Hort Innovation

Final Report

Technology review for fruit traceability at every stage of the Apple and Pear fruit production and supply chain

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Technology review for fruit traceability at every stage of the Apple and Pear fruit production and supply chain AP19004

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Content

Executive Summary

There are a multitude of systems and technologies employed in the Apple and Pear Production and Supply Chain (APPSC). These systems have been developed to address various important functional needs along the supply chain and have been augmented as traceability requirements have emerged. Each business has sought its own spectrum of systems from a wide and expanding market of solutions. Current systems tend to focus on (1) orchard operations, (2) storage and ripening services, (3) processing and packing, (4) inspection services and (5) transport and other supply chain services. These systems may interact with each other but tend to be discrete and independent. To date there are no purpose specific whole of chain fruit product traceability system solutions and only a few pilots to address a point of origin trace. Consequently, traceability data and the variety of associated contextual information are fragmented across systems and there are many significant improvements in access and efficiencies that could be achieved for the industry with a purpose-built system.

Traceability is based on identification of a fruit product in the supply chain and this and associated information is integrated into existing logistical, financial, and other systems. There will be significant disruption accruing from any attempt to provide a separate consolidated solution for its management. A better approach is to initially build a system in the cloud over to harvest the required data for traceability reporting with minimal impact on existing system investments. The change would require existing APPSC stakeholders to agree and support an appropriate data exchange standard. Such standards are already evolving with the Global Standard 1 (GS1) being the major leader. If these approaches can be implemented across the industry, this will also deliver whole of industry business activity reporting. It is recommended that this be approached initially as a pilot involving one or more Apple and Pear businesses and an appropriate consortium of technology providers.

In addition to a purpose-built system, the resolution of detail with respect to current traceability could be improved if:

(1) all fruit packs are individually identified

(2) spatial definition and identification of fruit production in the orchard are enhanced[1]

(3) mechanisms are developed to retain the traceability resolution from the orchard, from processing to packing

(4) items 1-3 are enabled with new technology such as robotic harvesting, sensors, and new approaches to labelling,

(5) industry is appropriately engaged to foster buy-in.

[1] The same spatial framework that would support this can also be used to integrate and better report other orchard information such as crop and pest monitoring.

Keywords

Apple, Pear, Fruit Traceability, Blockchain, Robotic Harvesting, Identifiers, RFID, QR Code, Chemical fingerprint, DNA fingerprint, Point of Origin, Provenance, Food Fraud, Food Safety, Product Recall, Biosecurity, Market Access

Introduction

Horticulture Innovation have contracted Agriculture Victoria to undertake a review of food traceability[2] within the Apple and Pear[3] industry including existing technology use and opportunities for improvement from emerging technologies. This report documents the findings of the review and is supported by information collected from industry and supply chain participants, technology providers and through review of pertinent published research. Developments in traceability systems in a limited number of other agricultural commodities and sectors have also been used to inform the analysis.

The Australian apple and pear industry produces just under $600 million of fruit per annum. Most of this fruit is consumed domestically with around 2% of apples and about 9% of pears exported. There is increased focus on exports and current imports of both are less than 20% of export volumes. On average over the last 5 years the volume of pear exports is double that of apples. Protocol markets require production and supply chains to follow prescribed protocols and may have more requirement for fruit traceability. Protocol markets for apples are China, Japan, Taiwan, and Thailand and for pears New Zealand and Thailand. Approximately 50% of apples are grown in Victoria and the remaining states[4] each produce around 10% of the Australian annual crop (± 1%). Victoria accounts for about 90% of pear production followed by South Australia with approximately 5% of national production. This report focuses on the fresh fruit supply chain for apples and pears with a particular emphasis to the export supply chain for future development of the newer premium apple and blush pear varieties.

A detailed review of next generation traceability technologies is provided that includes descriptions of the potential challenges and opportunities in developing and implementing these technologies across the apple and pear sectors, with broader application for other Horticulture fruit and nut crops. The objective of this report is to enhance industry intelligence to support the targeting, development, and adoption of solutions to improve traceability. This will assist in delivering a digital provenance to inform consumers and help realize opportunities for the further maintenance and development of domestic and exports markets for apples and pears.

The authors ability to connect with industry participants has been compromised by the Covid 19 pandemic. This has affected the ability to undertake full industry profiling of current technology use, but from a technology appraisal perspective this has been less of a hindrance.

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[2] Within Australia, food traceability requirements are listed under the following standards: Standard 1.2.2 - Food Identification Requirements, for labelling food Standard 3.2.2 - Food Safety Practices and General Requirements, for food receipt and food recall Primary production and processing Standards 4.2.1 to 4.2.6.

[3] In this report the term Pears is used inclusive of Nashi fruit.

[4] Except the Northern Territory

Methodology

The approach taken involved a detailed review of next generation traceability technologies, including the potential challenges and opportunities in developing and implementing these technologies across the apple and pear sector, with broader application to Horticulture fruit and nut crops. The review will allow industry to better understand the latest technology and how it could be used.

The project objectives are to:

a) Identify emerging technologies and trends for end-to-end production and supply chain monitoring, management and traceability for apple and pears.

b) Undertake a more detailed evaluation of technologies currently being used in apple and pear traceability supply chains and industry preparedness to embrace next generation technology developments.

c) Summarize challenges, opportunities and risks for industry adopting these technologies and the impact on industry and government. This includes understanding:

   - the status of grower's readiness to accept and their capability and capacity to adopt new technologies for market access purposes.
   - disruption costs across the entire supply chains if new technology is to supersede existing traceability technology.

d) Identify the possibilities and impacts of standardizing traceability technologies and data. The development of industry-wide standards for data collection, use and sharing will likely be an enabler for adoption of new technology and more effective traceability systems. This project will seek to understand where it should participate in (or initiate) the development of industry-wide standards for data and/or technology for enhanced supply chain traceability. This includes understanding the implications of giving complete monopoly to one provider or system.

e) Identify how technology could be customized by the apple and pear industry to optimize its supply chain traceability systems by integrating multiple new technologies to achieve product compliance and differentiation in the marketplace.

Agriculture Victoria (AV) has already undertaken substantial work to establish tree and other feature identification and registration systems that support the recording and integration of research measurements in the Tatura SmartFarm apple and pear orchards. A development environment will be created to use advances in fruit tracking and the establishment of API services to support controlled information exchange to industry stakeholders via an exemplar API gateway. This provides a functional environment that mimics the current industry setting and allows the testing and deployment of the proposed design elements for industry and stakeholder scrutiny.

The projects apple and pear industry engagement has been impacted by the COVID 19 pandemic and the project team was largely unable to undertake face to face interview and property and system inspections. In the narrow windows where this was permitted under State Health Directions the larger and more complex operations and facilities were targeted for visitation, as this enabled efficient contact with the broadest and most sophisticated range of technology solutions. To counter limitations on engagement a survey was developed to gauge industry use of technologies and provide a pathway for growers that were prepared to further engage via virtual means. There were very few responses to the survey and where possible these were followed up.

A substantial amount of effort was focused on the review of on-line material, published research and virtual meetings with technology groups and vendors across the globe.

New conceptual models and frameworks were developed to better describe and communicate traceability aspects of the industry, relevant technology, and current and potential traceability solutions.

Outputs

What does fruit traceability mean?

Traceability is the capability to trace something, which may involve information discovery by investigation. In this context it is the ability to track fruit through all stages of production, processing, and distribution (including export).

Traceability, when defined in this manner requires an identification unit (individual or by lot). The identification or "product management unit" and its identifiers may vary along the supply chain and where this occurs associations need to be established between these identifiers if traceability is to be maintained. At a minimum in these situations, traceability should mean that movement can be traced one step backward and one step forward at any point in the supply chain. This form of traceability is called direct product traceability and is greatly augmented if other contextual information (metadata) is also recorded against or relatable to the product units along their pathway through the supply chain.

In the food industry, the term traceability is also often applied to indirect (or logical) tracing where events along the supply chain are logistically connected and analysis of their location and time information may be linked to a consignment. In these situations, the traceability is more oriented to the supply chain processes rather than product tracing. Often this kind of information is generated from supply chain monitoring, rather than comprehensive tracking, and this may affect its ability to inform the product traceability required by an issue or event.

To complete the picture, there are other types of information generated from supply chain monitoring such as environmental monitoring used to understand the conditions experienced by the fruit during its journey to inform management and forecasting of fruit quality and shelf life. Additionally, "spot measurements" are often used to detect contaminants, biosecurity issues or assess product credence. This information can be important in supporting traceability and is hence often incorrectly seen as part of the core traceability function (which is track and trace), but its functional orientation is towards issue detection and forward planning and management of supply. An example of this is DNA fingerprinting which takes two forms in horticulture. The first is the application of DNA tags to products for the purpose of identification. The second is the analysis of DNA naturally associated with the product, or finding DNA from other unwanted lifeforms, such as natural bacteria or contaminating organisms. This approach supports quality assurance and is useful for identifying food safety and biosecurity issues[5].

The process can be summarised to describe three aspects of fruit traceability, (1) fruit or product track and trace, (2) supply chain process/event track and trace and (3) supply chain monitoring and issue detection. These concepts are explored further in the "traceability foundations and concepts" section of this report.

What does fruit provenance mean?

Fruit provenance is taken to mean or describe the origin of the fruit. This usually refers to the source of production but could refer to an entity further along the supply chain. In this setting fruit provenance may be established at differing levels of resolution from a specific tree, an orchard block, a property or even to the company that packages the fruit for market.

It usually represents a limited form[6] of fruit identification focused on its source of origin rather than support for track and trace of the fruits journey along the supply chain.

What role does technology play in traceability?

Technology supports the systems that underpin traceability by providing the security, capture (including measurements), storage, access, and maintenance of the information that is used to trace the journey of fruit, manage the supply chain, and provide evidence to inform issue resolution for markets and associated stakeholders. Technology plays a vital role in traceability to create and support product and other identifiers and

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[5] Can be very specific in industries like red meat but is less useful for apples and pears because fruit varieties are essentially clones with the same genetics.
[6] Point of origin traceability is used to answer the question "where did this product come from?" and plays a role in supporting determination of product authenticity. If point of origin traceabilty is applied at a fine resolution and maintained along the supply chain, it has to converge with product tracking and traceability.

to facilitate mapping and connecting these between systems along the production and supply chain when multiple identifiers are in play. Additionally, technology is essential to fruit grading and processing and the measurement and forecast of fruit quality and issue detection.

Four primary areas of traceability application in the apple and pear industry

As a result of the review, four traceability areas or contexts have been identified. Within these contexts the nature of traceability functions, requirements and objectives may differ. The traceability operations, systems and technologies within these areas need to interoperate and improvements to this engender more powerful and effective opportunities for whole of industry and supply chain traceability. These areas will be described and discussed more fully in the supply chain description section. The four traceability contexts or zones are (1) Traceability in the orchard or production setting, (2) Traceability during storage, processing, and packing, (3) Traceability post packaging and (4) Fruit provenance traceability.

Traceability data and associated information

The data and information associated with traceability functions is varied and the connections or associations between different types of information with "traceability" can range from close to indirect. This can be potentially confusing for traceability discussions. For clarification three broad groups of data and information are formulated and used within the review. These are shown in Figure 1 below. The first category (central in the figure) comprises the data and information directly related to supporting fruit tracing. These information assets are at the core or heart of traceability and provide the backbone for linking other categories of information. Deficiencies here compromise the foundations of traceability.

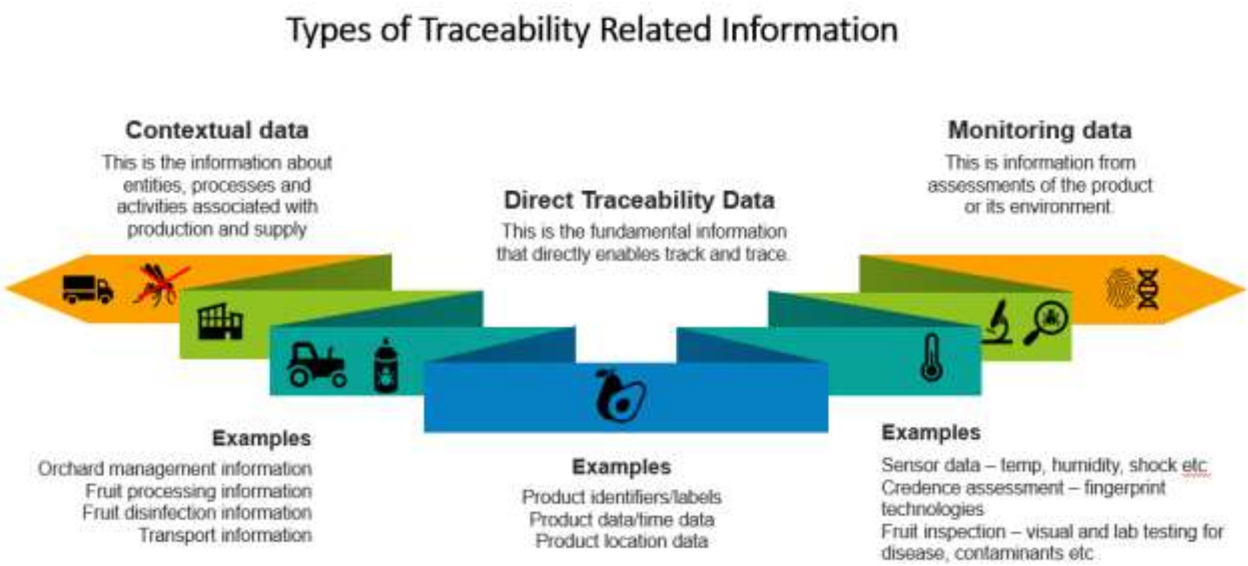

Figure 1 Broad Traceability Information Categories

The key information elements in this category are product identifiers[7], identifiers for the "receptacles" that contain or aggregate product and the information about their relationships and journey in space and time (ie date /time and location). The second information group comprises contextual, or traceability metadata and its primary function is to provide meaningful context and evidence to inform traceability. This information needs to be linked to the information in the first group to benefit traceability and when this is in place it can provide powerful descriptive detail and evidence of supply chain processes. This information is usually directly linked to the identifiers from the first group (hard linkages) but may be supported by inferred associations (soft linkages) usually based on combined spatial and temporal coincidence. The detailed information in this group is often held and

[7] These can range from product descriptors such as variety (including point of origin) through to specific identification codes or numbers for units of product.

managed in systems external to a core traceability system.

