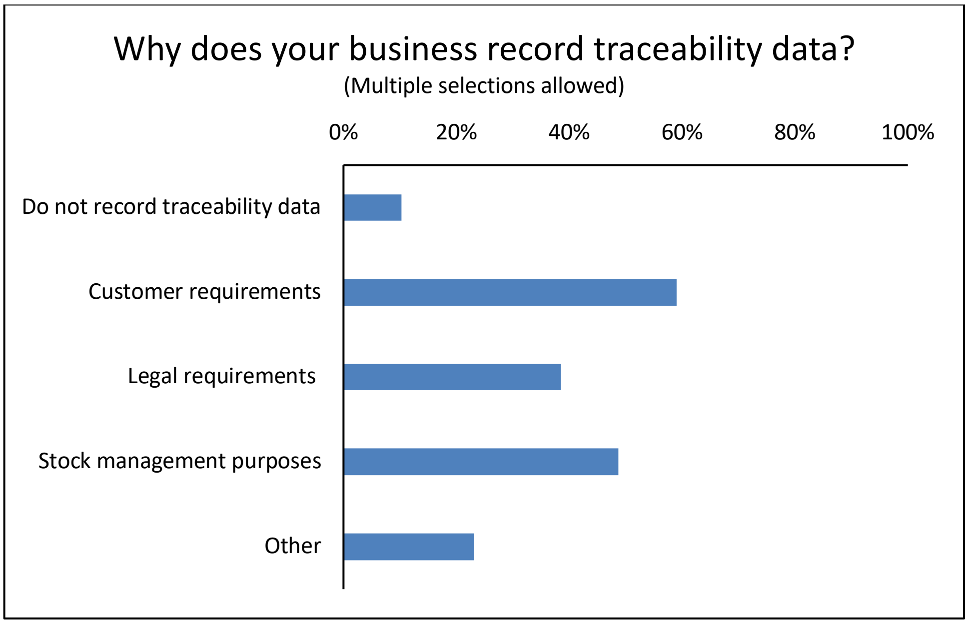


Figure 4.10 Reasons (%) of traceability recording from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

4.3.3 Current practices in relation to traceability

Over half of respondents (70.0%) use their own cards or labels on the outer crates or boxes of products leaving their businesses, while some growers (32.5%) use customer specified labels for product labelling (Figure 4.11). Based on the percentages, some growers may label their products in multiple ways depending on the customer requirements. For example, products could be labelled with a mix of their own labels/crate cards and customer defined labels. A minority (7.5%) handwrite product traceability information on the outer boxes or crates of products. However, 5.0% of respondents do not label their products.

Apart from that, 22.5% of respondents in the 'other' category specified that either product labels were provided by packhouses, or a combination of handwrite and machine print labels were used for their products.

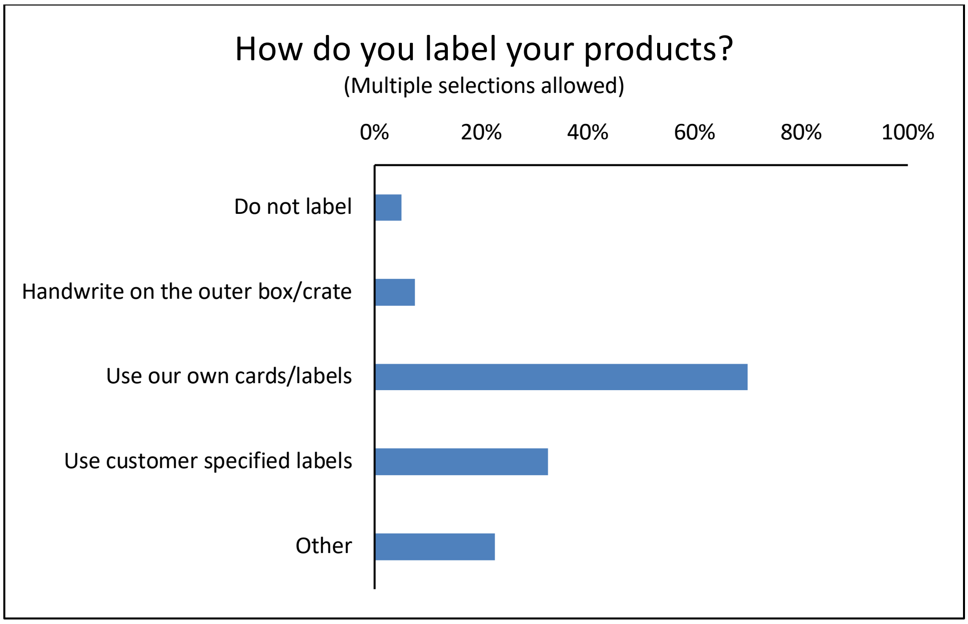


Figure 4.11 Differences (%) in method of product labelling from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

Product label details are predominantly defined and required by their customers such as wholesaler (52.5%) and retailer (50.0%) (Figure 4.12). Only a few (17.5%) use GS1 standards for product labelling. Moreover, there are approximately one third respondents (32.5%) who use an internally designed label for their products.

Among the responded growers who indicated that product traceability details on box or crate labels were determined by wholesaler requirements, most indicated that traceability data was recorded by their businesses due to customer requirements compared to other reasons. These differences were significant (X^2=4.812, df=1, $p<0.05$).

For respondents who considered that product traceability details on box or crate labels were determined by retailer requirements, the majority of them indicated that traceability data recording was important to businesses for stock management purposes compared to other reasons. These differences were significant (X^2=14.436, df=1, $p<0.001$). The outputs of statistical analysis results are shown in Appendix 9.4.

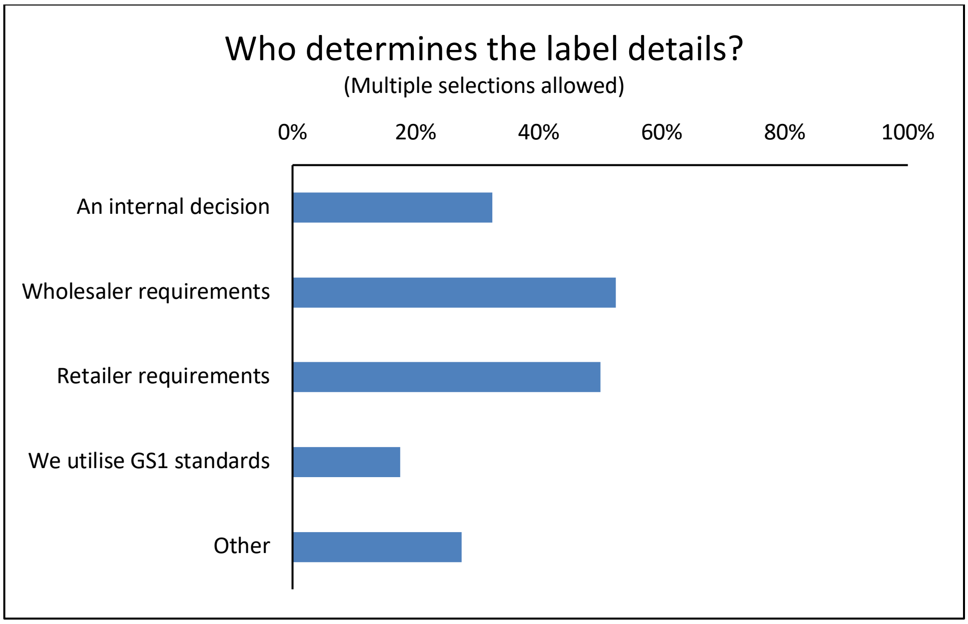


Figure 4.12 Different drivers on product label determination.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

The majority of respondents supply fresh produce via wholesale markets (85.0%), with other customers being supermarkets (50.0%) and independent retailers (32.5%) (Figure 4.13). Based on the percentages, some growers may distribute their products through multiple channels along the fresh produce value chain. A minority sell products via farmers markets (10.0%), their own stores (7.5%), online sales (5.0%) or other channels (22.5%). In particular, other channels include sending products to packhouses, brokers, exporters, food processors, and food services.

