FPSC
FRESH PRODUCE
SAFETY CENTRE

Fundamental Guidelines

FOR FRESH PRODUCE FOOD SAFETY

Version 5

2025

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Executive Summary

The ***Fundamental Guidelines for Fresh Produce Food Safety*** provide a comprehensive, science-based framework for managing food safety risks in the fresh produce industry. The scope includes production, harvest and post-harvest handling of fresh produce (i.e. fruit, vegetables, herbs and mushrooms).

The Fundamental Guidelines aim to support businesses in implementing good practices that safeguard consumer health, protect the business and industry from food safety incidents, and support compliance with regulations and food safety standards. They are generic in nature so are applicable to all fresh produce categories and can be used by all businesses regardless of their scale or complexity. They do not cover extensive processing activities, which typically introduce risks beyond those associated with whole, fresh produce.

The Fundamental Guidelines are based on Hazard Analysis and Critical Control Point (HACCP) principles to address physical, chemical (including allergens) and microbiological hazards. Rather than prescriptive standards, they provide practical information and insights on hazards identification, sources of contamination, risk assessment, good practice and continuous improvement.

The Fundamental Guidelines have been developed by the Fresh Produce Safety Centre (FPSC) through extensive scientific review and industry consultation. They have also been developed in alignment with food safety regulations and standards. The Fundamental Guidelines are voluntary and therefore do not impose obligations, though food safety standards or regulations may refer to elements within this document. Businesses are required to comply with relevant food safety regulations, food safety standards and assurance programme requirements.

These Fundamental Guidelines are accompanied by ***Quick Guides for Fresh Produce Food Safety*** which provide a user-friendly summary for day to day use by growers and team members. The Quick Guides enable rapid identification of key hazards and practices for each management area. They have been developed using the same structure as these Fundamental Guidelines so users can easily find more information on a topic.

Key Updates in 2025:

- New chapters on Managing Critical Incident and Recalls, as well as Food Safety Culture
- Additional Appendices:
  - » Appendix 02: Food Safety Regulation and Assurance Programmes
  - » Appendix 04: The Use and Significance of Faecal Indicator Bacteria
- Enhanced guidance on water quality criteria and microbial testing protocols
- Updated content and layout for improved usability
- Updated visuals including refreshed images, figures and decision trees
- Development of complementary Quick Guides for Fresh Produce Food Safety.

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CHAPTER 1
Introduction

Overview

The Fundamental Guidelines for Fresh Produce Food Safety (referred to throughout this document as 'the Fundamental Guidelines') aim to support hazard analysis, risk assessment and the adoption of good practice for food safety in the fresh produce industry. They also support consistency in the development, implementation and auditing of food safety standards across the fresh produce supply chain.

The primary audience for the Fundamental Guidelines is growers and packhouses given the food safety risks associated with production and post-harvest handling of fresh produce. In addition, they are commonly used by those throughout the supply chain, including wholesalers and retailers. They are also highly relevant to service providers including auditors, contractors, consultants, educators, trainers, researchers, assurance programmes, laboratories and input suppliers. The Fundamental Guidelines support their work, provide consistency on an agreed approach, and ensure that services complement and promote practices that improve food safety outcomes.

The Fundamental Guidelines are designed to reflect current good practice, scientific evidence and practical experience. Rather than a prescriptive standard, they provide a user-friendly framework for managing food safety risks based on the best available knowledge at the time of publication. For latest updates, visit www.fpsc-anz.com.

1.1 Scope

The scope of the Fundamental Guidelines includes food safety considerations (e.g. hazards, risks and good practices) for minimally processed fresh produce (fruit, vegetables, herbs and mushrooms). The content is generally applicable and useful to fresh produce growers globally, though the document is written primarily for fresh produce businesses in Australia and New Zealand with reference to locally specific hazards, practices, guidelines and regulations.

The Fundamental Guidelines are designed to assist fresh produce businesses to identify and manage potential food safety hazards. They describe the causes and sources of hazards, the risks they may present, and their potential impact across the supply chain. Practical guidance is provided on measures to manage, minimise or eliminate these hazards, supporting the production and supply of safe fresh produce for consumers.