KEY FINDING: ***There are three types of traceability data, which can be categorised as, (1) direct traceability data, (2) contextual data, and (3) monitoring data. At present direct APPSC traceability data tends to be spread across systems and does not have a purpose-built system solution.***

The example below is provided to assist in understanding these categories.

"A fruit package has a unique identifier and at each step in its journey this may be scanned to create a record of its journey in a parent system/s. Let's say the package is being loaded onto a truck. The minimal associated record would fall into information category 1 and contain the package identifier, a location and the date and time. If an identifier for the truck is added to the record, then that can potentially be used to interrogate the trucking companies' system to identify the driver, consignment details and details of the truck movements. The truck identifier and the associated information would fall in category 2 as it provides context but doesn't support traceability unless it is linkable to the fruit package. If the truck id and the fruit package id are both in the record registered in a traceability system this is a hard linkage. If this isn't the case, then to get this context the location and time of loading the package would need to be reconciled with the location and time information associated with the truck from the truck company system. This would be an example of an inferred or soft linkage."

The third category of information (in the right section of Figure 1) relates to monitoring the supply chain and for traceability purposes largely covers the results from assessments or measurements of fruit and its environment along the supply chain. This information tends to be based on samples that are episodic or event driven. The exception to this is the emerging use of sensors that provide more continuous readings for a subset of fruit and/or its environment.

The role of labels or information carriers and associated functions

To achieve traceability product identifiers need to be carried and accessible along the APPSC. Labelling is the means used to achieve these outcomes. Product labelling can range from more traditional approaches that are "human readable" through to sophisticated approaches using DNA or particles that stick to product and require advanced technology to "read". While that later may be quite good for point of origin traceability, the most feasible approaches from individual product traceability rely on electronic or printed labelling of fruit packs or associated fruit package assemblies (ie logistical units such as pallets). Radio Frequency Identification (RFID) tags are increasing used to label and identify logistical fruit containers such as bins, pallets, or shipping containers because they can be read at a distance. For fruit packs printed labels remain the most universal carrier for identifiers and other information. The GS1 labelling standards for bar codes, QR codes and RFID are the most widely adopted across many industries. One of the most universal GS1 labelling standards used is the Serial Shipping Container Code (SSCC) barcode. And to provide an example of a standard label this is shown in figure 2 below.

Figure 2 The GS1 SSCC -18 standard barcode description.

Standards

There is a plethora of systems that currently contribute or could better contribute to supporting more effective fruit traceability within the Apple and Pear industry. A key to achieving this is the application of a range of standards. These are used to underpin and manage key aspects of the APPSC. Some key areas for the application of standards include identification schemes, labelling, event recording, product assembly and disassembly, and information exchanges.

Because there are both domestic and export APPSC there are strong benefits and opportunities that accrue from the utilization of global standards. The principal suite of global standards is referred to as Global Standard 1 (GS1) and applies to supply chains across a wide spectrum of industries. The GS1 codifies the syntax and semantics for supply chain events including global standards and controlled lists for product, associated stakeholders, and event descriptions. It contains fundamental models to support logistics and standards for labeling. The GS1 has been present for some time[8] and historically these labels operated without the backing of on-line responsive systems and can be regarded as a precursor or substitute for not having these systems.

The most relevant parts of the GS1 for traceability in the Apple and Pear industry are the suite of identification schemes, the Electronic Product Code Information Service (EPCIS), and the GS1 Digital Link standard. While there are at least 12 different standard identification schemes within the GS1 framework, the following list covers the most important for fruit traceability.

- Global Trade Item Number (GTIN) – for Products and services
- Global Location Number (GLN) - for Parties and locations
- Serial Shipping Container Code (SSCC) – for Logistics units
- Global Identification Number for Consignment (GINC) – for Consignments
- Global Shipment Identification Number (GSIN) – for Shipments

[8] Consequently, the body of associated knowledge and documentation is immense and due to time constraints only the most relevant parts of the GS1 were reviewed.

Each GTIN created is unique to a company and applied to each "product" type that is produced. The GTIN can then be utilized in a range of situations to identify product and if utilized by an GS1 Digital Link implementation can facilitate connection to other information or a purpose-built overarching traceability system. The EPCIS can be employed to support supply chain events such as product assembly into logistic units and disassembly.

KEY FINDING: ***The GS1 standards are well developed and integrated into global supply chains. They will be key to Apple and Pear traceability solutions particularly as these evolve to better support Globally Unique IDentifiers' (GUID's) for fruit packages***

A lot of the thinking has been done in GS1 to enable traceability but there are weaknesses. GS1 tends to be top down and supports structuring the contextual information for traceability very well. Its foci are to provide standards and facilitate globally consistent and structured approaches, rather than delivering system solutions. For instance, the implementation and management of SSCC's needs to be supported by a APPSC stakeholder or associated vendor system. Additionally, the GS1 doesn't really get down to the level of identifying and tracing fruit packages. It tends to cut off at a batch or lot level. In particular, the GS1 labelling standards do not support beyond this level of product resolution. For individual fruit package track and trace the use of additional identifiers is required. The current GS1 expectation is that identifiers managed by participating organizations/businesses are serialized (ie sequential numbers generated and managed by APPSC participants systems). This imposes a limit on the number of items that can be active and requires approaches to re-use the identification numbers.

The best traceability outcomes for the APPSC will occur as the GS1 evolves to support the use of GUID's. This will remove any current limitations associated with system generated serialized identification approaches.

<u>References:</u>

GS1 (2010) Traceability for Fresh Fruits and Vegetables - Implementation Guide

Issue 2, May-2010.

Traceability foundations and concepts

A significant part of developing the report has required the creation of several models or frameworks to help describe and assist understanding of fruit traceability. These foundations and associated concepts are described in this section and will be drawn upon throughout the remainder of the report.

Tracking, Traceability, Credence and Product Authenticity

There are several different types of traceability and there is a tendency for these to be used interchangeably and somewhat indiscriminately in traceability conversations. To further confuse the situation, addressing some types of traceability can also address or support other types. For clarity, four different types have been identified and are used in the report. These are detailed in Figure 3 where each type has been formulated to address a specific traceability function or question.

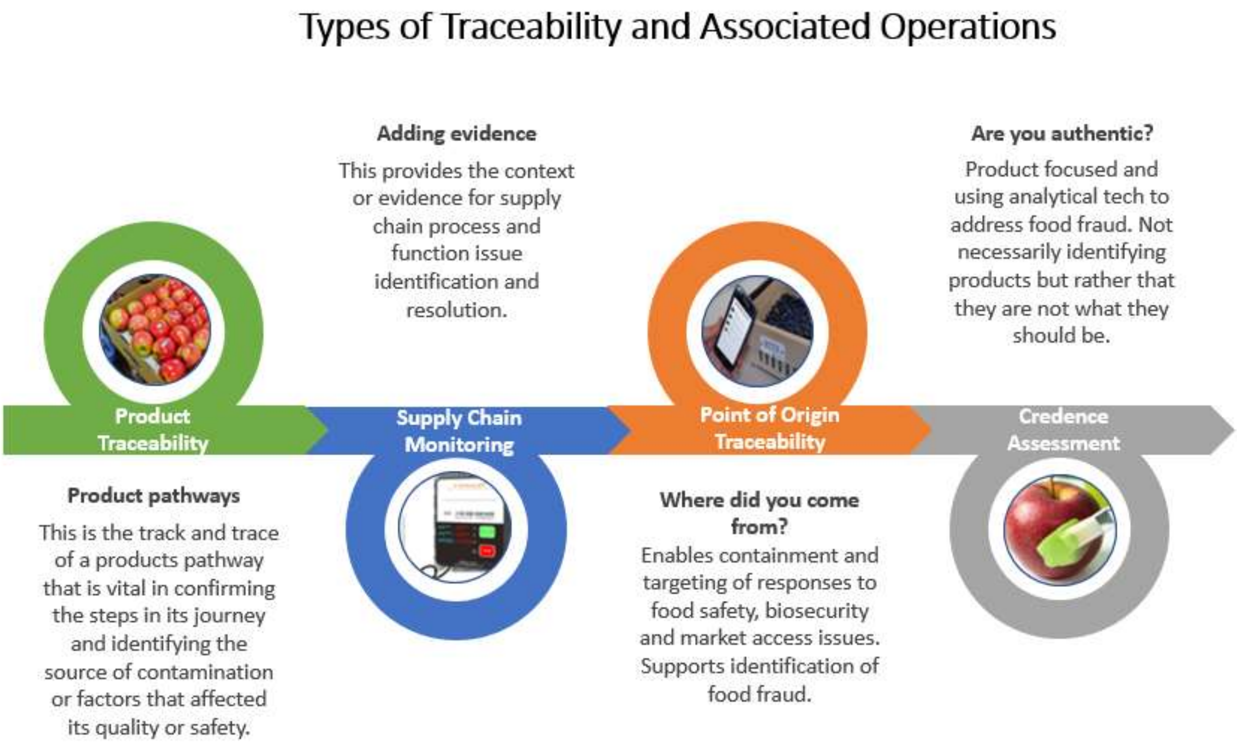

Figure 3 Fundamental Types of Traceability

The identification of these different types creates a framework that assists in understanding and analyzing the applicability or strengths and weaknesses of the varied suite of technologies that can potentially aid fruit traceability. Specifically, some technologies better support a particular type of traceability than others. In the main, as you move along the diagram from right to left, the complexity, number of systems and demands on solutions increase. The traceability types are briefly described below. Each type is described according to its core function.

Product traceability or tracking

This is the traceability that allows the tracking of the products journey from fruit inception through to its consumption. This form of traceability if effectively implemented will deliver all other forms of traceability except production and supply chain monitoring, an effective marriage with this produces optimal traceability outcomes. Product traceability can support different functions or purposes at different points in the production and supply chain. Within the production setting more detailed traceability can improve the resolution of the business intelligence around production and contribute to enhancing orchard operations. However, this level of traceability detail is almost always reduced by current processing and packing processes particularly in larger facilities. This type of traceability aligns to the type of information in the central category of figure 1 and its foundations are based on product identifiers.

Production and Supply chain monitoring

The traceability delivered by supply chain monitoring is oriented towards quality assurance of the events and processes in the chain and can involve compliance tracking the sequence and efficacy of processes. It typically may not be directly relatable to specific product that is moving along the chain but may be linkable in space and time. The information collected is ancillary but provides powerful evidence to verify supply chain function and add background detail to product traceability. In many ways this type of traceability is somewhat removed from the other forms but is important in verifying and demonstrating quality management of the supply chain. The associated activities and systems capture information about the operation of the production system and supply to assure that food safety and market protocols are in place and being maintained as required. Environmental monitoring along the chain may also be undertaken to assist in supply chain and product management. From a traceability perspective the main function of this type of traceability is to provide the contextual evidence to augment food traceability. Typically, there will be many systems at play with each supporting a particular type of event or facet of production or supply. These systems support both the contextual data and the monitoring data described in Figure 1 but not the core product traceability information.

References:

Wang X, Fu D, Fruk G, et al. (2018) Improving quality control and transparency in honey peach export chain by a multi-sensors-managed traceability system. Food Control 88: 169–180.

Point of origin traceability

This form of traceability answers the question "where did you (the product) come from?" There are many solutions and technologies that can deliver this type of traceability. It is also accommodated by default if product track and trace is established. Point of origin trace will address the same issues as product authentication. Additionally, it also addresses biosecurity issues and product recall associated with food safety issues delivering containment and targeting of associated responses for both. This enhances market access recovery and retention and potentially assists in substantially minimizing both reputational and financial costs to the industry and its stakeholders. To achieve these outcomes, it is important that point of origin trace is rapid and efficient. By itself this form of traceability will not address issues in the production and supply chain such as where potential product contamination or spoilage occurred. Point of origin traceability can be applied with different degrees of precision and differ in which part of the supply chain is better supported as the point of origin[9]. Solutions that do not go beyond point of origin traceability may be of similar sophistication to those addressing fruit authenticity.

Credence assessment and product authenticity

In its pure form this is the rawest form of traceability. It addresses the question "is the product under examination authentic?" To answer this, it may not be necessary to precisely identify the product or exactly where it came from. It is often enough to establish that the product does not have the expected characteristics. In its most minimalist form, this traceability consists of an assessment that produces a result that is then compared to reference information. If it fails to match, then the product is deemed different and not authentic. Although the systems and technologies utilized in assessing product samples may sophisticated and complex the associated traceability system is functionally simple as it just needs to support the lookup and comparison of the results and report the outcome. Some technologies specifically address this traceability type like chemical and DNA fingerprinting or application of persistent immovable unique tags to product.[10] To achieve this type of traceability does not require product tracking nor precise point of origin but either of these types of traceability will also address product authentication if they are effectively established. The main issues that this type of traceability addresses are food fraud and protection against reputational damage. This may be an early form of traceability that is applied in situations where there is high value product and high brand name recognition or promotion.