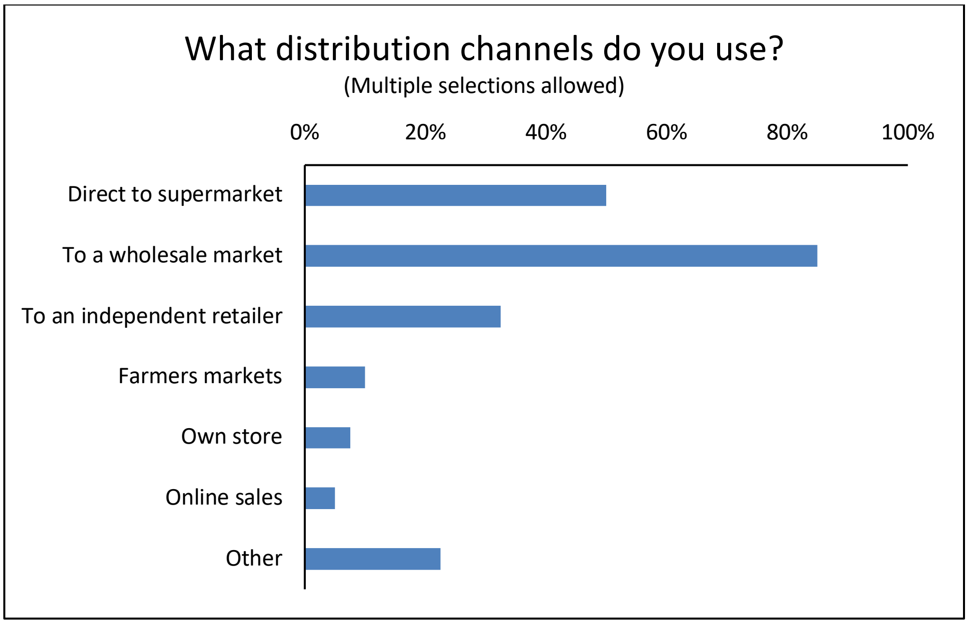


Figure 4.13 Distribution channels of domestic fresh produce.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

Figure 4.14 shows that 64.1% of growers responded in this survey sell their fresh fruit and vegetables in both loose and pre-packed formats. In addition, less growers supply their fresh produce as pre-packed items only (20.5%) or loose products only (15.4%).

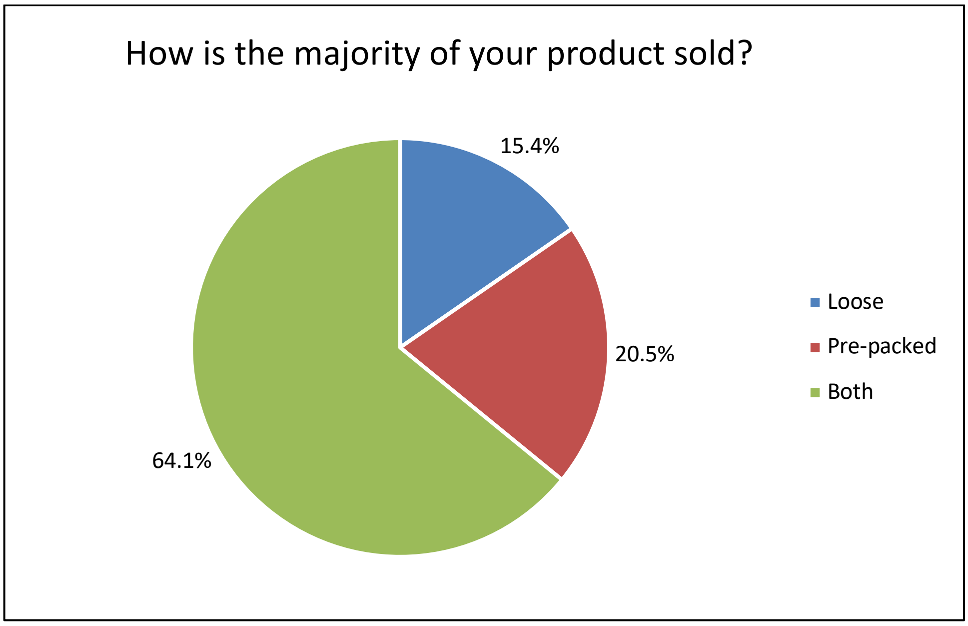


Figure 4.14 Product packaging format at selling point from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

For fresh produce that is pre-packed, the majority of them are packed by growers in their own packhouses (63.2%) (Figure 4.15). A small amount of fresh fruit and vegetables are either sent to a third party packhouse for packing (10.5%) or packed by their customers (2.6%). Another small percentage of growers (7.9%) considers this question is not applicable to them because their products are sold as loose items. It is worth mentioning that a few responded growers (15.8%) consider themselves into 'other' category and specify that their pre-packed products are packed by means of all above: in own packhouse, to a third party packhouse, by customers, or sold loose.

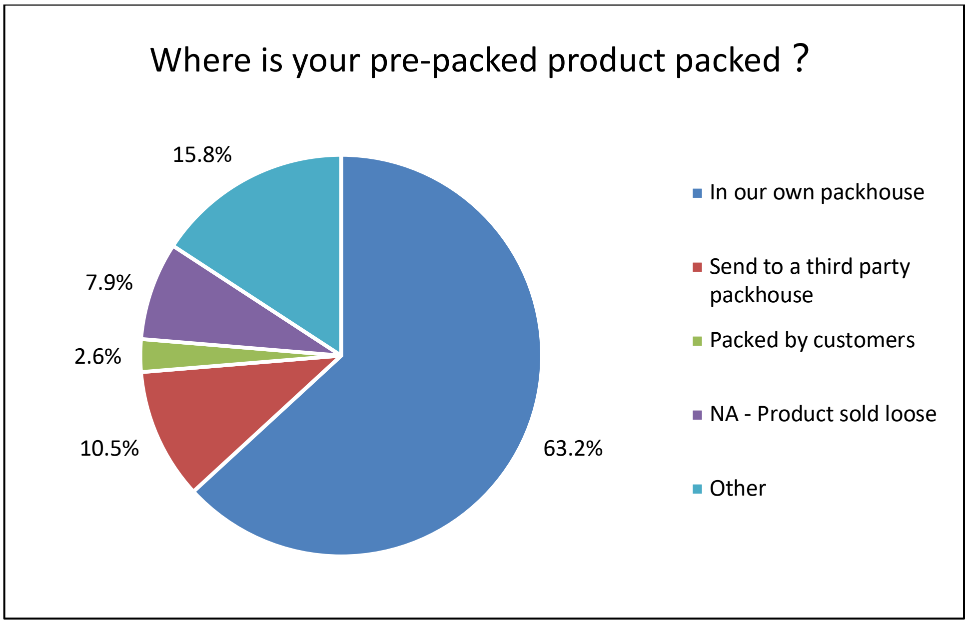


Figure 4.15 Premises of packing for pre-packed products.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

For pre-packed products, growers are labelling some of their products with a barcode provided by customers (50.0%) and others are using a GS1 barcode owned by themselves (50.0%) (Figure 4.16). However, it is illustrated that 17.5% of respondents says they use GS1 standards for product labelling in a previous question (Figure 4.12), which suggests that there may be some confusion over GS1 barcodes. In addition, 83.3% of respondents consider this question is not applicable to them because their products are sold in loose format. However, it is noted that only 7.9% of growers indicate that their products are sold in loose format according to Figure 4.15, which implies there may be some confusion in terms of loosely sold products from growers.

Over half of the respondents (61.1%) have a pack date on their product labels. According to the percentages, some produce growers may have both a barcode and a pack date on their product outer packaging.

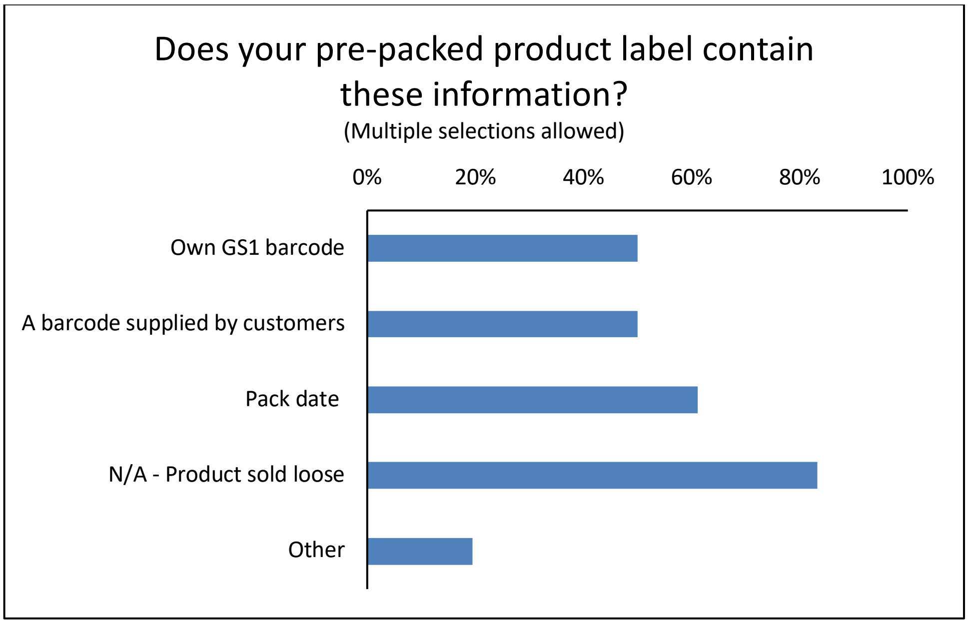


Figure 4.16 Traceability information on pre-packed products.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

The biggest reason for growers to use their product labelling systems is due to client requirements (48.7%) (Figure 4.17). The other main reasons are because it is simple (38.5%), cost effective (38.5%) and to meet logistics requirements (41.0%). Some growers believe that the technology they currently use for their product labelling can streamline their systems (33.3%). A minority thinks it saves time (15.4%) or they have always done it in this way (18.0%).