In these Fundamental Guidelines:

- Fresh produce – refers to fruit, vegetables, herbs and mushrooms.
- Food safety hazards – refers to physical, chemical (including allergen) and microbiological aspects that may impact consumer health if not effectively managed, minimised or eliminated.

The Fundamental Guidelines apply to all stages of fresh produce production and handling, including growing, harvesting, packing, storage, ripening and transportation, from initial planting through to delivery at retail distribution centres or retail stores. Growing encompasses both field production and structures where produce is grown.

They do not extend to processing activities, which typically introduce risks beyond those associated with whole, fresh produce.

The recommended practices in this document are based on the Hazard Analysis and Critical Control Point (HACCP) framework for risk assessment and mitigation, which also underpin fresh produce food safety standards and assurance programmes.

The Fundamental Guidelines aim to support hazard analysis, risk assessment and the adoption of good practice...

1.2 Fresh Produce Safety Centre (FPSC)

The Fresh Produce Safety Centre (FPSC) was established in 2014 as an industry-led, not-for-profit organisation with a mission to enhance food safety outcomes across the fresh produce industry in Australia and New Zealand.

The current vision is 'safe produce and a thriving industry' while the purpose is to 'create, connect and sustain independent, science-driven food safety guidance'.

Since its inception, FPSC has served as the custodian of the Guidelines. This role involves reviewing, updating and disseminating the Fundamental Guidelines in line with emerging science, evolving regulatory expectations and changing industry needs. Through collaboration with growers, industry, retailers, researchers and government, FPSC ensures the Guidelines remain accurate, relevant, practical and underpinned by science.

1.3 Version history

Version 5.0 (2025): Comprehensive review and the Horticulture Food Safety Initiative

Commencing in 2023, FPSC led the Horticulture Food Safety Initiative project (Hort Innovation Project No. HN21000) in collaboration with industry, retailers and government partners across Australia and New Zealand. This trans-Tasman effort strengthened food safety capability, alignment and responsiveness with a focus on improving the practical application of food safety practices, building technical capacity, and promoting greater consistency across the industry.

As part of this project, FPSC undertook a full review of the current Guidelines. The resulting version 5 (2025) reflects updated scientific evidence, current good agricultural and hygiene practices, and extensive industry consultation. Key updates include:

- New chapters on Critical Incident Management and Recalls, as well as Food Safety Culture
- Additional Appendices:
  - » Appendix 02: Food Safety Regulation and Assurance Programmes
  - » Appendix 04: The Use and Significance of Faecal Indicator Bacteria
- Enhanced guidance on water quality criteria and microbial testing protocols
- Updated content and layout for improved usability
- Updated visuals including refreshed images, figures and decision trees
- Development of complimentary Quick Guides for Fresh Produce Food Safety.

These updates support more consistent implementation across the industry and reflect the evolving challenges and expectations facing fresh produce food safety.

Version 4.1 (2022): Targeted update to fertiliser guidance

Section 6.2 on microbial contamination from fertilisers and soil amendments was revised based on a peer reviewed literature search, forming a partial update to the 2019 version.

Version 4 (2019): Iterative updates based on new research

The 2015 Guidelines were revised in 2019 to reflect additional research and industry developments.

Version 3 (2015): Trans-Tasman expansion and modernisation

FPSC published a new edition in 2015, extending The Guidelines across the Australian and New Zealand supply chains and incorporating current scientific knowledge.

Version 2 (2004): Second Edition expands scope and industry uptake

The second edition added new content on contamination risk assessment and product testing. It was widely adopted, with thousands of printed and online copies distributed.

Version 1 (2001): Origins of the Guidelines

The Guidelines were first developed in collaboration between government and industry which was initiated in 1999. The Australian Government's Department of Agriculture, Fisheries and Forestry convened a working group to support alignment in safety and quality systems.

This led to the original Guidelines for On-Farm Food Safety for Fresh Produce, published in 2001. The document provided good practice guidance for the growing, harvesting, packing, storage and dispatch of fruits, vegetables, herbs, mushrooms and nuts destined for wholesale, retail, food service or processing markets.