Identity, labelling and associated functions

Identification of product and other things associated with production and supply is at the heart of fruit traceability. A thing must be "known", and this identity carried or accessible along the production and supply chain to allow reliable and accurate attribution of information about it and its journey (evidence). An essential function associated with identity is its registration. Identity is codified as an identifier and registration of this in a system creates a secure reference for future validation and authentication. It is the security of the systems associated with identity authentication that contribute most to the establishment of product credence rather than the identifiers per see. Identity can take many forms and be assigned at different levels of product aggregation and can operate differently in the varying contexts associated with production and supply. For fruit this can range in scale and resolution from specifically identifying an individual fruit to the bin it was initially put in, to who produced it, who processed/packed it or even just what variety it is. The identification scheme or approach taken will directly impact the traceability and quality of associated information that can be achieved. The current reality is that typically each stakeholder in the chain may apply different identifiers to suit their operation and the services they provide to the supply chain. It is vital that these identifiers and the systems authenticating them can be at least accessed[11] if not interoperate if traceability is to be supported.

There are two classes of identifiers (1) product centric identifiers (ie bin number/code, fruit carton identifier), and (2) context centric identifiers (ie, key supply chain entities, events, important locations, sensor id's). The first class

[9] In some solutions product labelling and accessible systems may only be able to easily identify the packhouse as the point of origin necessitating further investigation to trace back to an orchard.

[10] Note point of origin traceability may also be supported to varying degrees depending on how these technologies are used.

[11] Access may range from restricted to an open audience and the identification approach may be chosen or tailored to support different functions for each audience and limited to the different phases of production and supply where these operate.

is essential for product track and trace and the second for the organized collection of descriptive and other associated metadata or evidence of supply chain events, activities, or functions. The tighter the two classes are linked the stronger the power for traceability. For example, there is stronger traceability if we have temperature sensors in every fruit carton versus having a single sensor in the shipping container. However, these improvements need to be balanced against cost, implementation, and management practicalities. It should be noted that the function of certain groups of context centric identifiers may increasingly be replaceable by the combination of location and time stamps as more and more technologies become spatially aware. For example, if we know the location and when a fruit carton was unloaded from a truck, we can tap global spatial data services to spatially infer what facility was nearby. One advantage of using location and date/time as a surrogate context identifier is it promotes the ability to record details easily even when fruit departs from its normal supply route. There are five core functions associated with a comprehensive approach to effective identification for traceability. These are shown in Figure 4 below. Some of these functions may be inherent (such as identity establishment if based on intrinsic identifiers in the cherries like chemical fingerprints) or implemented in tandem. They may not necessarily apply in the order listed in the diagram, but all are required for traceability. The reason these functions are identified is that different technologies and approaches to identification will have strengths or weaknesses in relation to their support for these functions. The functional breakdown provides a framework that contributes to the analysis and discussion of available solutions for apple and pear traceability. The effectiveness of security in the systems supporting the identity registration and lookup functions largely determine the security of a traceability solution.

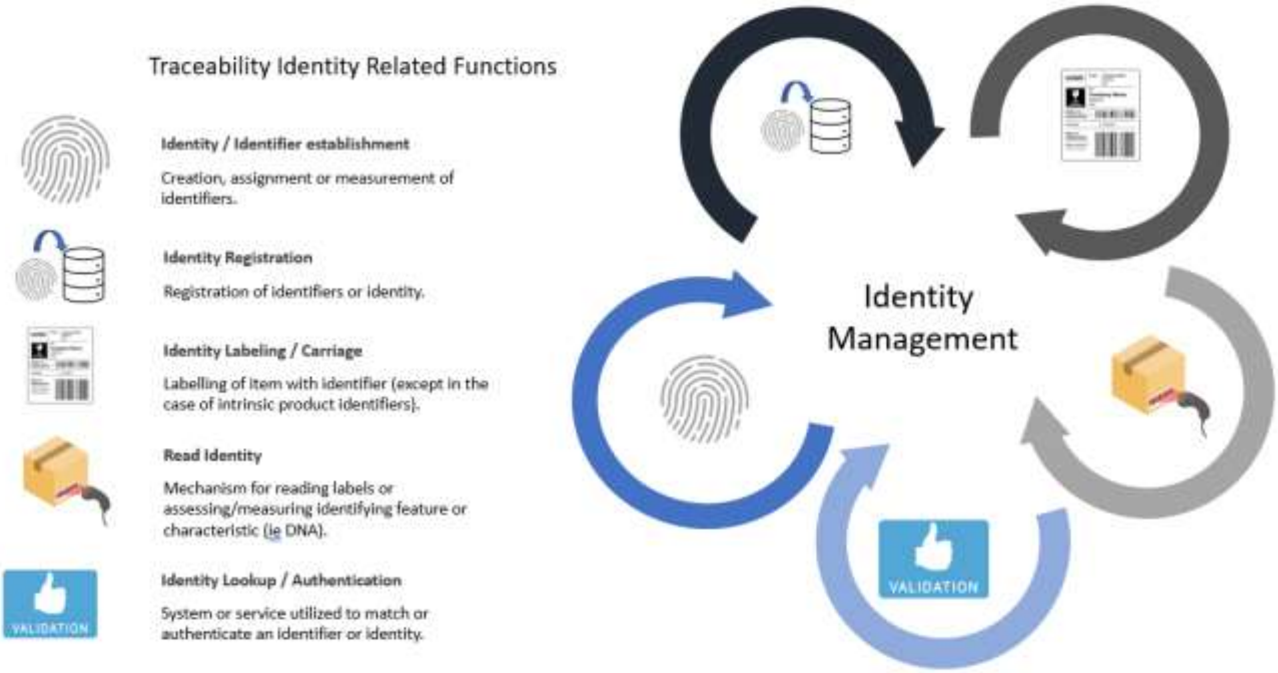

Figure 4 The five core functions required for identity management in fruit traceability

Identifiers and Identification

Identification schemes can be highly dependent on the technologies and systems that underpin them. There are two broad types of identifiers namely those that must be externally assigned and applied and those that are intrinsic to a product. The key types of identification within these groups are described in the Figure below. These can apply to both classes of identifiers (product and context centric) but across the board have greater use for product centric identification.

Each identification type is described in the sections below in more detail with a brief assessment of its relevance to the apple and pear industry.

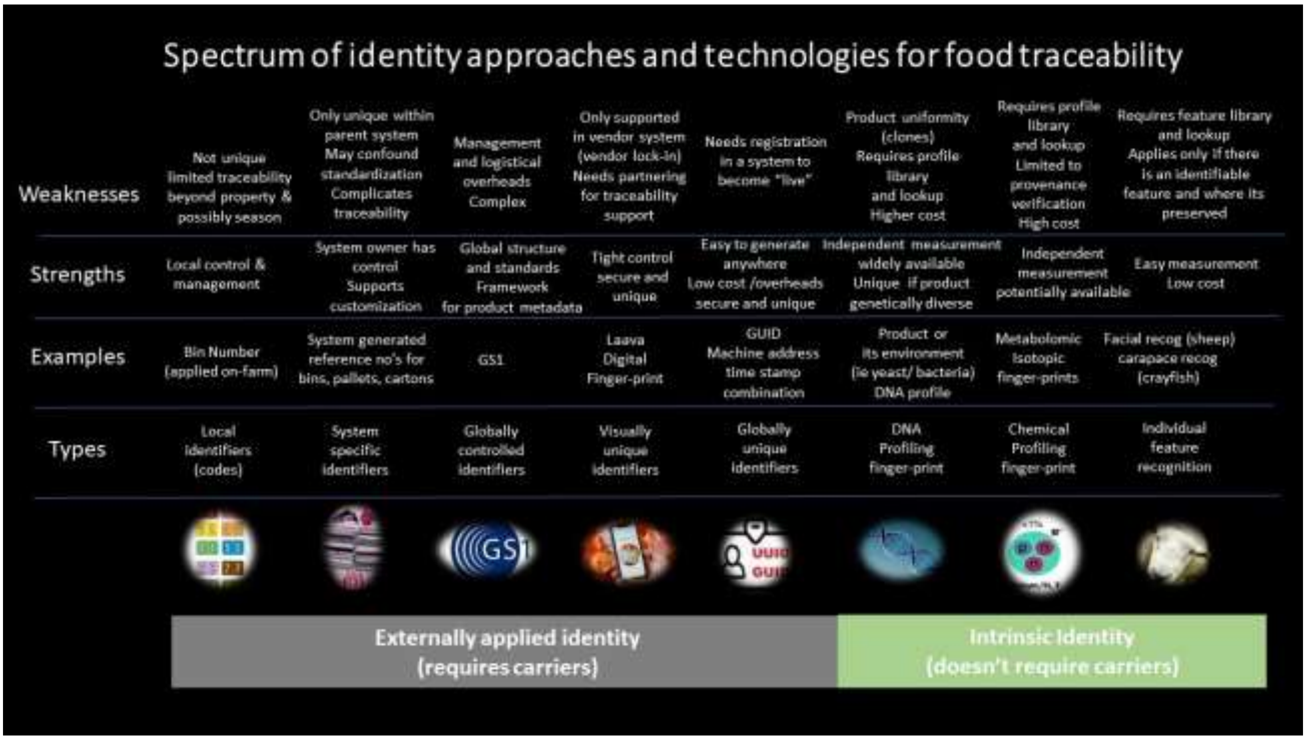

Figure 5: Summary of approaches to identification in fruit traceability.

Group - External Identifiers

Overview: For product traceability, externally identifiers must be affixed, associated or linkable with the product unit. External identifiers are not intrinsically part of a product, object, or event and need to be applied and supported by a carrier. This usually takes the form of a label, RFID chip or some other physical element that can store information in a readable manner. Reading may be via visual scan and interpretation or via a device (a reader). Like all identifiers they need to be registered in a system to support their security, validation, and use for traceability. In most instances the process of' identifier registration is equivalent to creating a digital or virtual equivalent or record of the identifier. It is common for these identifiers to be born digital or created and registered simultaneously within a parent system. If a contextual external identifier has a fixed location its linkage may be supported via spatial inference.

Local Identifiers

Description: These are identifiers that are created or minted in a localized setting and tend to be accessible and used in a focused area of operations. They may not be supported by a system, and where they are, the accessibility of the system may be limited.

Assessment: These identifiers are most often created and used on farm or within a facility. They are typically only unique within this setting and in production settings may be re-used in subsequent seasons. Examples may be the bin numbers and labels that a farmer applies to their fruit bins or picker bag identifiers used to support picking tallies and picker payment. They almost always lack uniqueness and must be either paired with a property/facility code to create a more unique combined key or replaced by another identifier further along the chain to support use for traceability. The later scenario appears the most common. The lack of uniqueness and often difficulty of access reduce their practical use for traceability.

Relevance to Apple and Pear Industry: (For direct traceability = Problematic) This kind of identifier appears to be most often used on-farm in the apple and pear industry. They are most likely to be recorded in a farm management system or on paper-based records. The ability to leverage this information is impeded due to the diversity of these systems and the lack of labelling and information exchange standards. Typically bins from the orchard having local identifiers are reidentified/relabeled on arrival to a storage or packing facility. Their new identifier will be registered in the management system associated with the facility and the original farm identifier may or may not be stored against this. Overall, the use of local identifiers creates a barrier to effective and efficient traceability.

System specific identifiers

Description: These identifiers are generated within a system and their uniqueness operates in that context. They are often serialized where the next item to be identified takes the next sequential number in the systems list. To identify a new item or thing the parent system must be either be contactable to get an identifier to put on a label or the labels (and associated system identifiers) need to be pre-generated and printed. Advanced systems may support many different system specific identifiers for different purposes. While these identifiers may be complex and contain descriptive or metadata, effective traceability requires the ability to access, exchange or extract information from the parent system.

Assessment: As these identifiers are system specific, traceability becomes dependent on system exchanges and the ability to match identifiers when multiple systems using this type of identifier exist along the production and supply chain. These kinds of identifiers work best when a system operates across large portions or the entire production and supply chain because these exchanges and associated complexities are minimized. Many very advanced and sophisticated traceability systems still use this kind of identifier and there are some arising from the manufacturing sector that can cover the bulk if not all of a production and supply chain.

Relevance to Apple and Pear Industry: (For direct traceability = highly relevant for current solutions but may be superseded in the future) The more mature and comprehensive system solutions using these identifiers have arisen in the manufacturing sector. There are examples where billions of product units are being efficiently traced and traced along the full supply chain including providing support for consumer feedback. The applicability of these solutions is compromised because the apple and pear production settings are substantially different from the manufacturing equivalents. Consequently, the application of these solutions for fruit traceability currently aligns best to operations after fruit is packaged. If these identifiers continue to be used by the industry either (1) current system solutions should be looked at to enhance operation across more of the chain (vertical integration) with particular emphasis in expanding to support operations and traceability in the production setting or, (2) standards and protocols need to be designed to support interoperation and information exchange between the systems operating along the chain.

Globally controlled identifiers

Description: This is a specialized variant of the preceding class of identifiers where governance of the creation of identifiers is globally controlled and managed. Because this effectively represents a single system with overarching command and control, the identifiers minted are globally unique within the system. These approaches are just an extension of system specific approaches but have global coverage and adoption.