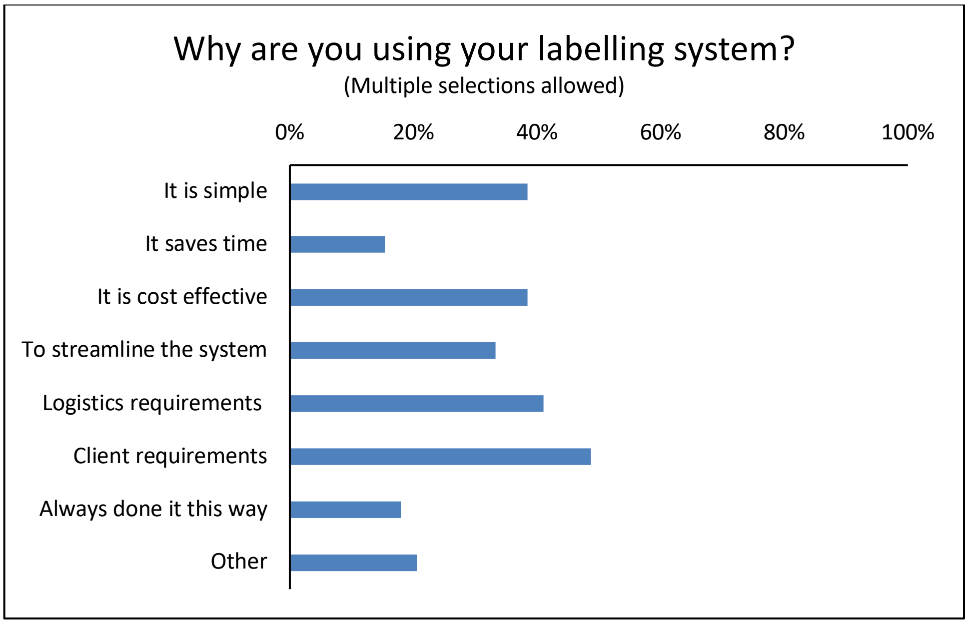


Figure 4.17 Reasons of using labelling system from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

It is approximately a fifty-fifty split between respondents who print their own labels on site (51.3%) and those who do not print (48.7%) (Figure 4.18). For growers who do not print their own labels on site, it is explained that they either use pre-printed labels or products are sold loosely without packaging or labels on.

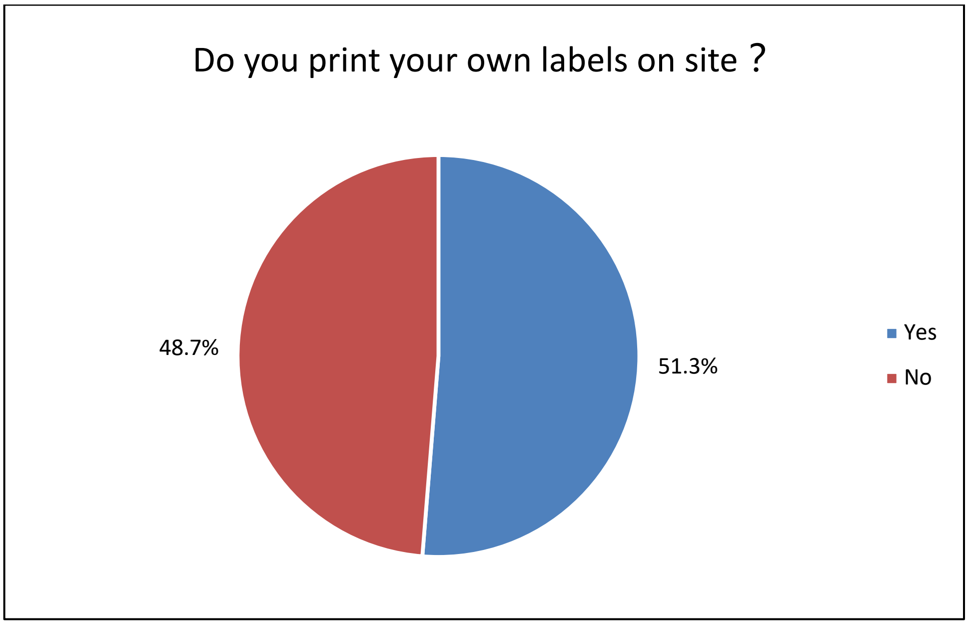


Figure 4.18 Product labels printing from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

The majority of respondents advise their wholesaler or distributor of product delivery by paper delivery docket attached to the product (70.0%), with other growers advise product dispatch through electronic portal (45.0%), phone calls/text messages (37.5%), and emails (30.0%) (Figure 4.19). However, a few growers do not notify their wholesaler or distributor of product delivery (12.5%). There are 2.5% respondents indicating that they do not know the process they use for advising product dispatch.

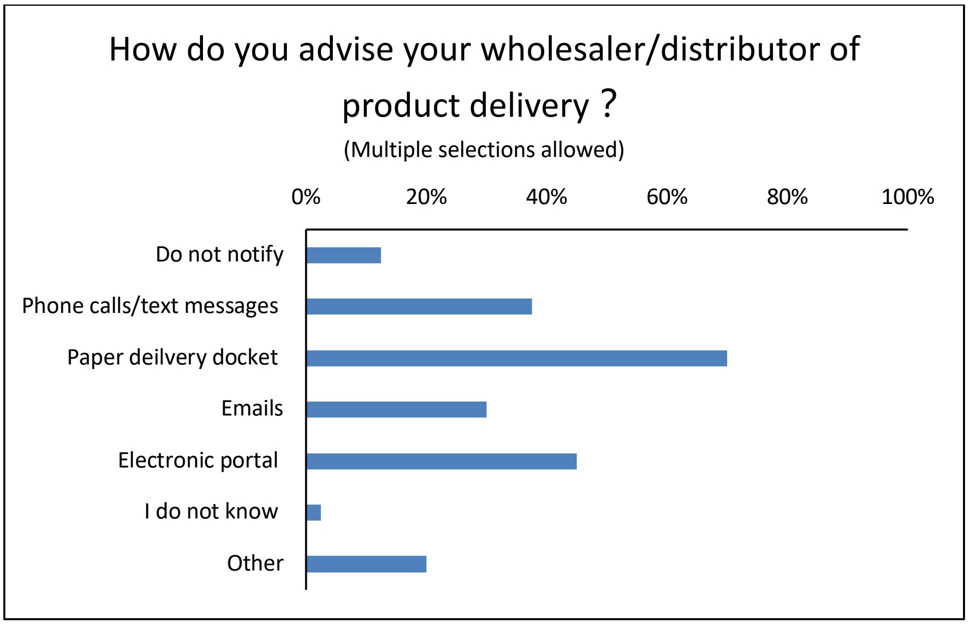


Figure 4.19 Notification methods on product delivery to wholesaler or distributor from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

Most of respondents (80.0%) either have conducted mock recalls only or have never been involved in a product recall before, indicating that they may not have sufficient experience on performing a product withdrawal or recall in the event of a food crisis (Figure 4.20). Only a few growers have ever been involved in a genuine product recall caused by microbial contamination (10.0%). It could also be explained that recall events within the responded growers have historically been low in the past (Mattevi & Jones, 2016). A minority (2.5%) have been involved in a product recall due to chemical or residue issues. The remaining (7.5%) answered this question of 'other' category, with some specified that a genuine produce recall was conducted due to incorrect labelling and others explained that the fresh produce industry has carried out product recalls previously even though they did not experience it. However, the latter answer and explanation implied that the respondents seemed to show a lack of understanding on the question or there was a misunderstanding to complete it.