1.4 Overview of chapters

Chapter 3 Food Safety Hazards outlines the main physical, chemical (including allergen) and microbiological hazards that may contaminate fresh produce, along with their potential sources. It serves as a concise reference to support identification of critical control points across the fresh produce supply chain.

Chapter 4 Where Contamination Can Occur in the Supply Chain provides example flow charts illustrating typical processes and inputs across growing, harvest, packing, storage and distribution. Developing a flow chart tailored to your own business operations is an important first step in identifying where contamination risks may occur.

Chapter 5 Managing the Growing Site emphasises the importance of assessing potential growing sites for their suitability in fresh produce production. It provides decision trees to support the evaluation of risks associated with potential hazards (e.g. persistent chemicals and heavy metals).

Chapter 6 Managing Fertilisers and Soil Amendments outlines potential food safety hazards associated with fertiliser and soil amendment use, with particular emphasis on untreated animal manures. To support risk mitigation, general guidance is provided on minimum exclusion periods between livestock grazing or manure application and crop harvest. These intervals are crop-specific and based on mean maximum air temperature ranges at the growing site, as reflected in temperature-based decision trees evidenced from peer-reviewed studies.

Chapter 7 Managing Water highlights potential food safety hazards associated with water use across production stages including growing, harvesting, washing, packing, and distribution. It provides guidance on risk assessment, water quality analysis and applicable standards to support safe and compliant use.

Chapters 8 to 15 describe the inputs and operational areas linked to potential food safety hazards in production and supply. Potential sources of contamination include chemicals, facilities, tools, equipment, containers, packaging, vehicles, animals and pests. Human activity presents distinct challenges, with targeted training playing an essential role in reducing contamination risk.

Chapter 16 Managing Allergens focuses on the increasing challenges businesses face in managing allergens. It identifies the allergens that are required to be declared and specifies the associated labelling requirements to support regulatory compliance and safeguard consumer health.

Chapter17 Identification and Traceability describes the importance of ensuring produce is identifiable from grower to retailer and preferably to the consumer, as well as being traceable in reverse. Effective traceability enables the swift removal of potentially unsafe produce and supports identification of the contamination source. In the event of a food safety incident, traceability plays a critical role in protecting public health.

Chapter 18 Testing explains the role of testing as a verification tool for managing chemical, microbial, allergen and environmental hazards. While testing supports compliance and helps trace contamination, it cannot guarantee product safety on its own. Guidance is provided on sampling methods, laboratory selection and interpreting results.

Reinforcing that testing should complement hazard analysis and preventive controls within a broader food safety system.

Chapter 19 Managing Critical Incidents and Recalls defines the nature of critical incidents in fresh produce supply chains, including natural disasters, criminal activity and confirmed food safety risks that disrupt normal operations. It emphasises the importance of maintaining and regularly testing an Incident Management Plan (IMP), which details procedures for managing disruptions, protecting consumer safety and ensuring operational continuity.

Chapter 20 Food Safety Culture emphasises the importance of a mature food safety culture, where safe practices are consistently upheld across all roles, not only during audits. All businesses operate at varying levels of food safety culture maturity. The chapter provides resources to support culture improvement, monitoring tools and guidance on aligning food safety objectives with daily operations.

Appendix 1 Food Safety Management Systems outlines the role of a Food Safety Management System (FSMS) in preventing, detecting and responding to a contamination event. It emphasises root cause analysis and the use of data to identify control failures. An overview of food defence and food fraud is provided, highlighting risks from intentional attacks and deceptive practices such as mislabelling and substitution.

Appendix 2 Food Safety Regulations and Assurance Programmes describes the integrated food safety framework across Australia and New Zealand, combining regulatory requirements and voluntary assurance programmes to mitigate risk, demonstrate compliance and support adoption of good practice. It emphasises coordinated stakeholder collaboration in maintaining food safety, ensuring regulatory alignment and enabling market access within the fresh produce industry.

Appendix 3 Microbes Associated with Fresh Produce introduces the range of microorganisms that can cause foodborne illness, including bacteria, viruses, parasitic protozoans and microscopic worms. It emphasises the need for awareness and control measures to prevent severe health impacts across the fresh produce supply chain.