Assessment: The main example of this type of identifier is the GS1 system. The GS1 identification scheme provides structure and global governance of minting and registering identification tags for a broad range of things. This particularly supports a structured approach to identify contextual "things" in relation to supply chains but has some overheads. At present it appears to become more unwieldy to apply to product tracking at resolutions below the concept of a consignment or "batch" (although it can support finer resolution). To achieve fruit package identification current GS1 approaches require the combination of the GS1 GTIN with a serialized package identifier to create a unique identifier. The GS1 standards include ways to describe products, locations, business entities, processes, and events. The emerging GS1 digital link standard will potentially provide a standard way of structuring links between identified things and their associated information in other systems along the production and supply chain. Although the GS1 identifiers and standards are at heart system specific, the momentum and extent of their current adoption make them an essential consideration for any significant traceability solution.

Relevance to Apple and Pear Industry: (For direct traceability = probably essential) The GS1 standard provides example mechanisms to manage the information linking the assembly and disassembly of fruit cartons/packs into pallets and containers. The GS1 digital link standard and the food traceability information standards emerging in America will inform approaches to enable information exchanges along the apple and pear production and supply chain.

References:

The full suite of GS1 documentation and standards can be found at https://www.gs1.org/standards .

GS1 Digital link Standard v 1.1 (2020 Feb). Published at https://www.gs1.org/docs/Digital-Link/GS1_Digital_link_Standard_i1.1.pdf

Externally applied unique identifiers based on "fingerprints"

Description: These are tags that are unique when created that are then registered in a database for later reference in authentication processes. They are functionally no different to other forms of globally unique identifiers except they do not carry any readable information. In definition they are no different to a human fingerprint except their genesis guarantees uniqueness. These tags may be image based (on printed labels or silica tags), trace element based[12] or based on DNA biomarkers[13].

Assessment: Only two examples of these identification solutions have been reviewed in detail. The first is the visual fingerprints created by the proprietary company Laava. But the following analysis would apply to other solutions of this form. The unique Laava digital images are generated and stored in the Laava system and then assigned to purchasers/users who print them as labels for product. Validation of the label requires connection to the Laava system. Because their generation is the core product of the company, they then need to be combined with other vendor systems if traceability beyond point of origin is desired. Because no other vendor can create a Laava visual fingerprint any partner or client using the technology is locked into the Laava solution. In function they appear no different to the globally unique identifiers (GUID's), except these others can be easily generated, read, and hence integrated into solutions anywhere with no vendor lock in. A point of difference in the Laava solution is that the authentication processes are very sophisticated and strong, relying on more than just the fingerprint. When a product label containing a Laava fingerprint is first scanned more than just the fingerprint is captured. This creates a second image reference that enables detection if the fingerprint is copied and applied to a different label.

A new application of DNA technology by Aanika Biosciences is using genetically modified forms of microbes that are individually and uniquely tailored to a farm or even a batch of product establishing a globally unique DNA identifier. These edible and encapsulated microbes are resilient and applied to the surface of products early in the production and supply chain. This enables the product source to be reliably and more precisely identified but depends on verification or lookup from the Aanika system to authenticate identity and other associated information. Aanika Biosciences is working with GS1 to see how the technology can be integrated with their frameworks. Often just the knowledge that these technologies have been applied to product discourages food fraudsters.

Relevance to the Apple and Pear Industry: (For direct traceability = very good for point of origin traceability but may take more effort than other GUID's for product tracking) The use of these forms of unique identifiers for traceability is very useful but the overheads and dependencies of being locked to single vendor's systems may lessen the attraction. Types of solutions in this space should consider both (1) the ease of the associated assessments and preference given to those that can be undertaken cheaply and in-situ and (2) the credibility and uncertainty of the assessment which impact the strength of the results for legal and evidentiary purposes.

References:

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Laava connect API documentation. Accessed Jan 2021 at https://connect.laava.id/

Globally unique identifiers

Description: Globally unique identifiers are "globally unique" and typically formed from the combination of a machine address and a fine resolution date/time stamp. This enables them to be produced by almost any contemporary device be it a computer, phone, printer, barcode reader or other mobile device.

Assessment: The ability to create or mint GUID's on the spot in most contexts is a significant advantage. When their registration is then coupled to a service and/or backend system this makes them "live" and the system then provides the security for authentication and further use. Ideally when a GUID is minted it will be simultaneously registered (ie through a cloud or web-based service) and ideally printed as a label that is immediately affixed to a

[12] Trace elements are present in very low levels in fruit and unique patterns of trace elements can be constructed that are still at low levels (but significantly higher than background traces). These are then used to dose product creating a trace element fingerprint. This works best for point of origin traceability.
[13] DNA biomarkers can be artificially created DNA segments or even bacteria with genetically modified DNA that are applied to products. These DNA components can be uniquely tailored for a specific grower or even batch of fruit but require specialised equipment or services to enable verification.

unit of product. That product instance is now uniquely identified for its journey along the entire chain and every time the label is scanned this, and associated information can potentially be recorded. If the label is copied for use elsewhere then a product will immediately appear to have multiplied thereby providing evidence of food fraud. The ability to combine identifier creation, with registration and labelling aligns well to use with automated or robotic systems. In practice any labelling system that can encode information can support these GUID's. These more open GUID's have low to no overhead for their creation, are easy to read and potentially provide many of the same benefits of other globally unique approaches like visually unique fingerprints (Laava) and genetically modified fingerprints (Aanika Biosciences). Many new and advanced traceability systems are using these open GUID's as the basis for identification. A good example of the power that can accrue from them is displayed in the Eon traceability solution that is applied within the garment industry. This enables full individual tracing from manufacture where constituent materials are recorded all along the chain through to purchase, purchaser details and subsequent re-sale for as long as the garment exists.

Relevance to Apple and Pear Industry: (For all forms of traceability = could enable significant improvements) The use of open GUID's can potentially allow multiple systems along the apple and pear production and supply chain to use the same identifiers and lay the foundations for system interoperation and information sharing. They create the opportunity for the most advanced traceability support when integrated into traceability solutions and with frameworks such as GS1.

References: N/A

Group - Intrinsic Identifiers

Overview: Intrinsic identifiers are integral to a product or its close environs (such as its surface) and are extremely difficult if not impossible to disassociate or remove from the product. In the case of food, they usually lack precision to provide individual identity for a unit of product. Their main application in traceability is largely limited to detecting food counterfeiting by providing a means of establishing if a product could not have the provenance that is claimed.

DNA profiles/fingerprints

Description: The results of a DNA assay that has been registered and provides a subsequent reference to compare with new sample analysis results. Such reference DNA profiles are termed DNA fingerprints and where the analysis is focused on a particular area of the genome may be termed DNA Barcodes.

Assessment: This increasingly sophisticated technology can only have precision in direct product identification if the product units display genetic heterogenicity (ie variability in an individual unit of product's DNA such that it supports unique characterization). In horticulture the genetic variability is such that identification using this method will not deliver better than a fruit type and variety[14] (unless a variety exhibits some form of mutation that has propagated to become characteristic for a locale or district, or a genetic marker has been applied). However, if a genetic fingerprint can be taken of the population of bacteria or yeast on the surface of fruit this may be characteristic of the setting or locality from where the fruit originated. If this fingerprint is stored it can be compared to that of fruit along the chain. Fruit that doesn't match the fingerprint can be judged to be originating elsewhere. It is yet to be confirmed this second form of DNA fingerprinting is unique to locations as not enough have been recorded and there does not appear to be a reference library established for them yet. Consequently, fruit from multiple locations may have the same fingerprint. Until a substantial reference library of these kind of DNA fingerprints is established and more is known about if and how they may vary from season to season it is unlikely this approach will enable fruit provenance to be identified. Another utility for DNA fingerprinting is in biosecurity where the DNA fingerprint of an undesirable organism is used to detect the presence of such.

Relevance to Apple and Pear Industry: (For product traceability = Limited; For biological contaminant detection = Useful; For fruit provenance traceability = some potential) Because apple and pear production is based on varieties (clones) DNA fingerprinting of the product will be constrained to supporting fruit identification on that basis. More research would need to be done to establish the usefulness and applicability of yeast /bacteria DNA fingerprinting for the industry. At this point a limited use for DNA fingerprinting would be during consignment inspection to establish/confirm the variety of fruit if this is not already known or knowable by other means and more

[14] A range of recent literature was reviewed, and this indicates that while apple and pear varieties can be distinguished using DNA analysis there is no evidence there is sufficient genetic variability to identify individual trees within a variety as they are clones.

importantly to assist in detection of biological contamination in the production and supply chain.

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Guyon F. et al (2020) Traceability of fruits and vegetables. Phytochemistry Vol 173

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Chemical profiles/fingerprints

Description: In the food industry the chemical constitution of a product in particular its isotopic and /or trace element makeup can reflect the location where it was produced and/or the processes it has undergone. In this setting the chemical analysis profiles can be termed “chemical fingerprints”. Typically, a focus chemistry like certain isotopes and their ratios are used from a product sample to establish these fingerprints. If only isotopes are used these are called isotopic fingerprints and it is the combination of isotopes present and their relative abundance that is used to establish the profile. In horticulture Isotopic fingerprints are heavily influenced by the soil, biophysical environment, and management in the production setting.

Assessment: A wider range of factors can impact these kinds of fingerprints and only some areas (like wine and beverages) have done enough research and sampling to establish a solid reference library to support accurate regional provenance tracing let alone test if identity can be established or driven to a finer level. The situations where these technologies are currently applied tend to focus on detection of product tampering or substitution rather than precise product identification and traceability. In other words, the technology better supports understanding what a product isn’t rather than necessarily exactly where it has originated. Research indicates the reading of the fingerprints requires lab-based facilities and services and has yet to be translated into a “field tool”. The technology is applied to detection for food alteration (adulteration) but for supply chain monitoring of chemical contaminants existing standard detection tests would be more accurate and appropriate. Companies using this technology like Oritain maintain a database of product “fingerprints” and subsequent product tests are matched against these to determine the likelihood the product was produced in the area claimed. The Australian company Source Certain uses the same approach but additionally tests the soil from the production location and reputedly analyses a wider range of chemistry than competitors. Having a fingerprint from the production system provides an additional benchmark for product comparison and identification. While Oritain demonstrates the ability to identify product origin to a production area, Source Certain claim their solution with adequate initial sampling is precise enough to identify the paddock or fruit block where production occurred. The technology appears good at identifying when a product is not what it is claimed but wider adoption is probably required to generate larger reference libraries of fingerprints to provide sufficient evidence that fine discrimination of point of origin is completely reliable (ie there may be other locations in the world that have similar fingerprints). Because the technology is based on fundamental chemistry samples that are stable in this respect, specialized lab facilities are required to support their measurement and there may be limited localities where these are present. This may require samples to be sent some distance impacting turnaround times to obtain assessments.

Relevance to Apple and Pear Industry: (For provenance traceability = proven cases with further potential). The establishment of a reference library of these fingerprints is essential and more research would need to be done to (1) establish how and if these vary seasonally and (2) the level of local identity they can reliably support. The technology appears to apply to provenance tracing for fresh fruit with examples from both companies in apple supply chains[15]. There is no reason it could not apply equally for pears. It has been used successfully to detect adulteration of other processed products (ie wine, honey). Again, this would be applied during consignment inspection (or later) for food substitution detection or point of origin traceback. In other industries, like the wine sector, these fingerprints are used for testing high value bulk product (where a small sample is directly representative of the whole batch). The cost benefit analysis for use of the technology for apples and pears would need to be done and is likely less attractive than the wine example cited.

References:

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Suzuki Y. & Nakashita R. (2013) Chapter 18 - Authentication and Traceability of Fruits and Vegetables. Comprehensive Analytical Chemistry Vol 60 pp 461-477

Individual feature recognition

Description: This method uses digital imaging, AI, and machine learning to analyze an image and compare this to an image in a reference library to establish a match or "recognition". The technology has its foundations in facial recognition research. For these approaches to work (1) a thing needs to visually have something that is individually unique, (2) the images need to have sufficient reference points or features to assist image orientation for matching, (3) there needs to be an accessible library of images with the reference image in it for comparative purposes, and (4) the feature must retain its character to be recognizable and be present to be scanned.

Assessment: For individual identification purposes this technology needs the subject for identification to have features that are consistently present for reference purposes. One of the key functions of these it to enable a subsequent image scan to be orientated to the original and other reference images so matching can occur. While a sheep, cow, eye, crayfish carapace or salmon have features that allow this a fruit generally only has a top and a bottom. Put simply this will support have images that are respectively "up the right way" but the question is where you start the match on a 360degree scan of a fruit. There is absolutely no guarantee a subsequent scan will start in the same position. For this reason, individual fruit identification is problematic. However, initially fruit imaging was focused on being able to automate the identification of fruit to its type and perhaps variety. This evolved to the use of imaging not for fruit identification but for fruit measurement and characterization. This was applied and now forms a foundation in contemporary fruit grading and packing systems. Now the push is on to move these and an additional suite of functions to find fruit within the tree into the orchard as this is essential to enable robotic harvesting.