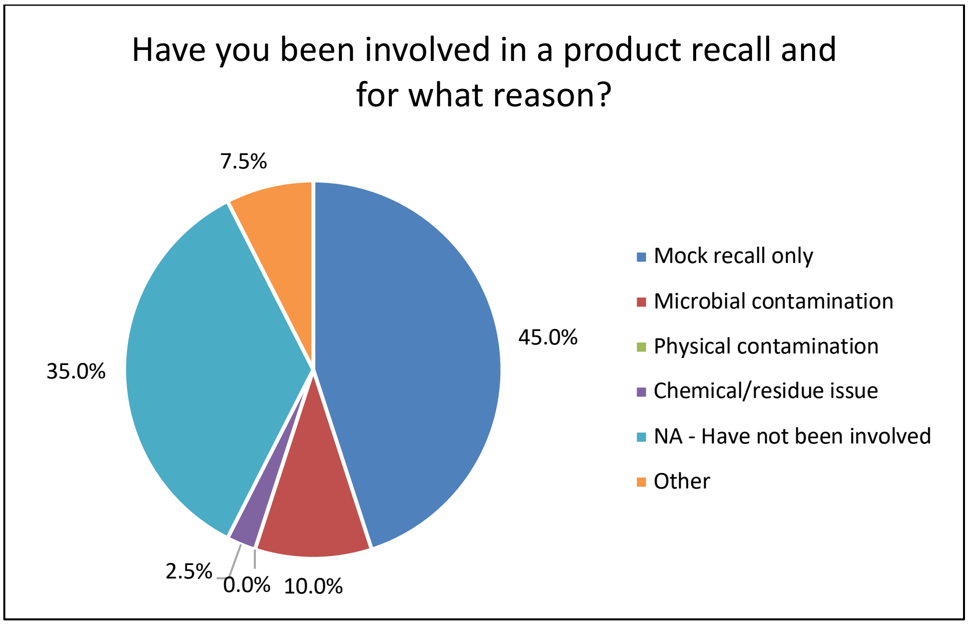


Figure 4.20 Involvement in product recall from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

There are 50.0% growers responded that they have never been involved in a product recall and the others (50.0%) have an opposite situation (Figure 4.21). However, this result is slightly different from the previous answer when growers are asked if they have been involved in a product recall, indicating that there may be some misunderstanding between mock recall and product recall. Of those who have been involved in either a real or mock recall, time to identify where the product went in the supply chain was split evenly between minutes and hours.

Speed is considered as a critical element in the event of a product recall to minimise the number of people affected by a food illness outbreak (Fresh Produce Safety Centre Australia & New Zealand, 2019). For the 50.0% respondents who have been involved in a product recall, approximately half of them (27.8%) consider that it takes minutes to trace their product while the other half (22.2%) think it takes hours to identify where the product went in the supply chain. Noticeably, the effectiveness of a traceability system was partially determined by the speed of data capturing, recording and retrieval (Olivier et al., 2006).

Interestingly, for the responded growers who supply fresh produce to wholesale markets compared to other distribution channels, it only takes minutes or hours to identify where the product went in the supply chain when an issue is identified. These differences were significant ($X^2=6.413$, df=2, $p<0.05$).

However, for the respondents who supply fresh produce to independent retailers, more growers take hours than minutes to identify where the product went in the supply chain when an issue is identified compared to other distribution channels. These differences were significant ($X^2=9.342$, df=2, $p<0.05$). The outputs of statistical analysis results are shown in Appendix 9.4.

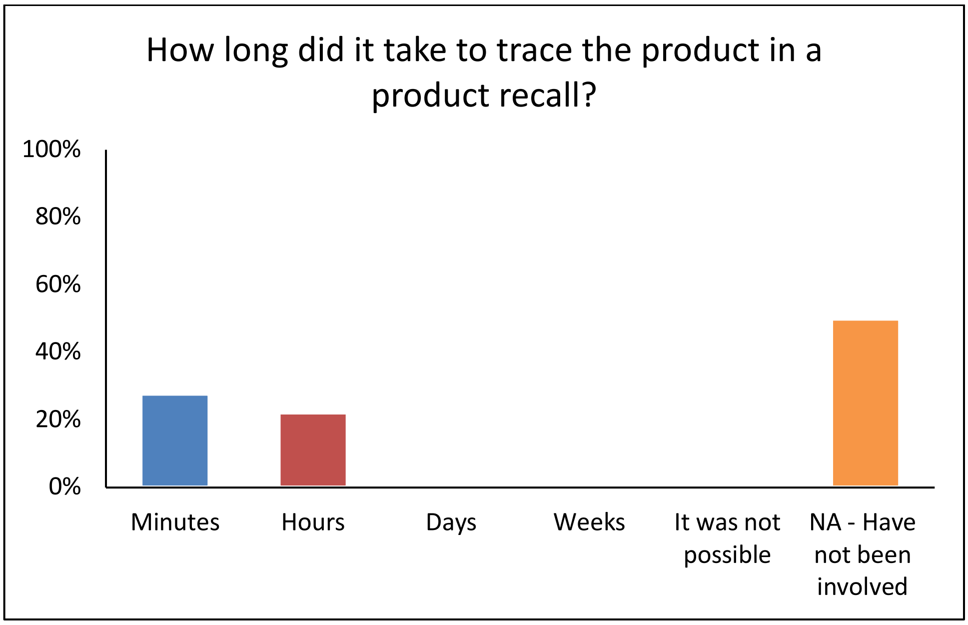


Figure 4.21 Time spent on tracing fresh produce in product recall from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

Most of growers believe it is very easy or easy to contact the relevant supply chain partners in the worst-case product recall scenario (88.2%), with only a few consider it is difficult (11.8%) (Figure 4.22). This results show that the majority of growers believe they have a reliable system and traceability plan including communication with trading partners in a timely manner to address unexpected events such as product recall.

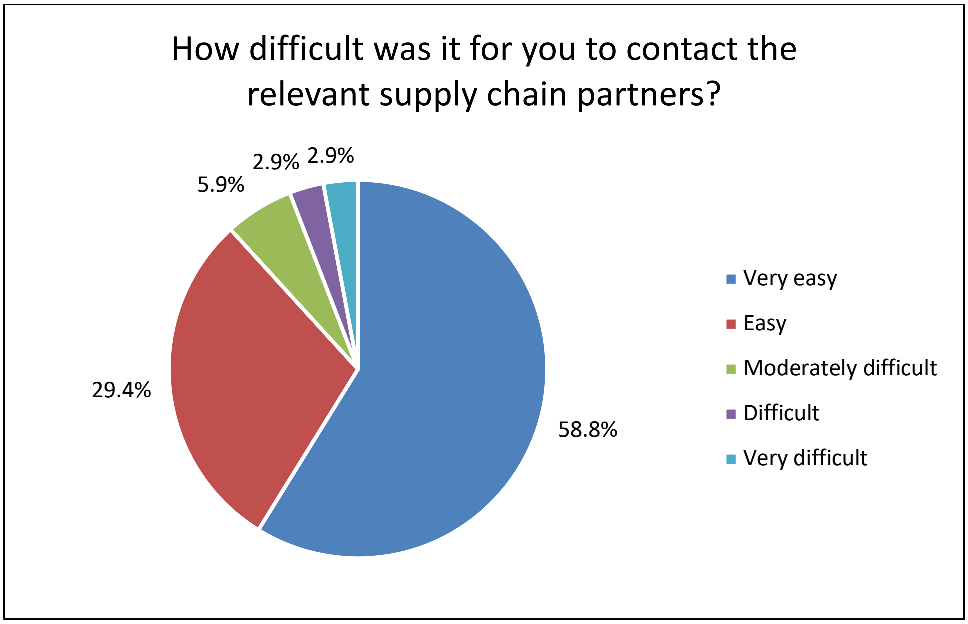


Figure 4.22 Extent of difficulty of contacting supply chain partners from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

The majority of businesses have an internal recall plan in place (84.6%) but 10.3% of respondents do not have it (Figure 4.23). A recall plan requires product traceability information to be maintained and relevant records to be kept on file, suggesting that the 10.3% of growers without a recall plan do not record product traceability data. This finding is consistent with the result of 10.3% respondents do not record any traceability data as shown in Figure 4.10. Of those that don't have a product recall plan, none have been involved in a recall scenario.

Product Recall New Zealand (Product Recall NZ) is an automatic and web-based system for communicating product recall and withdrawal information with business trading partners and customers in a timely manner (GS1 New Zealand, 2019). Product Recall NZ enables effective and efficient communication of product recall information between businesses in the event of a food crisis (GS1 New Zealand, 2019). Noticeably, some growers are registered with Product Recall NZ (15.4%).