Appendix 4 The Use and Significance of Faecal Indicators describes the use of indicator bacteria, such as *E. coli*, to signal potential pathogen presence. It highlights their cost-effective, rapid detection attributes and explains that results indicate possible, not confirmed contamination.

Appendix 5 Glossary offers a quick reference guide to key terms used throughout the Fundamental Guidelines. It ensures consistent understanding across the fresh produce industry by defining terminology in a clear and practical language.

CHAPTER 2

How to use the Fundamental Guidelines

Overview

The Fundamental Guidelines serve as a reference document describing potential hazards in the production and supply of fresh produce and recommending good practices for managing the risk of contamination by those hazards. They are voluntary guidelines and designed to inform, educate and support the fresh produce industry in enhancing food safety outcomes. Importantly, they do not impose obligations, nor do they involve certification or audits. Users should check that they are using the latest version of the Fundamental Guidelines by visiting the FPSC website: www.fpsc-anz.com.

2.1 Hazard versus risk

Understanding the difference between hazard and risk is essential for using these Fundamental Guidelines and managing food safety in a fresh produce business.

- **Hazard**: something that can potentially cause harm including injury or illness (e.g. a pathogen)
- **Risk**: the probability of a hazard being present in fresh produce (e.g. remote possibility – once per year) combined with the severity of the harm (e.g. will cause serious illness in people).

Hazards are objective and easily identifiable items like physical, chemical (including allergen) or microbiological contaminants. They are described as 'black and white' given something is either considered a hazard or it is not. Risk, on the other hand, is uncertain as it involves context, judgement, and probability of a hazard being present. Risk is therefore considered 'grey' given it is related to something that might happen.

Agrichemicals, for example, are hazards as they are inherently harmful. The risk of harm to peoples' health depends on how they are used and applied, therefore growers conduct a risk assessment then adopt relevant good practices including those described in the Fundamental Guidelines to manage, minimise or eliminate the risk to an acceptable level.

2.2 Quick Guides for Fresh Produce Food Safety

The Fundamental Guidelines are complemented by Quick Guides for Fresh Produce Food Safety (known as the 'Quick Guides') which provide an easily digestible, user friendly aid for day to day use by growers and team members. The Quick Guides enable rapid identification of key hazards and practices for each management area. They have been developed using the same structure as these Fundamental Guidelines so users can easily find more information on a topic if needed.

2.3 Structure of The Guidelines

The Fundamental Guidelines are comprised of numerous chapters which are generally based on a management area (e.g. water), supporting system (e.g. testing) or useful information (e.g. microbes associated with fresh produce). A list of chapters can be found in the contents page, while an overview of the content within each chapter can be found in the introduction. The Fundamental Guidelines are published in two formats to meet varying user needs:

- Integrated – A complete document including all chapters and appendices
- Modular – Each chapter and appendix can be viewed or downloaded individually.

2.4 Structure of each chapter

To provide for user friendly experience and ease of use, each chapter for managing risk is comprised of a similar set of sub-headings including:

- Overview
- Hazards and sources of contamination
- Additional information for significant hazards and good practices
- Good practices for managing risk
- Resources

2.4.1 Overview

This section provides a brief summary of the chapter content including why it is important for fresh produce food safety.

2.4.2 Hazards and sources of contamination

This section introduces the relevant physical, chemical (including allergen) and/or microbiological hazards associated with that management area. It also provides a list of the most common sources of contamination for each type of hazard.

2.4.3 Additional information for significant hazards and good practices

Many chapters include additional sub-headings which provide further information on the key hazards and good practices for the relevant process or management area. For example, Personal Hygiene (Section 14.3) is a sub-heading in Chapter 14 on Managing People. It provides additional guidance on hygiene practices including handwashing and sanitisation given the importance of this practice for minimising the risk of contamination of fresh produce.