Relevance to Apple and Pear Industry: (For direct traceability = None; For influence on production operations that will enable traceability = Potential substantial influence). This technology is unlikely to be useful to support direct identification for apple and pear traceability because (1) the cost ratio of system establishment (imagine storing all those images) and operation over unit value (and volume) of product is prohibitive, and (2) it is not proven nor likely to allow identification for individual fruit as there are insufficient reference points to orientate the scanned image for comparative purposes. However, the ability to use imaging technology to recognize the location of fruit on the tree and assess its qualities is essential to enabling selective robotic harvesting. This imaging and

[15] For traceability Oritain is used by Mr Apple New Zealand Ltd and Source Certain in case study with Fruit West Cooperative Ltd in Western Australia with the Bravo Apple variety.

interpretative analysis is synonymous with the fruit grading function and creates the potential to grade and pack at harvest in the field. If trees (or tree blocks) have an RFID or visually scannable identifier, then the robotic system could automatically associate packed fruit with the parent tree or block. The identifier for the fruit pack could then operate across the whole supply chain until it is unpacked at point-of-sale providing potential full traceability from the tree (or close to it). Substantial research is required to realize this operationally and there would be significant impacts on industry operation, but this is currently technically feasible.

References:

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Lu Y., He X. & Wen Y. (2014) A new cow identification system based on iris analysis and recognition. International Journal of Biometrics Vol 6(1) pp 18-32 DOI: 10.1504/IJBM.2014.059639

Rojas-Olivares M., Caja G., Carne S., Salama A., Adell N. & Puig P. (2011) Retinal image recognition for verifying the identity of fattening and replacement lambs. Journal of Animal Science Vol 89(8) PP 2603-2613 DOI: 10.2527/jas.2010-3197

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Vo S., Scanlan J., Mirowski L. & Turner P. (2018) Image Processing for Traceability: A System prototype for the Southern Rock Lobster (SRL) Supply Chain. Proceedings of the Digital Image Computing: Techniques and Applications (DICTA), Canberra, Australia DOI: 10.1109/DICTA.2018.8615842

Traceability Architectures and Systems

The diversity of traceability functions within the Apple and Pear industry is usually supported by many systems that have evolved over time. The emphasis and requirements of fruit traceability has grown and is increasingly important in maintaining market access and addressing food safety. This continues to drive the evolution of the systems that contribute to traceability. Facilitation of traceability requires the right kind of system functionality at each point in supply chains, but just as importantly needs these systems to support one another or “interoperate”. An apple or pear fruit pack’s specific supply chain is made up of all the participants and supporting systems in its journey to the consumer. Any variation in this chain such as in the participants, freight carrier or destination market creates a different supply chain. Consequently, there are many supply chains in operation. Some elements of these will be common across chains such as the processor/packer, disinfection facility, freight company and destination market. This creates a complex setting and difficulties for the assessment of systems and associated technologies.

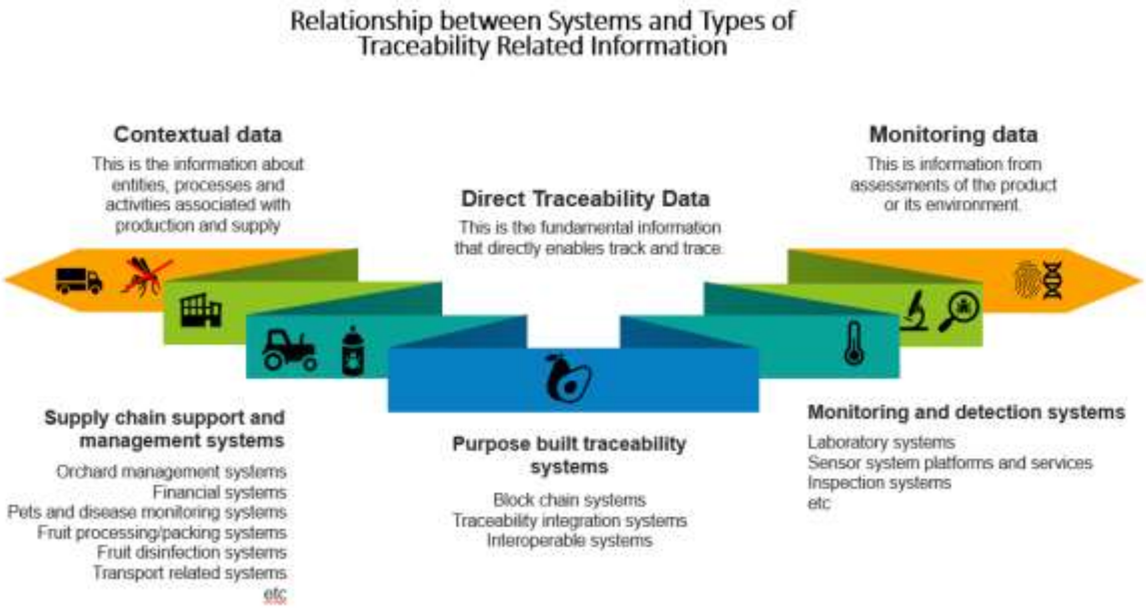

Figure 6 Relationship between traceability related information and current systems

The earlier traceability information classification scheme (Figure 1) is used to partition the systems within the APPSC to assist in understanding this complex setting. This partitioning is outlined in Figure 6 above. In the main the systems that actually support the operation of supply chains sit in the left of the diagram while those underpinning supply chain monitoring are on the right. Most of these systems are discrete, and any current system integration is usually centered around steps within the supply chain like the processing and packing step.

An initial assessment of the APPSC's identified the following issues:

- In each area of the production and supply chain there is a mix of system solutions from multiple vendors. These can range in complexity from simple spreadsheet-based applications through to sophisticated service-based solutions operating in the cloud.
- The focus and objectives of these systems (particularly legacy systems) is to support the operations of the various stakeholders and services at points along the chain. Considerations of traceability may not have been central in system designs and current functional support for traceability may be a by-product of addressing logistical and other management operations[16].
- There are so many systems present that it has been impossible to encompass the assessment of all in this review[17].
- The Apple and Pear industry is beginning to test and implement purpose-built traceability systems and solutions.

To provide further clarity a traceability maturity model for the APPSC (Figure 7) has been developed. This recognizes various "traceability development states" that may be present within the industry.

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[16] An example is that the need to exchange data along the chain (a key requirement for traceability) is particularly poorly developed in many older and even some current systems.

[17] While a desktop web-based review of many of these system products has been undertaken the pandemic has restricted our ability to observe these in operation. A limited number of key exemplar system solutions were selected for follow-up interview with their developers to gain a more detailed and technical understanding of these products.

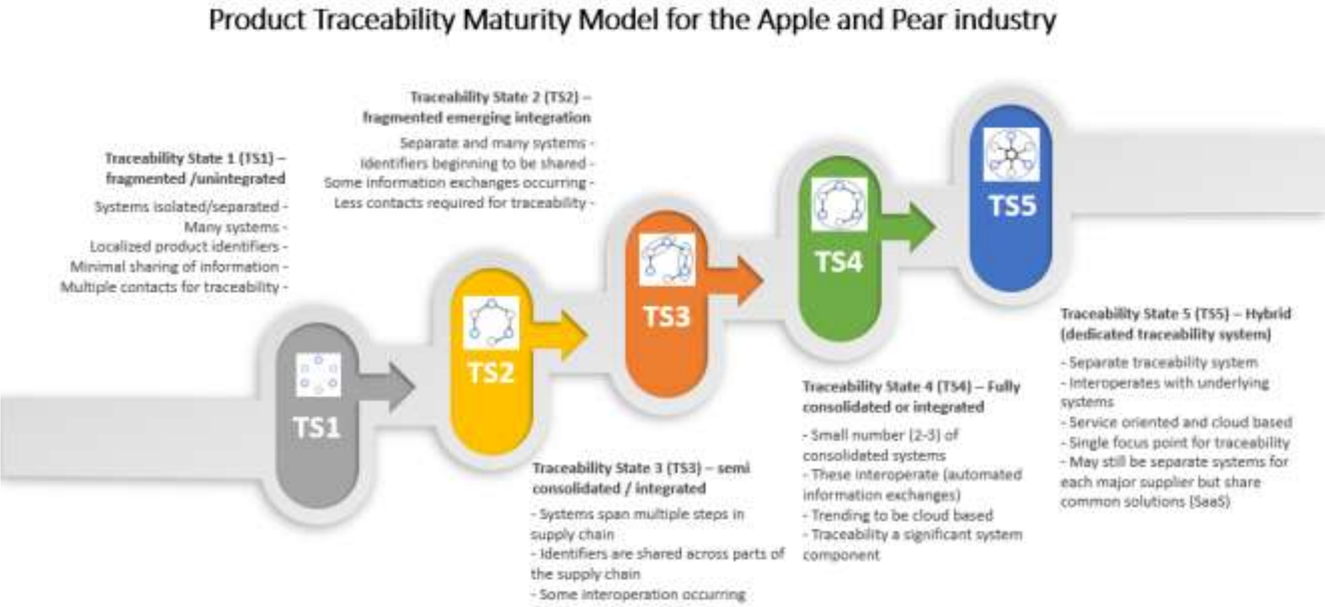

Figure 7 A maturity model for comparison of system solutions in Apple and Pear Traceability

The following are brief descriptions of the traceability states in the above figure.

- Traceability State 1- The systems along the production and supply chain are discrete and focused on the specific functions and operations associated required by the chain component where they operate. New product identifiers are usually created and managed independently within the many systems that often operate. There is limited information exchange, and this is often hardcopy such as on bin cards. Traceability may require access to each individual system.
- Traceability State 2 - The systems along the chain are still fragmented or discrete in their operation (as in TA1) but are using and sharing common identifiers in areas of the supply chain (ie may have same fruit bin identifiers at harvest through to processing) and are now capable of supporting more automated exchange of information between systems. This is establishing the beginnings of easier traceability.
- Traceability State 3 - Multiple steps within the supply chain are now being supported by common systems and as a result there are less systems to contact for traceability purposes and there should be a higher degree of information integration within these consolidated systems.
- Traceability State 4 - While there may be multiple component systems these have a level of integration to operate collectively as one system along most of the chain. This is usually associated with an enterprise with a high degree of vertical business integration. Typically, this kind of solution may operate from the production stage through to export or receipt at market.
- Traceability State 5 - This is a bit different in that there is a specific traceability system that operates across the whole or major portion of the production / supply chain. The underlying systems within the chain interact with this to lodge information for product traceability and authentication purposes. The actual deployment and nature of the underlying systems within the chain can vary but to be effective this architecture requires they interact with the traceability system overlay. Effective implementations of this type are service oriented and based on open standards.

During 2020 it has been difficult to engage with APPSC supply chain participants due to the Covid19 pandemic. Consequently, it has only been possible to inspect and directly interview some of the larger APPSC operations. However, it is our assessment that generally the APPSC is fundamentally operating in traceability state 3 (TS3) with some of the bigger operations in the early phase of moving to a dedicated traceability system (traceability state 5-TS5). The analysis indicates the increasing pressure for traceability linked to export market requirements has initially resulted in traceability functions being added into the systems currently in operation in the left of Figure 6. This is logical as these systems are intrinsically essential for the operation and logistical support in production and supply so need to be maintained. Because much of the APPSC requires sophisticated fruit handling, processing, and packing many growers have "connected" in various ways with larger companies who have these facilities. This is producing degrees of vertical integration that has assisted system consolidation/integration and underpins the assessment that the APPSC is mostly at TS3. However, to move from this state to Traceability State 4 (TS4) would require all participating systems to become interoperable. This is confounded by the number and diversity of vendor systems and products.

With the development of the cloud and Internet of Things (IoT), it has become simpler and more achievable to develop traceability systems that sit over the top of the existing systems and use standardized services to harvest required traceability data from these and/or chain events (this is the emergence of TS5). Some of the larger operations have begun approaches of this nature in the APPSC over the last year. A specific example is Fruit West Cooperatives use of Source Certain International scientific technology, TSW Trace® (chemical fingerprints) and blockchain technologies for Bravo Apples in Western Australia. Similarly, a new pilot project funded under the federal "Traceability Grants Program" and supported by APAL utilizes FreshChain's block chain solution.

KEY FINDING: ***The analysis suggests some major participants in the APPSC are in the early adopter space for purpose-built traceability systems that focus on food fraud and point of origin traceability.***

The current initiatives are focused on point of origin and fruit authenticity traceability because the major drivers at this point are food fraud, reputation protection and biosecurity and food safety trace to point of origin for issue resolution such as product recall. The industry has yet to implement TS5 style solutions for full product traceability because they add to the complexity of integrating logistical unit tracking and hence it is operationally difficult to support broad coverage for fruit package scanning.[18] If it did go down this path, the use of a common supplier of the authentication and traceability component of solutions should be considered as when a vendor provides software and data as services, these can be tailored for specific clients/operations within the industry and provide a platform for whole of industry analytics. In such a setting the performance of multiple supply chains could be analyzed for instance of those contributing to a specific market. Blockchain and other analogous cloud-based data platform technologies are already aligned to this style of solution with blockchain potentially having the advantage of being "immutable"[19].

Apple and Pear production and supply chain

Chain description

A generalized description of the APPSC is shown in Figure 8 below. This has been segmented into four different settings or zones. These zones have been formulated to better allow identification of traceability functions and are described in the following subsections. These descriptions briefly cover the operations in the zone and its specific traceability aspects or opportunities. The current approaches to traceability and potential technological improvements are then discussed. The fourth setting (point of origin trace) extends and can apply across the whole chain except before harvest where it is irrelevant[20]. The APPSC is characterized by multiple fruit pathways with export and domestic showing marked differences. Additionally, because pome fruit can be held in storage for extended periods there are pathways that involve storage and ripening steps and fresh fruit pathways that are very efficient with an objective of some operators to get fruit to point of sale within 11 days after harvest.