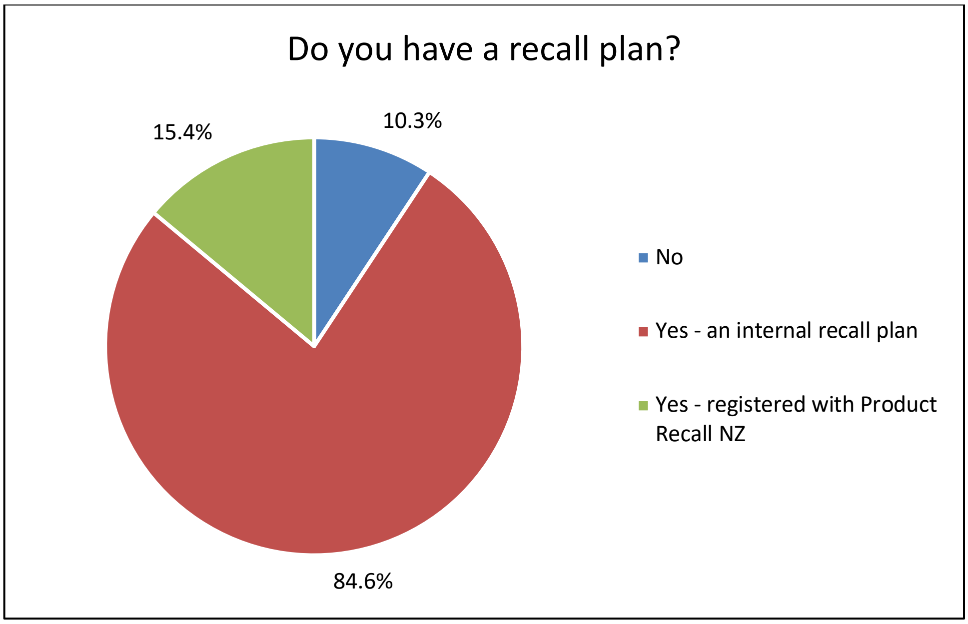


Figure 4.23 Product recall plans development from growers.

Note: n=40.
(The percentages indicated are the percentage of received responses on each category of answer.)

There could be various challenges when a product recall is carried out by growers. Difficulties encountered with product recalls from growers includes incompatible technology (9.4%), incorrect or out of date contact details (9.4%), insufficient product records (18.8%), language barriers (6.25%) such as communicating with seasonal workers from overseas, and dependency on others in the supply chain (Figure 4.24). The majority of respondents (71.9%) choose to answer 'other' and most of them further specify that there is no challenge during a product recall as it goes smoothly in their companies.

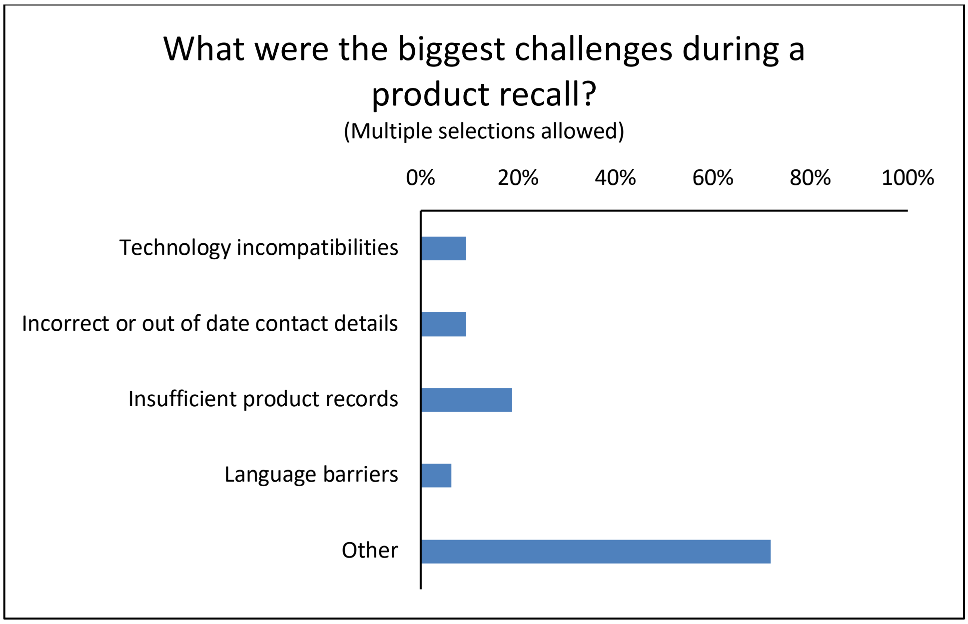


Figure 4.24 Challenges in a product recall from growers.

Note: n=40.
(The percentages indicated are the percentage of respondents that agree with this statement.)

4.3.4 Summary of the grower survey

In summary, the majority of responded growers believe traceability is important to assist with product recall, food safety, meeting customer requirements and stock management. Some respondents think traceability is required for record keeping or regulatory purposes. Most growers use some form of label on their fresh produce products while a few do not label at all. Some companies design and determine their own product labels with a few businesses have labels designed by their customers.

There are various distribution channels in terms of fresh produce supply. Most growers sell their products to wholesaler markets and some directly to supermarkets or independent retailers. Only a few supply their products to farmers markets, own stalls or via online sales. More fresh produce is sold in pre-packed format than loose items. More than half of growers use barcodes on product labels and these are either owned by themselves or provided by the client.

Most of respondents have product recall plans and procedures. The time and ease to carry out product recalls is generally acceptable to the grower. Challenges faced cover technology incompatibility, record completeness and language barriers.

4.4 Pilot study

The one pallet of strawberries at grower/packhouse A contained 25 crates with 24 punnets in each crate and therefore was composed of 600 punnets in total. The other pallet of strawberries at grower/packhouse B also included 600 punnets in total but it carried 20 crates with 30 punnets in each crate. All strawberry punnets (n = 1,200), crates (n = 45) and pallets (n = 2) were uniquely identified using GS1 barcode and most of them were successfully tracked from the packhouse through the fresh produce supply chain to the simulated consumer in this pilot using GEM software monitoring system (Table 4.3).

Table 4.3 Details of strawberry punnets tracked along the supply chain present in this pilot study.

Details of strawberry punnets tracked from grower/packhouse A			Details of strawberry punnets tracked from grower/packhouse B		
Location	**No. of punnet**	**Percentage of punnet**	**Location**	**No. of punnet**	**Percentage of punnet**
Grower/packhouse A	600	100%	Grower/packhouse B	600	100%
Retail distribution centre	600	100% [a]	Wholesaler	600	100%
Retail store A1	360	100%	Independent store B1	150	100%
Retail store A2	168	100%	Independent store B2	150	100%
Simulated POS at retail store A1	2	0.56% [b]	Independent store B3	300	100%
Simulated POS at retail store A2	2	1.19% [b]	Simulated POS at independent store B1	2	1.33% [b]
			Simulated POS at independent store B2	2	1.33% [b]
			Simulated POS at independent store B3	2	0.67% [b]

[a] 100% strawberry punnets were tracked at retail distribution centre. However, 72 punnets (12%) were not tracked further due to time constraint as they were retained at retail distribution centre and not picked immediately for delivery to retail stores. Strawberries at retail stores A1 and A2 were not affected by this and still tracked as 100%.

[b] Only 2 strawberry punnets were purchased at POS from each retail store or independent store to simulate consumer purchasing process. Therefore, the percentages of punnets tracked at POS appeared to be low.

The date, time, location, and transport truck details of strawberries at each stage of the pilot was captured and stored in the monitoring system and available at all times. The scanning point at process step 7 (Pallets Depart from DC/Wholesaler) of tracking strawberries from grower/packhouse A was a simulation process due to time constraint. Therefore the truck license plate information was missing during the simulated scanning process at step 7 and it was replaced with a simulated truck license plate AAA222.

As GS1 barcodes were applied in this pilot and a unique identification code was given to each strawberry punnet, crate and pallet, it was feasible to track every strawberry punnet rather than to crate level only. In the event of a food recall, a real-time tracking could potentially be conducted with the GEM monitoring system. It was concluded that each single punnet of strawberries could be clearly identified and tracked throughout the supply chain using the GS1 barcodes and GEM software system to achieve full traceability. Similarly, Souza-Monteiro and Caswell (2010) investigated the economic implications of a voluntary traceability system in food supply chains in the UK and concluded that full traceability was feasible when there were net benefits to a downstream company that required traceability.

The strawberry punnet with its unique identification code GTIN 00000940.00611.0502 was taken as an example to show vertical product traceability through the supply chain in the pilot using GEM software system designed and provided by GS1. When product traceability data was required for the strawberry punnet (GTIN 00000940.00611.0502), all information related to the punnet with GTIN 00000940.00611.0502 was extracted from the GEM software system and illustrated as below in Table 4.4.

Table 4.4 Product traceability information extracted from GEM software system for strawberry punnet GTIN 00000940.00611.0502.