2.4.4 Good practices for managing risk

Throughout the Fundamental Guidelines, good practice replaces best practice to recognise continuous improvement and the evolving nature of evidence, technology and operations. This section provides a summarised and tabulated collection of good practices that businesses can adopt to manage, minimise or eliminate the risk of contamination. Good practices are grouped into relevant management areas (e.g. growing, training) to highlight the options available for users.

2.4.5 Resources

List of scientific papers, industry guidelines or regulatory documents relevant to that chapter where users can find more information on the topic.

2.5 Visual aids and diagrams

2.5.1 Decision Trees

These tools use a flowchart approach to support users to make decisions based on risk (e.g. assessing the risk of contamination with cadmium). The flow charts facilitate interpretation by using a series of questions, hazards, practices and operational settings to assess the level of risk, then direct users to good practices which manage the risk.

2.5.2 Figures

Figures provide visual presentation of processes, useful information and good practices.

2.5.3 Tables

Tables provide structured presentation of information and have been used mostly for sections on hazards and sources of contamination and good practices for each management area.

2.5.4 Images of good practice and risk

Images help to present information in a more meaningful way using practical examples from the fresh produce industry. There are two types of symbols used on images to illustrate if they are considered good practice or a potential risk.

Example of good practice in action.

Example of hazard or scenario with risk of contamination.

CHAPTER 3
Food Safety Hazards

Overview

Fresh produce can be affected by physical, chemical (including allergen) and microbiological hazards. Awareness and understanding of these hazards is essential to minimising contamination. Identifying where such hazards may occur is key to minimising the associated risks.

It is important to identify and assess all possible food safety hazards throughout the supply chain, no matter how high the standard of operations and regardless of the level of perceived potential risk. This process is called hazard analysis and is fundamental to contamination prevention or minimisation.

Hazard analysis should be undertaken to provide a baseline when a food safety standard is implemented for the first time. The process should then be repeated each time a significant change is made to inputs or processes and at least annually. A change may reduce or eliminate a hazard, increase the risk from a hazard or introduce a new hazard, either by itself or by influencing other inputs or processes. There also comes a time when, instead of modifying an existing hazard analysis, remapping the entire process and starting again should be considered [refer Chapter 4 and Appendix 1].

As part of this process, it is essential to develop a property or facility plan identifying hazards (e.g. contaminated sites, sensitive areas, water sources, adjacent habitation or reserves) and neighbouring areas that may create risks (e.g. feedlots, manure spreading, septic systems, landfill or industrial activities). In addition, the plan should include hazardous events (i.e. situations that increase the likelihood of hazard exposures) and processes that could lead to direct or inadvertent application of harmful chemicals or contaminated water [refer Chapter 7].

Having identified a potential hazard/hazardous event, the next step is to consider the risk (i.e. the likelihood of that event occurring, the consequences and the severity of the consequences associated with the hazard being realised). This process is called risk assessment [refer Appendix 1].

Hazards are broadly divided into four categories: physical, chemical (including allergen) and microbiological. This chapter also discusses harmful weeds, classified as unsafe plant material by FSANZ, as a sub-category of both physical and chemical hazards.

3.1 Physical hazards

Physical contaminants in fresh produce are surprisingly frequent and a source of constant concern to all supply chain stakeholders. They are a regular cause of consumer complaints, recalls, withdrawals and negative media coverage.

Physical contaminants are often reported in the news media for their novelty value, such as frogs and insects in packages of salad vegetables or their injury potential, such as glass, hard plastics, pins and staples. This category also includes intentional contamination (e.g. needles embedded within strawberries as occurred in Australia and New Zealand in 2018).

Image C3.1 | In-line metal detectors are used in fresh produce operations to identify and remove physical contaminants.

Table C3:1 | Physical hazards and sources of contamination.