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[18] For example, from existing case studies it is estimated that less than 10% of fruit packs with a Laava code will be scanned before being sold at retail.

[19] Immutable – once data is lodged it can't be changed giving it highest credence.

[20] Prior to harvest apples and pears are at the point of origin.

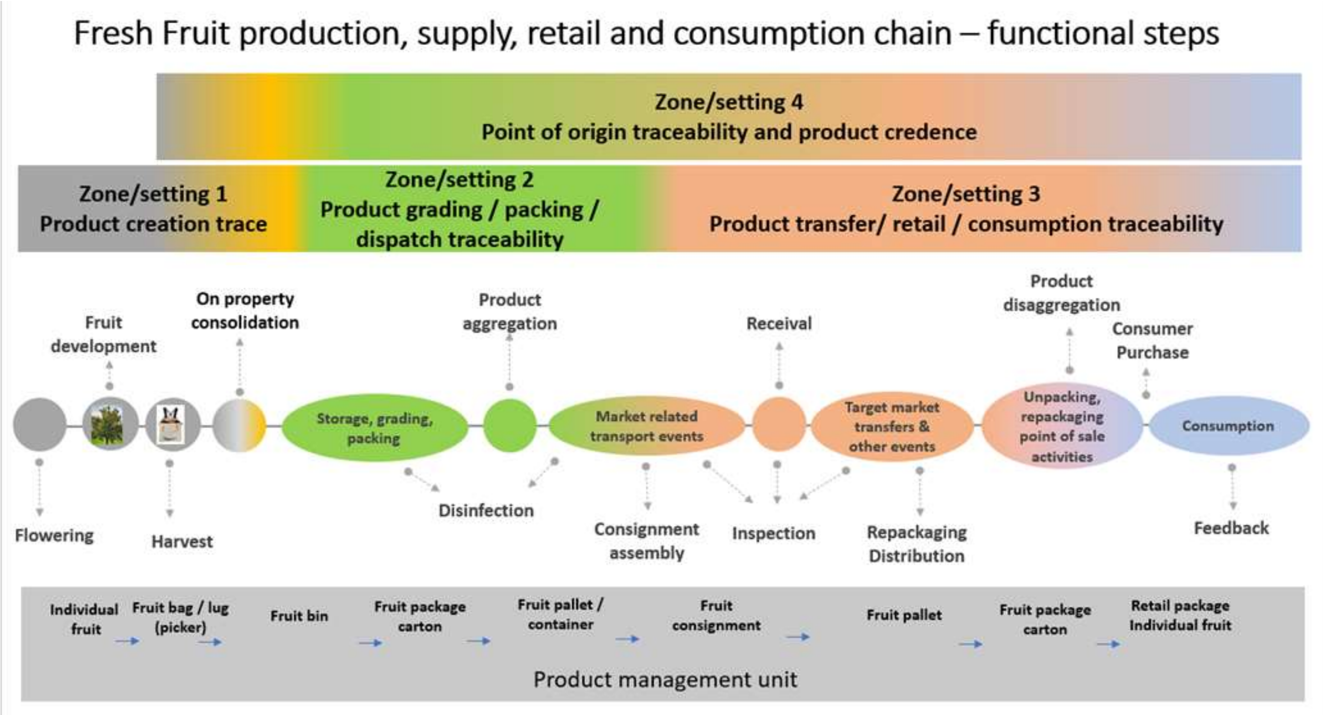

Figure 8 A generalized production and supply chain for APPSC

Zone 1 – Traceability in the production setting

The fundamental operations or steps in the production setting workflow are shown in Figure 9 below. These are aggregated into 3 stages "production", "harvest" and "transfers". Within and along these steps there is another level of detailed operations that may be occurring. The most relevant of these are outlined in table 1 against each stage.

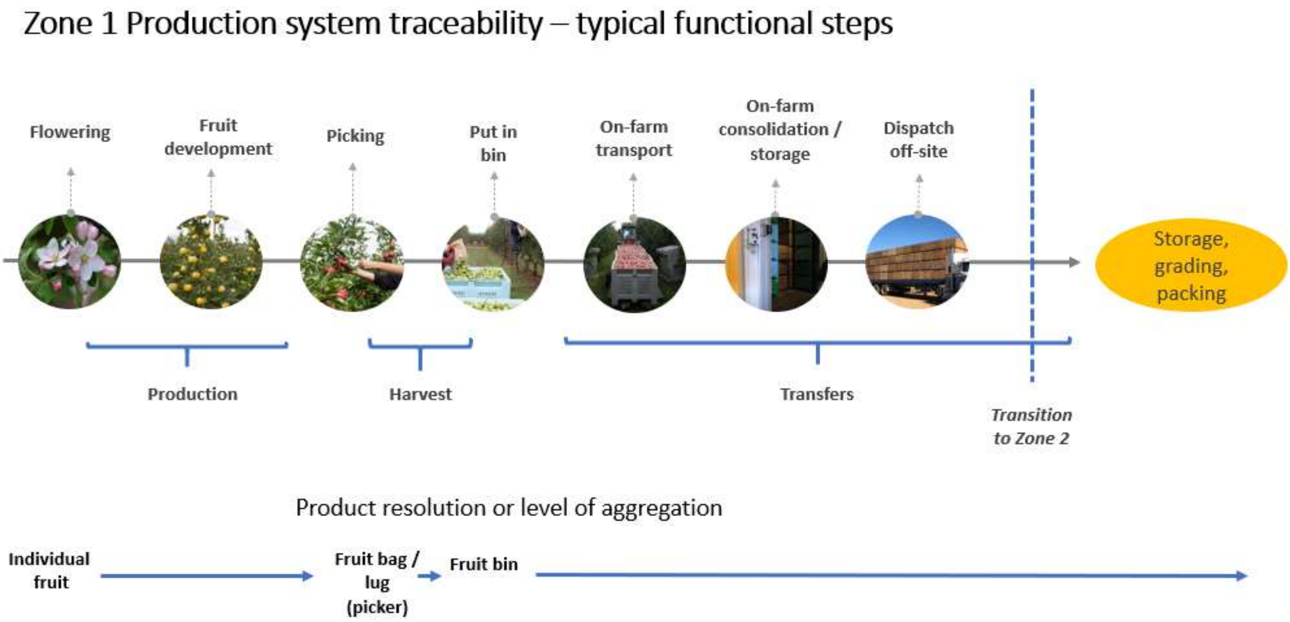

Figure 9 Apple and Pear production system traceability

The systems that may be currently operating within this zone include spraying systems, spray diaries, orchard, harvest, picker, and cool storage management systems. For some enterprises these may be consolidated into an integrated system solution such as GrowData, AgPick, Farmable or Tie up Farming. At their best, present systems operate down to the resolution of a fruit block or tree row/s. Production trace to a fruit block is one of the requirements from the national performance standard for horticultural farms[21]. Orchard blocks may be variable in shape and size, but a typical apple or pear orchard block could contain 6000 trees or be around 2 ha in size. Orchard blocks are not always comprised of a single variety and this may add additional definition within a block for traceability.

***KEY FINDING:* A traceability objective in orchards could be to improve the resolution of information capture so that production and other important information could be traced at or near to the level of individual trees.**

Pursuing the above objective would enable integration with information from emerging variable rate spraying and crop load sensor-based technologies that are already beginning to operate and capture data at this level. While current processing and packing operations may not be able to maintain this level of traceability for zone 1 the improved resolution would deliver detailed production information which could potentially be matched to data from the previously mentioned technologies and to orchard management information. This would enable more accurate assessment of the efficacy or effect of orchard management practices or inform where changes need to be targeted to improve production or its efficiency.

Stage	**Operation/Activity**
Production	- Crop thinning (ie chemical) - Chemical spraying for weeds, pests, and diseases - Crop monitoring for pests and diseases - Crop assessments (load, quality, and readiness for harvest)
Harvest	- Harvest planning/coordination/management - Picker training (pre-harvest) - Picking - Labelling of bins (if not prelabelled) - Picker tallies, payments and other records and recording - Consolidation of fruit into bins
Transfers	- Transfer from orchard to early chilling / cool storage - Transport off-site (if required for processing/packing)

Table 1 Production zone traceability related operations

To achieve this requires the emplacement of identifiers on smaller units within an orchard block such as a row,

[21] Australian Government Department of Agriculture Water and the Environment. Reference – Performance standard for farms.

group of trees or even individual trees (less commercially practicable at present[22]). This would facilitate registration of fruit picked (ie picker bag) to both production context and the bin that receives the fruit. Because pickers (or picker bags) and bins currently have identifiers orchards systems may already support the picker/bin association to varying degrees, but the production link is currently mostly at an orchard block level.

New developments in robotic fruit harvesting are beginning to create the potential to achieve even better traceability outcomes. A three-tier model describing incremental improvements for traceability that may eventuate from robotic harvesting is shown in Figure 10 below. This figure is largely self-explanatory.

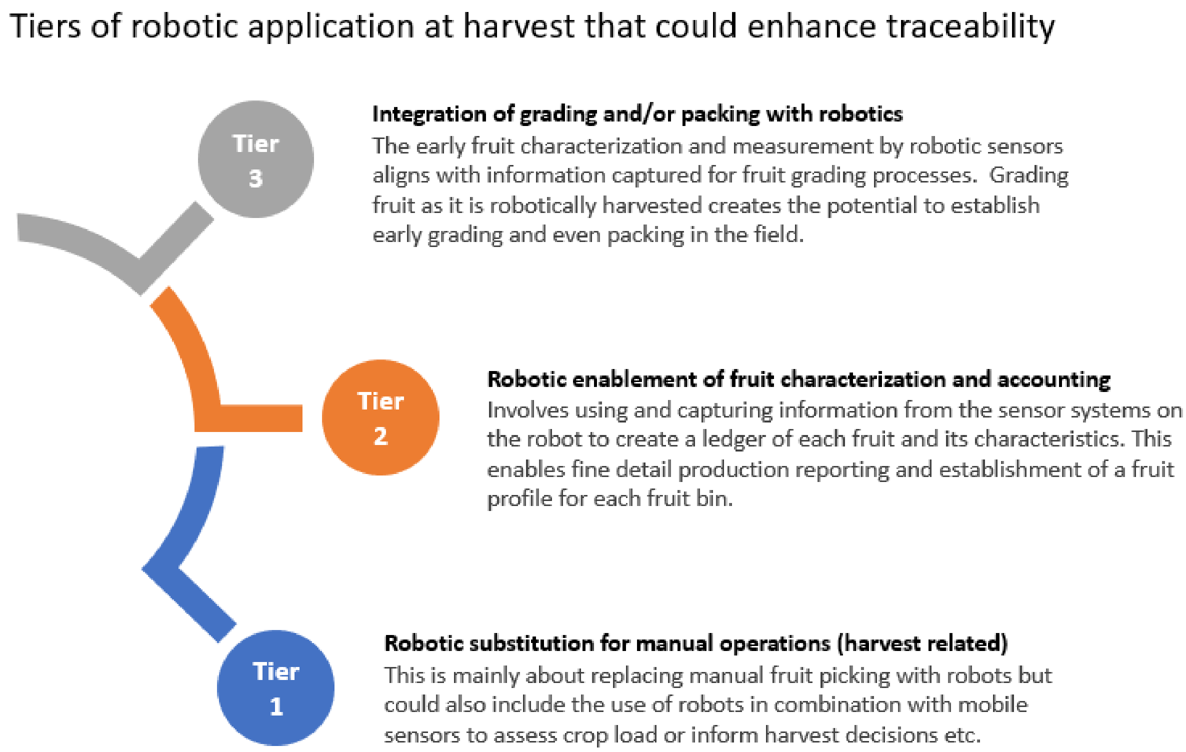

Figure 10 A hierarchy of robotic applications for enhanced operations at fruit harvest

If Application Programming Interface (API) services are used to facilitate exchanges of information from the robot to cloud based backend data stores, then this data potentially becomes immediately available to inform processing and packing operations. At tier 1 this should enable the assembly of bins for a processing batch at a finer spatial grouping than a fruit block. If operating at tier 2, bins could be strategically selected based on their known fruit grade profile to better align and manage batch sizes to orders. Both these refinements could improve traceability and the relationship between batches and traceability will be discussed further in the next section. At tier 2 information is recorded for all fruit but there is no individual fruit identification. This fruit characteristic information is generated both at tier 2 and 3 from the sensors required to support robotic harvesting. The amount of information is dependent on the sensors present in the robotics solution. At tier 3 if sufficient information is generated this could be harnessed to support the robot grading fruit and if this is combined with support for in field packing it should deliver fruit traceability to near tree level. More research is needed to enable this and progressing this style of approach should consider the market requirement for this level of traceability. Early approaches could focus on selectively grading and early packing premium grade fruit destined for export with the rest going through current processes. In the extreme it could be possible in this setting to put individual stickers to identify each fruit and register these to each carton as they are packed[23]enabling each individual fruit to be traced

[22] Agriculture Victoria Research is trialling individual tree identification within Apple, Pear, Stone fruit and Nut orchards at the Tatura research farm in Victoria.

[23] Stickers would be pre-printed with a GUID and when placed on a fruit and into a carton a record sent via a service to register both the fruit and the carton containing it in the cloud-based data store. Because further processing of fruit should not be required these individual fruit stickers should remain in place. This would support

up to consumer purchase.