Date	Time	Location	Product Status Description	Scanning Point
16/10/2018	10:03:31	Packhouse A	Strawberry punnet (GTIN 00000940.00611.0502) was packed into crate (GTIN 942101221.0999.0020)	1
16/10/2018	10:36:23	Packhouse A	Crate (GTIN 942101221.0999.0020) was loaded onto pallet (SSCC 942101221.30000000)	2
17/10/2018	11:16:23	Packhouse A dispatch area	Pallet (SSCC 942101221.30000000) was loaded into truck (license plate CRR680)	3
17/10/2018	13:51:22	DC inwards goods area	Truck (license plate CRR680) arrived and products received	4
17/10/2018	14:38:42	DC	Pallet (SSCC 942101221.30000000) was depalletised and crate (GTIN 942101221.0999.0020) was removed from this pallet	5
17/10/2018	15:00:46	DC	Crate (GTIN 942101221.0999.0020) was loaded onto new pallet (SSCC 94130000.300000006)	6
17/10/2018	20:15:26	DC dispatch area	New pallet (SSCC 94130000.300000006) was loaded onto truck (license plate AAA222)	7
18/10/2018	12:46:34	Retail store	Truck (license plate AAA222) containing new pallet (SSCC 94130000.300000006) arrived and products received	8
18/10/2018	12:47:42	Retail shop floor	New pallet (SSCC 94130000.300000006) was depalletised and crate (GTIN 942101221.0999.0020) was moved onto shop floor	9
18/10/2018	12:48:27	Retail outlet	Strawberry punnet (GTIN 00000940.00611.0502) was sold at retail outlet	10

The strawberry pallet (SSCC 942101221.30000000) from packhouse A was taken as another example to horizontally demonstrate fresh produce traceability system used in this pilot. In the event of a food recall, product traceability details are urgently required for the entire pallet of strawberries from packhouse A, provided that the whole pallet of strawberries have been delivered to DC and the pallet has been depalletised on-site within the DC facility. A timeline of product movement and relevant traceability information was extracted and expressed in Table 4.5.

Table 4.5 A timeline of product movement and relevant traceability details extracted from GEM software system for strawberry pallet SSCC 942101221.30000000.

Date	Time	Location	Product Status Description	Crate/Pallet Details
16/10 /2018	10:36:23	Packhouse A	There were 25 crates loaded onto pallet (SSCC 942101221.30000 000).	Crate GTIN list: 942101221.0999.0024, 942101221.0999.0022, 942101221.0999.0019, 942101221.0999.0000, 942101221.0999.0011, 942101221.0999.0004, 942101221.0999.0003, 942101221.0999.0002, 942101221.0999.0013, 942101221.0999.0018, 942101221.0999.0023, 942101221.0999.0017, 942101221.0999.0014, 942101221.0999.0008, 942101221.0999.0005, 942101221.0999.0021, 942101221.0999.0016, 942101221.0999.0001, 942101221.0999.0009, 942101221.0999.0006, 942101221.0999.0007, 942101221.0999.0010, 942101221.0999.0012, 942101221.0999.0015, 942101221.0999.0020.
17/10 /2018	14:27:54	DC	There were 15 crates removed from this pallet (SSCC 942101221.30000 000).	Crate GTIN list: 942101221.0999.0013, 942101221.0999.0018, 942101221.0999.0002, 942101221.0999.0009, 942101221.0999.0011, 942101221.0999.0019, 942101221.0999.0000, 942101221.0999.0010, 942101221.0999.0014, 942101221.0999.0017, 942101221.0999.0008, 942101221.0999.0016, 942101221.0999.0001, 942101221.0999.0015, 942101221.0999.0012.
17/10 /2018	14:32:52	DC	These 15 crates were loaded onto new pallet (SSCC 94130000.300000 005)	
17/10 /2018	14:38:42	DC	There were 7 crates removed from this pallet (SSCC 942101221.30000 000).	Crate GTIN list: 942101221.0999.0021, 942101221.0999.0020, 942101221.0999.0024, 942101221.0999.0023, 942101221.0999.0022, 942101221.0999.0003, 942101221.0999.0006.
17/10 /2018	15:00:46	DC	These 7 crates were loaded onto new pallet (SSCC 94130000.300000 006)	
17/10 /2018	20:15:26	DC dispatch area	New pallets were loaded onto truck (license plate AAA222)	Pallet SSCC list: SSCC:94130000.300000005, SSCC:94130000.300000006.
18/10 /2018	12:41:52	Retail store A1	The pallet was received.	Pallet SSCC list: (SSCC 94130000.300000005).
18/10 /2018	12:46:34	Retail store A2	The pallet was received.	Pallet SSCC list: (SSCC 94130000.300000006).

As all relevant traceability data was clearly shown in GEM software monitoring system, a real-time product tracking could easily be conducted even when the pallet of strawberries left packhouse A and was depalletised in DC. In the event of a food recall, all strawberries from pallet (SSCC 942101221.30000000) after depalletising in DC were tracked and shown in Table 4.6 as below.

Table 4.6 Strawberry traceability details extracted from GEM software system for pallet SSCC 942101221.30000000 after the pallet left packhouse A and was depalletised in DC.

Date	Time	Product Location	Product Quantity	Crate/Pallet Details
18/10/ 2018	12:46:34	Retail store A1	Pallet (SSCC 94130000.300000005) containing 15 crates.	Crate GTIN list: 942101221.0999.0013, 942101221.0999.0018, 942101221.0999.0002, 942101221.0999.0009, 942101221.0999.0011, 942101221.0999.0019, 942101221.0999.0000, 942101221.0999.0010, 942101221.0999.0014, 942101221.0999.0017, 942101221.0999.0008, 942101221.0999.0016, 942101221.0999.0001, 942101221.0999.0015, 942101221.0999.0012.
		Retail store A2	Pallet (SSCC 94130000.300000006) containing 7 crates.	Crate GTIN list: 942101221.0999.0021, 942101221.0999.0020, 942101221.0999.0024, 942101221.0999.0023, 942101221.0999.0022, 942101221.0999.0003, 942101221.0999.0006.
		DC	Pallet (SSCC 942101221.30000000) containing 3 crates.	Crate GTIN list: 942101221.0999.0004, 942101221.0999.0005, 942101221.0999.0007.

Furthermore, specific strawberry punnets could be clearly targeted in the event of a food recall and details of these strawberry punnets could be provided from the GEM traceability system. For example, there were 24 punnets in total on crate (GTIN 942101221.0999.0013) from Pallet (SSCC 94130000.300000005) at retail store A1 and details of these strawberry punnets were shown in Table 4.7.

Table 4.7 Strawberry punnets details extracted from GEM software system for crate (GTIN 942101221.0999.0013) at retail store A1.

Product Location	Punnet Details for Crate (GTIN 942101221.0999.0013)
Retail store A1	Punnet GTIN list: 00000940.00611.0332, 00000940.00611.0337, 00000940.00611.0329, 00000940.00611.0330, 00000940.00611.0333, 00000940.00611.0339, 00000940.00611.0340, 00000940.00611.0323, 00000940.00611.0338, 00000940.00611.0336, 00000940.00611.0335, 00000940.00611.0341, 00000940.00611.0331, 00000940.00611.0334, 00000940.00611.0322, 00000940.00611.0041, 00000940.00611.0036, 00000940.00611.0044, 00000940.00611.0033, 00000940.00611.0034, 00000940.00611.0035, 00000940.00611.0000, 00000940.00611.0001, 00000940.00611.0003.

As all product traceability information was stored in a software system in this pilot throughout the supply chain, real-time tracking was potentially achieved and therefore reduced the time and cost of seeking fragmented product traceability information from different companies. In addition, there was no further relabeling process involved in the pilot study from the grower or packhouse to the retailer once the labels were initially attached to strawberry punnets, crates and pallets, thereby simplifying the entire procedures within the strawberry value chains.

On the other hand, there were some challenges encountered in the strawberry pilot which were related to data collection devices or were market-specific (Table 4.8).

Table 4.8 Summary of the challenges encountered in the strawberry pilot study.

Challenge type	Challenge details
Device and data system	Some crate labels did not work well (not sticky enough) in chillers; Battery problems for laptops working in low temperature (10°C) chillers; Connection problems for scanners to laptops in low temperature (10°C) chillers.
Market-specific	Some fresh produce companies started very early with possibilities of missing out on piloted strawberries and relevant truck details.

5.0 General Discussion

Lack of standardisation in data format and information asymmetry between industry participants were found to be barriers in terms of the implementation of tracking and tracing systems in the fresh produce industry in New Zealand. Similar findings were presented in previous studies from other countries (Kim et al., 2018; Gokarn & Kuthambalayan, 2019).

In addition, it was identified that one of the obstacles to achieve effective industry-wide traceability was data fragmentation and traceability information loss during transmission between different companies. Dabbene et al. (2014) stated that a traceability system should be implemented at the entire supply chain level rather than a single business to ensure its effectiveness. In addition, this implementation should go beyond the basic requirement of "one-up, one-down' traceability where each industry player within the supply chain only handles the data coming from the supplier and those sent to the customer (Dabbene et al., 2014). As industry participants solely focused on their own or internal needs without appreciating the importance of an industry-wide traceability system in the fresh produce supply chain, it seemed that it was not sufficient and more work was needed in this area to improve current systems in New Zealand.

A more network-oriented approach and common data infrastructure are needed to ensure that external traceability can feasibly work. A general approach based on a distributed collaborative data system was also proposed by Bello et al (2005) and therefore all food businesses involved could potentially exchange traceability information between the others via a network in Italy.