Hazard	Source of contamination
Foreign objects from the environment **Includes grit, soil, stones, sticks, rats, insects, spiders, weeds, feathers, bones and other natural objects**	Harvesting ground crops during wet or windy weather. Dirty harvesting equipment, picking containers or packing materials. Picking containers placed on soil during harvest. Stacking dirty pallets, crates and bins on top of exposed produce. Inadequate pest and/or weed management during production and/or sorting during harvest, packing or processing.
Glass	Broken bottles or glass left from previous land use, discarded by team members or thrown into paddocks from passing traffic. Broken lights or mirrors from fork-lifts and machinery. Broken lights above packing equipment, inside cool rooms and storage areas where produce is exposed.
Foreign objects from equipment, containers and packhouses **Includes wood splinters, metal shavings, nails, nuts and bolts, tools, plastic objects, paint flakes**	Damaged picking containers, harvesting equipment, packing equipment and pallets. Damaged packaging. Inadequate cleaning after repairs and maintenance. Workshop areas located too close to packing and storage areas. Shotgun pellets.
Foreign objects from human handling **Includes hair, fingernails, jewellery, adhesive dressings, gloves, buttons and other clothing as well as staples, paper clips, pens/pen lids**	Careless or untrained team members. Inappropriate clothing or lack of protective equipment (e.g. hair nets, beard nets). Inadequate and/or poorly managed waste disposal facilities for team members.
Intentional contamination from foreign objects	Could be any of the above but more likely to be malicious (e.g. needles, glass).

3.1.1 Weeds

Weeds can be classified as physical or potentially chemical hazards. Some weeds have been implicated in allergic reactions and some are poisonous due to the accumulation of toxic tropane alkaloids (TA). These weeds should be removed prior to harvest or controlled during the growth of the crop if there is a risk of contamination of harvested produce. For example, contamination could occur if stinging nettles or nightshades are present during harvest of leafy vegetable crops. Intoxication of nearly 200 people in Australia occurred in 2022 when baby spinach was contaminated with thornapple. Internationally, several reported outbreaks have been linked to toxic weed contamination.

Toxic weeds can contaminate crops because there are limitations to integrated weed management. For example, fast-growing crops may not permit the use of the most effective herbicides due to withholding periods, weed seeds may survive in soil for long periods and emerge at intervals, weather conditions can affect herbicide efficacy and the toxic weed may be difficult to distinguish from the crop [refer Chapter 5].

Prevention of toxic weed contamination early in production is the best management strategy. Management options include:

- understanding land use history that could allow survival of toxic weed seed
- agronomic practices such as crop rotation and tillage to optimise weed control
- use suppliers of weed-free seed to minimise risk
- train and educate team members in weed identification and reporting weed contamination
- provide sufficient time for team members to visually inspect fields/growing site during the growing and harvesting cycles
- when using the same equipment across multiple growing sites, ensure that these are thoroughly cleaned/decontaminated before moving to a different site to prevent spreading weeds
- notify customers who process the crop when there is increased risk of weed contamination, enabling them to increase visual inspection during processing.

3.2 Chemical hazards

There are many potential sources of chemical hazards for fresh produce. We naturally think of agricultural chemicals used to manage pests, diseases and weeds. However, the definition and sources of chemical contamination are quite broad. Some chemical hazards occur naturally and may be an intrinsic part of the product itself (e.g. alkaloids in potatoes) or occur from microbial growth on the product or in irrigation water (e.g. cyanotoxins, mycotoxins, endotoxins) [refer Chapter 8].

While illness from most sources of chemical contamination is rare, this category includes food allergens. Even minute traces of certain substances can be fatal to susceptible consumers [refer Chapter 16].

There are many different types of chemical hazards including pesticide residues, heavy metals, natural and microbial toxins (e.g. cyanotoxins, endotoxins, glycoalkaloids, mycotoxins) and non-pesticide contaminants (such as persistent organic pollutants, mineral oil hydrocarbons (MOH), greases, lubricants) and allergens (refer Table C3:2).

Table C3:2 | Chemical hazards and sources of contamination.