Zone 2 – Traceability during storage, processing, and packing

The fundamental operations for this settings workflow are shown in Figure 11 below. The individual steps or operations are aggregated into 3 stages “ingest associated operations”, “processing and packing” and “order preparation and dispatch”. Note that there may be brief periods of storage occurring across these stages. Within and along these steps there is another level of detailed operations that may be occurring. The most relevant of these are outlined in table 2 against each stage. During processing and packing water is used to move fruit through these steps as gently as possible.

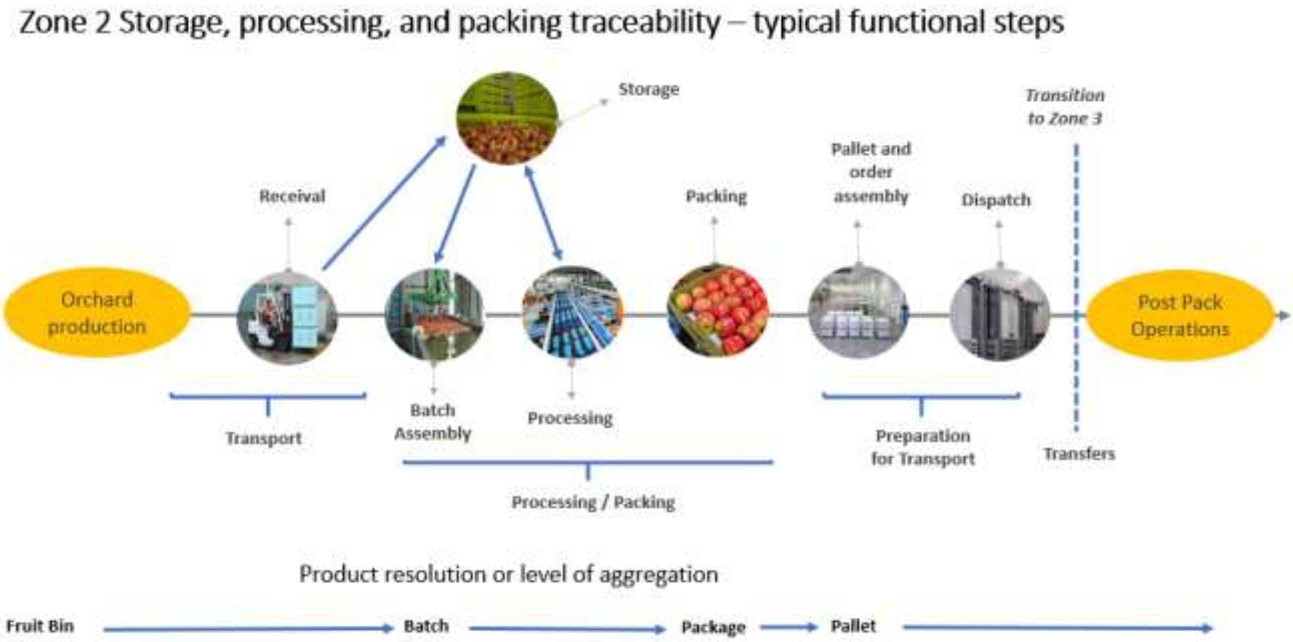

Figure 11 Apple and Pear storage, processing and packing traceability

From a traceability perspective the most significant activity is when and how batches are established. This is because in large operations the bins selected for a batch will be tipped into a bath where they will mix. This essentially reduces further point of origin traceability from this point to the level of a batch. The criteria used to form a batch is therefore important to maintaining the highest possible level of traceability. The criteria commonly used to form a batch for the APPSC are variety, orchard, orchard block and harvest date. Adding “picker” to the batch criteria potentially enables picker-oriented fruit quality feedback from the processor/packing house to inform harvest activities. All bins contributing to a batch need to match the same criteria to enable traceability. Some processing operations may not capture information to support resolution down to an orchard block particularly for external growers that are using their own bins and labels and specifically only contracting processing and packing services. In these cases, the orchard management systems must contain this detail and the multiple systems will need to be interrogated to meet traceability requirements. When the apples or pears have been processed and packed the resultant packages represent a stable unit that can now be identified and potentially traced along the rest of the supply chain. Consequently, the way these packages are identified and labelled sets the scene for further traceability. Historically these packages may have just been branded and has now evolved to adding the batch identifier into labels so a package can be linked to a processing batch. More recently packs are also additionally being individually identified as this creates appropriate support for individual package tracking, addressing food fraud and more precise identification of events and points of contamination and impact on fruit quality. This is where approaches based on GUID’s and associated new technologies such as Laava labels apply. There are well developed traceability systems in other industries that kick in at the level of a “product unit” and these are often leveraged to underpin solutions for fruit traceability. All these factors contribute to the often-held view that fruit traceability and associated systems begin with a fruit pack. This is bolstered by the fact

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fruit identification even when it is unpacked into a retail display for individual consumer purchase.

that the core foundations for product traceability are established in this zone and that all other participants further along the chain tend to rely on these. Indeed, for the Australian domestic market, even the large distributers and retailers may lack a product traceability system with almost full reliance on the identity and labelling established at the processing and packing facility.

Stage	Operation/Activity
Ingest and associated movements	- Receipt of bins and associated recording - Transfer into interim cool store (if required) - Transmission of order requirement to harvest operations
Processing and packing	- Batch establishment and tipping of selected bins into bath - Fruit washing (up to 4 times) - Fruit grading - Fruit QA and inspections - Fruit packing
Order preparation and dispatch	- Palletization of packed product to meet orders - Interim cool storage (if needed) - Organize transport - Load and dispatch

Table 2 Apple and Pear processing and packing traceability related operations

There are range of systems that operate in this zone. These include those that support logistics, financials, orders, fruit grading, fruit packing/ pack labelling, quality inspections, environmental sensing[24], order assembly/ palletization and grower and other reports. The systems in this zone may be the most integrated in the supply chain as they tend to operate within the same setting. In advanced situations these systems may be integrated and interact with orchard management and recording systems creating potential feedback loops to inform harvest operations.

Increasing the resolution of traceability in zone 1 and improving orchard production and subsequent pack out[25] provide an interplay of factors that may influence batch formation and hence traceability.

References:

Bollen AF, Riden CP, Cox NR (2007) Agricultural supply system traceability, Part I: Role of packing procedures and effects of fruit mixing. Biosyst Eng 98: 391–400.

[24] At several points and environments in the workflow such as maintaining water temperature and monitoring cool storage facilities.

[25] Increased production results in more bins meaning a batch may be constructed from a more constrained area (concept of smaller blocks). Increased pack out means less bins are required to deliver the same volume of fruit packed and if the improvement is significant enough this could possibly translate to less bins needed in a batch. These both potentially enhance traceability resolution.

Zone 3 - Traceability post packaging

This zone has been broken into four main stages. These are disinfection[26], transfers to freight carrier[27], transport to market and retail processes. This is the zone where supply chain monitoring and associated inspections really come into play. It is along this component of the supply pathway that food fraud attempts are initiated and the traceability identification and labelling that was laid down in the preceding zone is utilized and tested. A broad spectrum of inspections is also possible including, general, export, quarantine, seals integrity, post disinfection, perishable goods, cargo compliance and pest and residue inspections; to name a few. The results of some of these may be consolidated into an exporters system, the national Plant Exports Management System (PEMS) or both. But in the destination market, there may be separate system solutions such as laboratory systems to manage information created offshore. The use of sensors for automated and continuous supply chain and product monitoring is mostly deployed in this zone. Again, the data from these is often secured in separate vendor cloud-based systems. At present sensor-based approaches in APPSC's probably have more application in analyzing and better understanding supply chain function and identifying issues to improve their management. For instance, scrutiny of the temperature trace from an in-package sensor may provide the simplest accessible means to understand how long the various steps in its journey have taken as the impacts of these show as fluctuations in temperature. This is much easier at present than attempting to get this information from the various systems associated with the fruit movements. However, wider and more consistent adoption of sensors will be needed to create the evidence base to better support market dispute resolution. Some supply chain operations (such as disinfection by irradiation) confound the use of some sensors as they need to be removed and then replaced after the operation to prevent damage. This is the zone where the emerging purpose-built traceability systems such as TruTrace tend to focus as they deliver the means to consolidate and integrate the information from the variety of sources and systems for improved access and reporting.

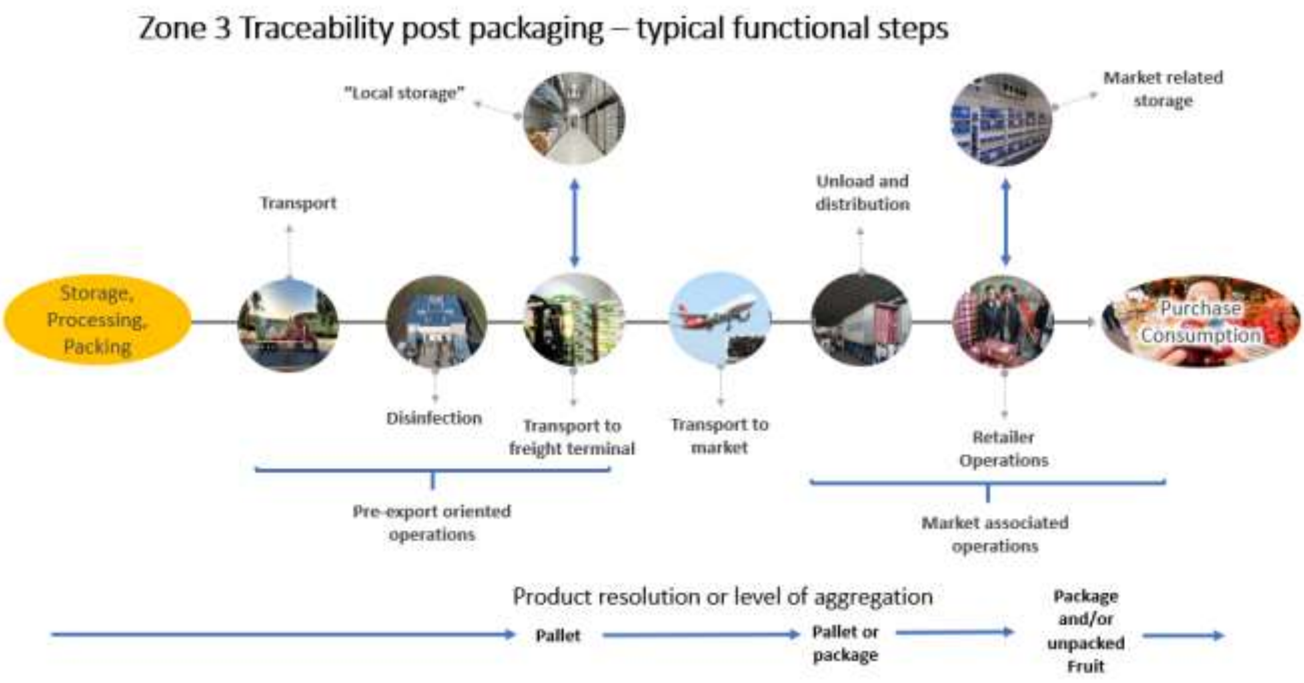

Figure 11 Apple and Pear traceability post packing

Much of the contextual information created in this pathway is presently associated with pallet identifiers and labels rather than to fruit packages. For the best traceability outcome, this requires the individual member packages to have identifiers that are linked to the identifier of the pallet. These relationships are often stored back in the packing system in zone 2 when an order or consignment is assembled. This traceability is weakened if packages are only identified by their batch number and this situation does currently occur. Traceability can be

[26] The type and hence timing and sequence of disinfection in the zone 3 workflow may vary.
[27] May only apply to export scenarios and may occur at or across various parts of the APPSC depending on the type of disinfection employed and market requirements.

further weakened if fruit packs without unique identifiers are unbundled from the original pallet and reassembled with other packs into new product aggregations. Even where unique package identifiers are in place this disaggregation and reaggregation should be registered in appropriate systems so that contextual information collected from events or issues related with subsequent supply can be accurately associated with the new product configuration. Some of the activities routinely undertaken as part of the workflow in this zone are outlined in Table 3. Note that none of the specific range of inspections have been included because while some are undertaken at routines stages many can occur at different times and more than once depending on who is participating and what different markets require. This creates a level of difficultly in generally assigning to the stages where and which inspections are applied.

Stage	**Operation/Activity**
Disinfection	- Transfer to facility - Removal and replacement of sensitive sensors and other devices - Record of events and processes against product identifiers - Forwarding to next step
Transfer to freight carrier[28]	- Transport and receipt - Temporary storage (to enable consignment assembly) - Inspections
Transport to market	- Loading and transport to market - Unloading and receipt by importer/purchaser - Inspections
Retail processes	- Retail distribution - Local storage - Unpacking and display - Sale or other disposal

Table 3 Apple and Pear traceability post packing

If fruit requires irradiation as the disinfection treatment the recent construction of a new office and warehouse facility for Steritech at Merrifield Business Park in Mickleham, Victoria will remove the need for southern operations to send fruit to the Queensland facility for irradiation.

Zone 4 – Fruit provenance traceability and credence

There is no complicated workflow associated with fruit authentication and point of origin traceability. To achieve either just requires an appropriate lookup process to verify authenticity or retrieve or read point of origin information. If the appropriate support is in place this kind of operation can be initiated at any point in the supply chain after fruit packing. The approaches and mechanisms required to deliver these forms of traceability have been previously described in the traceability foundations section and in the description of those identifiers that are better suited for this.