An effective and efficient external traceability system throughout the fresh produce value chain in New Zealand could be achieved by industry-wide cooperation from growers, packers, transporters and receivers/buyers. An organised and structured way is required to business management and commitment from company owners to address the implementation challenges. Similarly, Olivier et al. (2006) studied traceability systems in the fruit export industry in South Africa in the early 21st century and highlighted that a high level of supply chain cooperation was required to achieve effective traceability.

In order to establish a robust traceability system in the fresh produce supply chain in New Zealand, some elements became important and essential. Firstly, unique identification generated for each company, each product and each location within a system became the foundation of traceability. For example, product traceability information generated from growers since seeding or planting became unique identification for each product. All other data were added onto the grower primary information along the supply chain from packers, transporters and receivers.

It was important to achieve information sharing within the supply chain. An electronic traceability software system could be used by all supply chain players to facilitate data transmission and sharing. Dabbene et al. (2014) reported that the precision and reliability of data collection enhanced the implementation of tracking and tracing systems. A standardised and agreed format used for product traceability information was required by all supply chain players. Olivier et al. (2006) also explained that a standardised data format for traceability system would benefit the supply chain participants, including increased productivity, reduced company costs and better customer satisfaction for food businesses of all sizes.

6.0 Conclusion

In summary, lack of standardisation of data format and information asymmetry between industry participants were found to be possible barriers for the implementation of the tracking and tracing systems in the fresh produce industry in New Zealand. In addition, it was identified that some of the obstacles to achieve effective industry-wide traceability were data fragmentation and traceability information loss during transmission between different companies. Most growers believed traceability was important but had limited knowledge in terms of traceability system within the fresh produce industry in New Zealand. The data of the strawberry pilot study showed that it was feasible to achieve external traceability with industry-wide cooperation from growers, packers, transporters and receivers/buyers.

7.0 Recommendations

Further work is recommended to be performed on wider sources of sample selection for current fresh produce traceability observation in order to include informal supply channels such as online sales and farmers markets.

Considering the relatively low response rate during grower survey conducted in this study, alternative ways of obtaining information to understand grower perceptions and attitudes would be of interest.

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9.0 Appendices

Appendix 9.1 Traceability assessment questionnaire.

1. Objectives	
1.1	Is your organisation aware of traceability regulations, standards and implementation guidance (global or country specific) to which its trade items are delivered/dispatched/exported and/or sold? i.e. Food Act 2014, etc.
1.2	Is your organisation aware of all customer's traceability requirements to which its trade items are sold?
1.3	Is there a document (paper based/electronically based) defining your organisation's objectives, methodology and scope of its traceability system, with a designated person responsible for it? i.e. traceability plan.
1.4	Is the management team aware of the objectives and scope of your organisation's traceability system? i.e. documents containing scope and defined objectives of the traceability system have been signed off by management.
2. Product definitions	
2.1	Are all trade items received by the organisation identified with a unique identification number and described in a Master Data record for each product hierarchy level that needs to be traced? i.e. trade items are identified with a Global Trade Item Number (GTIN) if GS1 system is used in your organisation.
2.2	Are all trade items dispatched by the organisation identified with a unique identification number and described in a Master Data record for each product hierarchy level that needs to be traced? i.e. trade items are identified with a Global Trade Item Number (GTIN) if GS1 system is used in your organisation.
2.3	Are all assets (i.e. returnable plastic crates, pallets, or any other product containers) that need to be traced identified in a Master Data record with a unique identification number?
3. Internal traceability	
3.1	Are all personnel directly involved within the organisation (operation and distribution area) recognised and identified with a description and an identification number in a Master Data record? i.e. staff name, staff ID number, and position.
3.2	Are all trading partners assigned an identification number and have a description in a Master Data record? i.e. grower code and contact details, customer code and contact details, etc.
3.3	Are all internal locations of the organisation that need to be traced identified with an identification number and have a description in a Master Data record? i.e. Chiller 1/Chiller 2, or Auckland site/Christchurch site.
4. Establishment of procedures	
4.1	How are trade items received at your organisation?
4.2	How are trade items stored/dispatched in your organisation?
4.3	Are there procedures being defined to describe and record traceable trade items received, stored and dispatched by your organisation?
4.4	Does a procedure exist within the organisation for product resorting which needs to be traced?
4.5	Does the organisation have a procedure to align critical traceability data with its trading partners? i.e. consignment checks at inwards goods or picking slip checks against order at dispatch area.

4.6	Is there a procedure (digital or paper) at each stage of the traceability flow for data collection, recording and sharing of information between trading partners? If so, how is traceability information shared with trading partners? i.e. sharing with growers/customers.
4.7	Is there a documented procedure in an event of a food recall/withdrawal crisis?
5. Flow of materials	
5.1	Are trade items received by the organisation physically identified with an identification number? If so, is the identification number for the whole shipment, each pallet, each crate, or each trade item?
5.2	Are trade items dispatched by the organisation physically identified with an identification number? If so, is the identification number for the whole shipment, each pallet, each crate, or each trade item?
5.3	Is there a process flow diagram that illustrates the internal trace request process?
6. Information requirements	
6.1	Is the information of all trade items received by the organisation described in a record? i.e. software system or spreadsheet.
6.2	Is the information of all trade items dispatched by the organisation described in a record?
6.3	Is it possible to link the information of inputs with outputs (one to many, many to one, many to many) at all hierarchy levels? i.e. would the organistion be able to trace products from customer to grower in an event of a food recall/withdrawal?
7. Documentation requirements	
7.1	Are there records to validate all relevant processes from product receipt to dispatch? i.e. signed off by supervisors.
7.2	Are there documents describing administration of traceability information such as the organisational structure, operational responsibilities and traceability system capabilities?
7.3	How long does the organisation maintain documents related to traceability information?
7.4	Are all documents on the traceability system kept up to date and reflecting current processes?
7.5	Are documents related to traceability information kept in a restricted area/location with only authorised persons have access to it?
8. Structure & responsibilities	
8.1	Does a operational traceability team exist and are their roles and responsibilities defined and documented?
8.2	Does the traceability team have necessary resources to maintain the traceability system? i.e. resources include HR, IT and budget.
8.3	Are the traceability team members aware of the traceability procedures and instructions, and know where to find them and how to use them?
9. Training	
9.1	Has training on the organisation's traceability system been provided to personnel and are these trainings updated and given periodically?
10. External traceability	
10.1	Is it possible to obtain traceability information of all trade items received from all trading partners in a timely manner?
10.2	Is it possible to provide detailed traceability information to parties requesting it in a timely manner?
10.3	Does a crisis management team exist within the organisation and are their roles and

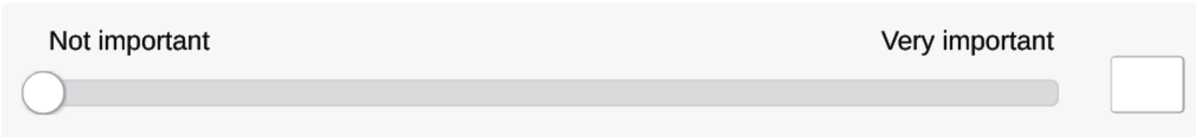
	responsibilities assigned?
10.4	Does a documented plan exist detailing how affected products are recalled/withdrawalled?
10.5	Is the recall/withdrawal procedure capable to operate at any time? i.e. operates 24/7.
11. Internal assessment	
11.1	Does the organisation maintain a register of internal assessments to ensure compliance to the traceability standard, and are these assessments conducted periodically? i.e. an internal audit is carried out annually.
11.2	Are there records of past traceability reviews and assessments?
11.3	Are there corrective action plans shown in internal assessments to resolve non-conformities involving traceability system requirements?

Appendix 9.2 Survey Monkey questionnaire.

Traceability Survey for Growers

This survey will provide an understanding of how traceability systems operate in the domestic fresh produce industry. We would appreciate 5 minutes of your time to complete this survey. All information gathered will be held in confidence and all published outcomes will be anonymous.