Hazard	Sources of contamination
Pesticide residues in produce that exceed Maximum Residue Limits (MRLs) MRLs are issued by Australian Pesticides and Veterinary Medicines Authority and FSANZ incorporates these into Standard 1.4.2 of the Food Standards Code Note: pesticides not registered or approved for use on specific produce (with permits) have a limit of 'no detectable residue' in Australia In New Zealand MPI enforces MRLs in the Food Notice: Maximum Residue Levels in Agricultural Compounds 2025 Note: In New Zealand the default MRL for off-label use is 0.1 mg/kg	Not reading/understanding the pesticide label. Pesticide applied incorrectly to the product or incorrect product used. Pesticide not stored correctly or stored for too long. Incorrect dilution, concentration higher than label rate. Withholding period not observed. Equipment incorrectly calibrated or not calibrated. Spray drift contamination from neighbouring crop. Pesticide residue in soil or water from heavy use over an extended period. Pesticide residue in picking bins, crates. Equipment not cleaned after use especially if used for multiple purposes (e.g. both washing and spraying). Postharvest use of pesticide or surface coating not approved for the intended application. Dumping, accidental or deliberate spillage or seepage of pesticide into soil or water source.
Heavy metal residues in produce that exceed maximum levels (MLs) MLs are regulated by FSANZ in the FSC Standard 1.4.1 and Schedule 19	Overuse of fertilisers with high levels of heavy metals. High levels of heavy metals present in the soil, naturally or remaining from past use. Development of soil conditions conducive to uptake of heavy metals by crops (e.g. acidity, salinity, zinc deficiency).
Natural/biological toxins	Unsuitable storage conditions (e.g. potatoes stored in the light become green and produce toxic glycoalkaloids like solanine). Toxins produced by algae and cyanobacteria in irrigation water systems. Fungal growth on crops, either pre- or post-harvest, including specific moulds that produce mycotoxins. Toxic weed plants not separated from the harvested crop.

Hazard	Sources of contamination
Non-pesticide contamination	Chemical and fertiliser spills on pallets. Leakage of chemicals and fertilisers transported with produce (i.e. not in accordance with dangerous goods transport regulations). Oil leaks and grease on equipment in contact with produce. Spillage of chemicals (e.g. pest control, cleaning chemicals) near produce or packaging materials. Cleaning chemicals and sanitiser residue in picking bins, crates. Chemicals such as sanitisers and cleaners not used in accordance with label instructions. Use of sanitisers not permitted in certain export markets. Residues in picking containers incorrectly used to store chemicals, fertiliser, oil etc. Intentional contamination of water supply. Persistent organic pollutants such as PCBs (polychlorinated biphenyls) and PFAS (per- and polyfluoroalkyl substances) from previous or adjacent land use causing contamination. Mineral oil hydrocarbons from packaging, including MOSH (Mineral Oil Saturated Hydrocarbons) and MOAH (Mineral Oil Aromatic Hydrocarbons).
Allergens [refer Chapter 16]	Sulphur dioxide. Contamination from contact with peanuts, milk, cereals (e.g. wheat, rye, barley, oats), crustaceans, molluscs, egg, fish, soybeans, sesame seeds, lupins and their products during growing (e.g. mulches, soil amendments), packing or processing (e.g. cross contact in fresh-cut salads). Tree nut waste used in soil amendments and mulches (e.g. almonds, brazil nuts, cashews, hazelnuts, macadamias, pecans, pine nuts, pistachios and walnuts). Cross contact from harvest and transport containers previously used for products containing allergens that have been inadequately cleaned. Some weeds (e.g. stinging nettles) may cause allergic rhinitis and urticaria skin rashes when handled. Use of waxes containing allergenic ingredients.
Radiological	Occur naturally in rocks, soil and water. Radioactive elements continually emit a small amount of radiation. Note: Radiological hazards are considered to be of very low prevalence and risk in Australia and New Zealand due to the absence of nuclear facilities or significant sources of radioactive contamination in the environment.

Note: When exporting produce, it is the responsibility of the supplier to comply with MRL regulations of the importing country.

3.3 Microbiological hazards

There are many microorganisms (sometimes simply referred to as microbes), in the environment. Most are essential for ecological processes and are harmless, some are beneficial to us such as those used in yoghurt and cheese-making but others cause food spoilage and rots in fruits and vegetables. Only a very small percentage of these microbes may cause disease to humans and are called human foodborne pathogens.

3.3.1 Foodborne pathogens

Examples of foodborne pathogens include bacteria such as pathogenic *Escherichia coli*, *Salmonella enterica* and *Listeria monocytogenes*; human viruses such as Hepatitis A and norovirus and parasitic protozoa, such as *Cryptosporidium hominis* and *Giardia intestinalis*.