Credence or fruit authenticity can be enhanced if the systems that underpin the validation of identifiers have broader access to relevant contextual information. This enables cross matching of data and the establishment of business rules and forensic style analysis to establish the probability that something is amiss. An example would be

[28] Mostly refers to air freight and relevant for export markets

if a fruit package identifier is scanned within a short timeframe at multiple locations or more times than expected it is likely the product label has been duplicated. Just making it obvious on product labels that credible approaches such as Laava labels and chemical fingerprints are being used may be enough to deter fruit fraudsters. Most of the purpose-built traceability systems that are emerging in the CCSC target this zone.

Production and supply participants

At present traceability data for the APPSC is spread across numerous systems and between different stakeholders. Most stakeholders are focused on their specific parts of the supply chain. In the production, processing and packing area of the APPSC a range of participants are adopting cloud-based solutions. This is as much because current vendors have moved their product offer into the cloud. Other producers are adopting these new service-oriented solutions because the functionality is bundled into service suites and there is flexibility to adopt and pay for only what is required. The advantages of these trends are that there is usually interoperation between the services, and this delivers enhanced information exchanges. The potential to undertake analysis and reporting across the industry increases as more producers use these common vendor platforms. However, this requires participants to endorse information sharing.

KEY FINDING: ***Most APPSC stakeholders recognize the need to better support traceability but are focused on their specific parts of the fruit supply chain. This reduces the awareness of the importance and need to exchange information.***

There are models emerging in other sectors[29] where solution or service providers are becoming the intermediaries in brokering broader industry access to producer information. Usually this is incentivized through reduced service fees to growers who sign up to share and the cost difference is underwritten by the industry body. In some cases, technology providers build the right to combine and utilize the data for their own purposes into the service contracts. This usually does not include the right to directly on sell the data to others in its raw form. There is usually recognition that any use of the data will protect the privacy of contributors.

At Present, there are difficulties in exchanging and easily accessing information along the full supply chain. It is mainly in situations described above where there are obvious benefits to operations that system consolidation and information sharing occurs. The other main area where stakeholders share information is in the processes and documentation associated with exporting where the provision of information is mandated. The federal Plant Export Management System (PEMS) provides a centralized facility for Authorized Officers (AO) along the chain to enter and submit export inspection and calibration records and supporting documentation. Additionally, the web based Next Export Document System (NEXDOC) provides support for facilitating export/import requests and associated processes and documentation. The PEMS has a data exchange standard to allow participants to bulk load records from other systems but there does not appear to be an equivalent standard to enable a traceability system to harvest data from the PEMS.

Outcomes

The three outcomes targeted in the project brief are shown in bold below. Brief descriptions of findings in the review that address these outcomes are detailed in point form beneath each of these.

Position the apple and pear supply chain to be better able to harness the power of IT and data systems to collect, connect and utilize business data to reduce costs, reduce harvest losses and improve fruit quality.

- The frameworks that have been developed to describe the different forms of traceability and the various related aspects will help promote understanding of the systems and technologies and options available to the

[29] This is part of the strategy behind the Australian national framework for soil information where laboratories are provided incentives to sign up clients to data sharing arrangements that deliver reduce fees to purchasers of the services.

industry.

- The detailed report contains specific evaluations from an industry perspective of the various identification approaches and technologies that underpin traceability.
- The analysis provided of new technologies such as robotic harvesting provides a description of some of the business opportunities that can accrue from different implementations of technology.

Complex IT integration is a key barrier to adoption and this project will demonstrate a strategic framework and industry pathway at pre and post farm gate for traceability system development and implementation.

- Creating standards for the data exchanges required for traceability provides a common target for current system vendors to conform with to support traceability.
- Creating purpose-built traceability systems that are service oriented and compile core traceability information from contributing systems and processes significantly reduces the complexity that would otherwise be needed to make all these systems interoperate. Having these systems operate in the cloud will facilitate access for all production and supply chain participants.
- A common and increased spatial resolution of orchard production units creates a strategic framework to integrate orchard information including that from existing and new monitoring and measurement technologies.

Inform approaches for Apple and Pear growers to achieve market product differentiation, efficiencies in the supply chain, rapid response to biosecurity risk management and market protection.

- The improvements to traceability resolution from the approaches recommended will increase the precision, responsiveness and richness of information that can be efficiently delivered to stakeholders and markets. This will enable rapid and easier traceback to resolve biosecurity and food safety issues. It will provide a point of difference from competitors in terms of traceability information and exceed existing market requirements for traceability. If implemented correctly this will protect markets, enhance the industry reputation and consumer confidence in both domestic and export markets.

Monitoring and evaluation

As outlined in the methodology section, industry engagement has been severely impacted by the COVID 19 pandemic and the project team was unable to undertake many face-to-face interviews and property and system inspections. Restrictions to engagement were also driven by the desire to minimize interaction with seasonal workers and harvest activities to reduce additional burden to the industry. This limitation extended to on-field demonstrations, grower workshops and associated events to be managed in partnership with Apple and Pear Australia Limited (APAL), who were also impacted in delivering face to face events, growers' workshops, field days and associated extension and learning activities.

The interim report and accompanying project risk register details how these limitations were countered by the research team delivering a strategic report targeting Horticulture Innovation and APAL executive and leadership teams with a deeper understanding of the complexities facing whole of industry investment and adoption in traceability systems.

Agriculture Victoria's background investment in API services outline in this report, provides a functional environment that mimics the current industry setting and allows the testing and deployment of the proposed design elements for industry and stakeholder scrutiny. The expectation is that with ongoing research and development opportunities associated with this report and subsequent investments Agriculture Victoria has in apple and pear traceability systems, growers (users) of this functional environment will have a purpose built application to test and evaluate as soon as Covid 19 movement protocols allow for that industry engagement.

Key Evaluation Questions:

- What are the barriers to adoption of traceability solutions for Apple and Pear growers?
    - Addressed in body of report. See lack of standards, plethora of systems with a level of traceability augmentation that don't interoperate.
- What are some emerging technologies and traceability solutions that would be cost effective for growers to adopt?
    - Addressed in body of report. See Service Orientated Architecture purpose-built traceability systems. Robotic harvesting was identified as key emerging technology to support higher resolution and improved automation for traceability systems.
- Were planned activities undertaken and outputs produced – and how well were these done/produced?
    - The fundamental outputs were produced despite impacts on planned level of stakeholder engagement and associated communication activities.
- What were the barriers, enablers and lessons learned from delivering the project(s)?
    - The diversity of stakeholders and systems currently operating made the review challenging.
- What was the reach of the project(s) – in terms of awareness and type of engagement?
    - The difficulty in engagement created risks with the project team's confidence in assessing an accurate industry profile of technology use. A delayed project initiation due to Covid 19 has meant there was less time for the information collection and analysis, however we believe we were able to overcome this limitation.
- What are the lessons for future investment decisions?
    - See body of report and recommendations.
- What was the influence of the project in terms of increased understanding of traceability for apple and pear industry?
    - This project has resulted in the Victorian Government investing further into developing traceability research outcomes for the apple and pear and Summerfruit industry. We expect that this report will foster the development of ongoing understanding with the industry and associated strategic and tactical interventions.
- What are the benefits arising from the research and associated opportunities for products, packers, processors, exporters, and supply chain?
    - See body of report and recommendations.
- What are the unintended/unexpected benefits or consequences?
    - The project team engagement with traceabilty system and AgTech providers has delivered new

collaborations and begun early work towards the design of a product traceabilty system for the apple and pear industry and potentially others as outlined in the report. This opportunity would require further funding partnerships.

- What contribution has the project(s) made to the industry's strategic priorities?
  - We believe it has provided another level of detail information to support strategic traceability objectives. This is a key requirement for developing and maintaining export markets as per industry priorities.
- What were the barriers and enablers to change –and where are the service delivery/adoption gaps?
  - See recommendation 1 - system priority or development / focus areas.

Recommendations

The following high-level recommendations are offered:

1) Partner with a traceability solution provider to pilot the design of a product traceability[30] solution with the aim to establish a platform for Apple and Pear industry wide traceability. Emphasis should be given to a solution that sits over the top of existing systems that employs (a) open architectures[31], (b) common standards particularly for traceability item identification (ie GUID's[32]), (c) strong security on fruit package, pallet, container and consignment registration, (d) a well-considered and designed governance model to manage access to the traceability information, and (e) supporting communication and engagement processes to build awareness and buy-in potential from industry.

2) Encourage individual enterprises to adopt point-of-origin traceability focused solutions because a key driver in this space is brand and reputation protection and more customized solutions will provide better outcomes. Additionally, encourage awareness of the spectrum of technologies that underpin these solutions and advise more careful consideration of those that rely on approaches that support rapid (ideally on the spot) results[33] via mobile verification and reporting (applications and devices).

3) Undertake a more detailed assessment of the emerging robotic harvesting technologies paying particular attention to the suite of sensors supported to understand the true potential more fully to characterize/grade fruit at harvest. This would involve consideration of the state of art in computer vision systems and digital image processing. There would also need to be consideration given to artificial intelligence and machine learning for potential in grading and classification of fruit quality.

4) Establish an orchard pilot that explores the design and implementation within orchard RFID or other tags to establish a finer resolution spatial network for orchard information. Linkages between new technologies and systems for spray recording and crop and disease monitoring and this framework should be investigated as this could integrate with robotic harvesting. This aspect could be investigated further by means of computer simulation of a complete supply chain. The integration of this information and support for recording more detailed harvest information should also be explored to enable fine detail within orchard point of origin or issue traceability.

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30 Focus should be product track and trace rather than "point of origin" as a solution focused on product track and trace will support both but deliver better traceability for food safety and biosecurity issues that may arise.
31 To support an incremental and easy pathway for producers, packing houses and other supply chain stakeholder's participation.
32 Because these can be generated almost anywhere and at any time by stakeholders.
33 Costs for sample transfer and laboratory based analysis and turnaround times for results may be greater.

Refereed scientific publications

Nil

References

This document is a high-level report that has been distilled from the attached detailed report. Specific references are more appropriate in the detailed report and that is where they are contained.

Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialization, or confidentiality issues to report

Acknowledgements

We wish to acknowledge all the support and input we have received from the broad spectrum of the industry stakeholders both in the Apple and Pear and Agritech industries. These are listed in appendix 1. All contacts and conversations that occurred have been highlights for the project team in a year that has been made more challenging by the Covid 19 pandemic. We appreciate the willingness of many people to make a real effort to support the team and go that extra mile.

Finally, the team would like to thank Horticulture Innovation for assistance and funding and APAL staff for further assistance in project delivery especially around industry communication.

Appendices

1 Engagement

Four stakeholder groups are identified:

- R&D Agency and industry bodies
- Growers/producers
- Post-harvest supply chain participants
- Technology / Agritech solution providers

The lists of participants engaged to provide information for each group are detail below along with the details of contact events.

Table A1.1 – Engagement -direct contacts

Group/ Entity	*Contacts*
APAL Suite G.01 128 Jolimont Road, East Melbourne, VIC 3002	Rosalie Daniel Justin Smith Alison Barber
CherryHill	Lisa
Coles	Monica Klein
CRC Food Agility – Block chain case study	Prof Ren Ping Liu (UTS)
Dept Agriculture & Fisheries QLD – fruit tracking dashboard	Andrew Macnish Neil White
Fruit Growers Victoria	Michael Crisera
Goulburn Valley Storage (GSV)	Ian Williams
GS1	Peter Carter Richard Jones
Horticulture Innovation, 8/2 Upper Dairy Hall, Bowen Hills, QLD, 4006	Bianca Cairns Kathryn Young

JefThompson	Bisi Odele
Koala Cherries	Michael Rouget (CEO)
Laava	Gavin Ger
Lab3	Alain Blanchette Elliott Wood Emma Nguyen-Huu
Montague Narre Warren North Vic	Rowan Little
Opal ANZ	Mark Krygger Steven Hutchinson
Origins Trace	Joel Stevenson
Persequor – SVP International Markets	Ron Volpe
Source Certain	Nathan Dubrich
TruTrace	Robert Galarza (CEO)

Table A1.2 – Engagement – on-line content review / email contact

Group/ Entity	***Type***
Agpic	Technology
Berg Hortimotive	Technology
Ceravolo Orchards - Includes Ashton Valley Fresh	Producer processing packing
Compacsort	Technology
Dataphyll NZ	Technology
Dematic	Technology
ESRI – GeoEvents and dashboard products	Technology
Evrythng	Technology
Farmable	Technology
Farmsoft	Technology
Freshcloud - Agrofresh	Technology
Goulburn Valley Storage	Cool storage
GrowData Developments	Technology
GS1	Standards
Ironbark – Fresh Produce Software	Technology
JefThompson	Producer, processing, storage, packing
Laava	Technology
Lab3	Technology
Montague	Producer, processing, storage, packing
Muddy Boots	Technology
Oritain	Technology
Persequor – SVP International Markets	Technology

Plunkett	Producer, processing, storage, packing
Pomona Valley - Canadian /Aust consortium to be estab 1st July 2021 merges: *Orchards:* Turnbull Brothers Orchards, Oakmoor Orchards (Varapodio family), Pickworth Orchards, Chatswood Farm (Hall family) *Packhouses:* OzPac Australia, Integrity Fruit	Producer, processing, storage, packing
Radevski Orchards / Coolstores	Producer, processing, storage, packing
Relex Solutions	Technology
Rullo Orchards	Producer
Silvestein	Producer
Source Certain	Technology
Tie up Farming	Technology
Thompson Orchards	Producer
TruTrace	Technology
Unitec	Technology
Zespri “Kiwi Gold”	Technology