1. Do you think traceability is important?



2. Why do you think traceability along supply chains matters? (select all that apply)

☐ So I get paid for my product ☐ For food safety purposes

☐ For record keeping purposes ☐ Meeting customer requirements

☐ To help with product recalls when there are problems

☐ Other (please specify)

3. Why does your business record traceability data? e.g. batch number, harvest date, etc. (select all that apply)

☐ I do not record any traceability data

☐ Customer requires traceability data

☐ Legal requirements (one up, one down traceability)

☐ Important to the business for stock management purposes

☐ Other (please specify)

4. How do you label the outer boxes/crates of product leaving your business? (select all that apply)

☐ We do not label the outer box/crate
☐ We use our own box/crate cards or labels
☐ We handwrite on the outer box/crate
☐ We use customer specified labels e.g. retailer
☐ Other (please specify)

5. Who determines what details are on your box or crate labels? (select all that apply)

☐ An internal decision
☐ Retailer requirements
☐ Wholesaler requirements
☐ We utilise GS1 standards
☐ Other (please specify)

6. Which distribution channels do you use? (select all that apply)

☐ Direct to supermarket
☐ Farmers markets
☐ To a wholesale market
☐ Own store
☐ To an independent retailer
☐ Online sales
☐ Other (please specify)

7. How is the majority of your product sold at retail? (select one answer only)

☐ Loose
☐ Both
☐ Pre-packed

Please specify

8. Where is your pre-packed product packed? (select one answer only)

- ☐ We pack in our own packhouse
- ☐ Our customer packs the product themselves
- ☐ We send our product to a third party packhouse to pack it for us
- ☐ NA – Product sold loose
- ☐ Other (please specify)

9. Does the label on your pre-packed product include any of the following? (select all that apply)

- ☐ A GS1 barcode that you own
- ☐ Pack date (label or ink jet print)
- ☐ A barcode supplied by wholesaler or retailer
- ☐ NA – Product sold loose
- ☐ Other (please specify)

10. What are the main reasons for using the labelling system you have? (select all that apply)

- ☐ It is simple
- ☐ Logistics requirements determine the system
- ☐ It saves time
- ☐ Client requirements determine the system
- ☐ It is cost effective
- ☐ We have always done it this way
- ☐ We use technology to streamline the system
- ☐ Other (please specify)

11. Do you print your own labels on site? (please select one answer and add reason)

- ☐ Yes
- ☐ No

Please specify the reason you do or do not print your own label

12. How do you advise your wholesaler/distributor of product delivery? (select all that apply)

☐ Do not notify, just dispatch product

☐ Emails prior to product dispatch

☐ Phone calls/text messages to advise product dispatch

☐ Electronic portal prior to product dispatch

☐ Paper delivery docket with the product

☐ I do not know what process we use

☐ Other (please specify)

13. Have you ever been involved in a trade withdrawal or recall of a product you have grown? What were the reasons for the withdrawal/recall? (select one answer only)

☐ Mock recall only

☐ Chemical / Residue issue

☐ Microbial contamination

☐ NA - Have not been involved in a product recall

☐ Physical contamination

☐ Other (please specify)

14. Once you identified an issue, how long did it take to identify where the product went in the supply chain? (select one answer only)

☐ Minutes

☐ Weeks

☐ Hours

☐ It was not possible

☐ Days

☐ NA - Have not been involved in a product recall

Text box to add additional comments

15. In the worst-case withdrawal / recall scenario, how difficult was it for you to contact the relevant supply chain partners?

Very easy — Very difficult ☐

16. Did you have a recall plan in place? (select all that apply)

☐ No – we do not have a recall plan in place

☐ Yes – we have an internal recall plan in place

☐ Yes – we are registered with Product Recall NZ

17. What were the biggest challenges encountered during a product recall (real or mock)? (select all that apply)

☐ Technology incompatibility

☐ Insufficient product records

☐ Incorrect or out of date contact details

☐ Language issues (i.e. English a second language)

☐ Other (please specify)

18. How much do you estimate your business spends on product labelling each year? Such as labels, printing, artwork, machinery etc. (select one answer only)

☐ < \$1,000

☐ \$1,000 - \$5,000

☐ \$5,000 - \$10,000

☐ > \$10,000

19. What region are you based in? (select one answer only)

- ☐ Northland
- ☐ Auckland
- ☐ Waikato
- ☐ Bay of Plenty
- ☐ Manawatu
- ☐ Wellington
- ☐ Marlborough
- ☐ West Coast
- ☐ Canterbury
- ☐ Otago
- ☐ Southland

20. What is the main crop type you grow? (please specify)

21. Are you a member of GS1?

- ☐ Yes
- ☐ No

Appendix 9.3 Permission from The AgriChain Centre Limited.

The AgriChain Centre
GROWTH VALUE STRATEGY
ANALYSIS SYSTEMS ACTION
AGRICHAIN-CENTRE.COM

PO Box 101 245,
North Shore Mail Centre,
Auckland 0745, New Zealand
T +64 9 414 4536
F +64 9 414 6140
E info@agrichain-centre.com

9th July 2019

Ms Jiaojiao (Yvonne) Gao

By hand delivery

Dear Yvonne,

Access to Company Information, Data and Images Related to Tertiary Study

Further to recent conversations, I am writing to confirm as follows:

- The AgriChain Centre has managed an MPI project entitled "FRSP 2017/2019 Plant Based Survey", Agreement Number 18141.
- The AgriChain Centre is currently managing a United Fresh project entitled "Effective Fresh Produce Traceability Systems". Agreement Number 405482. This project is funded via the MPI Sustainable Food and Fibre Futures programme.
- The Agrichain Centre has concluded an in-house project, analysing the process of delivering the above MPI FRSP project, based on the project management data the company had generated during the delivery phase.
- You have contributed to these projects as a member of the respective project teams, in all cases under the directions of the specific project directors, Massimo Ciccioni or Anne-Marie Arts.
- Ownership of information, data and material you are exposed to, are generating or are working with as an AgriChain Centre employee are covered in clauses 13.1 – Confidential Information and 13.2 – Copyright and Other Intellectual Property of your Individual Employment Agreement.
- Specifically, "All work produced for the Employer by the Employee under this agreement or otherwise and the right to the copyright and all other intellectual property in all such work is to be the sole property of the Employer", (13.2).

As you are now pursuing a Master of Science degree at Massey University in a related topic, we are pleased to advise that we grant you access to all material generated in relation to the above three projects, to enable you to further analyse and incorporate AgriChain Centre generated information, data, knowledge and images into your studies.

Yours sincerely

Dr Hans Maurer, *MRSNZ,CMInstD*
Director Strategy & Marketing

Appendix 9.4 Outputs of statistical analysis of grower survey

Q3_C2_Customer * Q5_C3_Wholesaler

Crosstab

			Q5_C3_Wholesaler		Total
			No	Yes	
Q3_C2_Customer	No	Count	12	5	17
		Expected Count	8.1	8.9	17.0
		Residual	3.9	-3.9	
	Yes	Count	7	16	23
		Expected Count	10.9	12.1	23.0
		Residual	-3.9	3.9	
Total		Count	19	21	40
		Expected Count	19.0	21.0	40.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.320[a]	1	.012		
Continuity Correction[b]	4.812	1	.028		
Likelihood Ratio	6.487	1	.011		
Fisher's Exact Test				.024	.014
Linear-by-Linear Association	6.162	1	.013		
N of Valid Cases	40				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.08.
b. Computed only for a 2x2 table

Q3_C4_StockMgt * Q5_C2_Retailer

Crosstab

			Q5_C2_Retailer		Total
			No	Yes	
Q3_C4_StockMgt	No	Count	17	4	21
		Expected Count	10.5	10.5	21.0
		Residual	6.5	-6.5	
	Yes	Count	3	16	19
		Expected Count	9.5	9.5	19.0
		Residual	-6.5	6.5	
Total		Count	20	20	40
		Expected Count	20.0	20.0	40.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	16.942[a]	1	.000		
Continuity Correction[b]	14.436	1	.000		
Likelihood Ratio	18.427	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	16.519	1	.000		
N of Valid Cases	40				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.50.
b. Computed only for a 2x2 table

Q6_C3_Wholesale * Q14_RecallTime

Crosstab

			Q14_RecallTime			Total
			Minutes	Hours	Not Involved	
Q6_C3_Wholesale	No	Count	0	0	6	6
		Expected Count	1.6	1.3	3.2	6.0
		Residual	-1.6	-1.3	2.8	
	Yes	Count	10	8	14	32
		Expected Count	8.4	6.7	16.8	32.0
		Residual	1.6	1.3	-2.8	
Total		Count	10	8	20	38
		Expected Count	10.0	8.0	20.0	38.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	6.413[a]	2	.041
Likelihood Ratio	8.714	2	.013
Linear-by-Linear Association	5.620	1	.018
N of Valid Cases	38		

a. 3 cells (50.0%) have expected count less than 5. The minimum expected count is 1.26.

Q6_C5_Independent * Q14_RecallTime

Crosstab

			Q14_RecallTime			Total
			Minutes	Hours	Not Involved	
Q6_C5_Independent	No	Count	6	2	17	25
		Expected Count	6.6	5.3	13.2	25.0
		Residual	-.6	-3.3	3.8	
	Yes	Count	4	6	3	13
		Expected Count	3.4	2.7	6.8	13.0
		Residual	.6	3.3	-3.8	
Total		Count	10	8	20	38
		Expected Count	10.0	8.0	20.0	38.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	9.342[a]	2	.009
Likelihood Ratio	9.458	2	.009
Linear-by-Linear Association	3.913	1	.048
N of Valid Cases	38		

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.74.