The symptoms most often associated with foodborne pathogen infections are nausea, diarrhoea and vomiting, collectively known as gastroenteritis, or gastro' because the symptoms are caused by pathogens in the gastrointestinal tract (enteric pathogens). Less common are opportunistic pathogens, being those that can grow in the environment and which are not necessarily related to faecal contamination such as *Legionella* and non-tuberculous mycobacteria. Consumers who have a compromised or weakened immune system, such as the very young, pregnant women, the elderly and those with an existing illness, are more susceptible to infection from enteric and opportunistic pathogens, which is likely to result in more prolonged illnesses following exposure to contaminated foods.

Consequences of infection may also be severe for these more vulnerable groups. Microorganisms may also carry antimicrobial resistance (AMR), (i.e. resistance to therapeutic drugs). When drug-resistance genes are taken up by human pathogens which can happen wherever they grow, their increased resistance to antibiotic treatments can lead to prolonged infections and higher health burdens to individuals and society. Antibiotic-resistant pathogens and their genes are most prolific in produce contaminated by sewage, animal excreta and manures (e.g. commercial, feral and domestic animals) as these environments promote gene transfers between microorganisms in those situations [refer Appendix 3].

3.3.2 Mycotoxins

Fresh produce harbours fungi (yeasts and moulds) as well as bacteria. Some fungi that cause rots can produce mycotoxins. Mycotoxins are toxic fungal metabolites, mainly produced by *Aspergillus, Penicillium* and *Fusarium* species. Acute illness affects liver or kidney function. The prime chronic effect is the induction of cancer, especially of the liver.

Image C3.2 | Microbial testing using selective agar helps detect pathogens such as *E. coli*, *Salmonella* and *Listeria*, which can contaminate fresh produce through water, soil or handling.

Image C3:3 | Aspergillus niger, or black rot of onions, can produce a toxin that affects human health.

The most important fungi causing toxic effects in humans and animals are the species that produce aflatoxins. These fungi (i.e. *Aspergillus spp*.) have an affinity for nuts and oilseeds, particularly peanuts, corn and cottonseed because they can grow and persist under relatively dry conditions. In general, control of aflatoxins relies on Good Agricultural Practices. Preventing plants from becoming infected with aflatoxigenic strains of fungi is the best means of control.

3.3.3 Causes of microbiological contamination

Table C3:3 lists potential microbiological hazards and hazardous events that may result in fresh produce contamination. Although contamination of produce can occur at any stage of the supply chain [refer Chapter 4], many pathogens are traced back to human and animal origins. This means that direct or indirect on-farm sources of contamination such as fertilisers, water, soil, equipment and team members are the most likely suspects when there is an outbreak of foodborne illness.

Table C3:3 | Microbiological hazards and sources of contamination.

Hazard	Source of contamination
Human pathogenic microbes on produce Bacteria, viruses and parasites	Direct contamination of produce in the field by birds and animals in the crop area. Water used for growing, harvest, processing, packing and cleaning processes contaminated by: • faeces from pests, wild and domestic animals, including birds • remains of dead pests, wild and domestic animals • human sewage and contaminated stormwaters • effluent, including wind-blown dust/soil, from intensive animal facilities • inadequately treated water used to cool, wash or transport produce • water pooling in packing and storage areas • contaminated water leaking from recirculating cooling systems in cold rooms. Fertilisers and soil amendments containing manure contacting produce directly or indirectly via the soil or by water splash. Harvesting produce that has contacted contaminated soil. Picking containers and harvesting, grading and packing equipment contaminated by soil, decaying matter or faeces from pests, wild or domestic animals. Survival and/or growth of pathogens on equipment surfaces and in niches inadequately cleaned and sanitised. Pallets, crates and bins contaminated with soil and faeces stacked on top of exposed produce. Packaging and packing material contaminated with faeces. Handling of produce and equipment by contaminated team members due to inadequate toilet and handwashing facilities, poor personal hygiene practices or by water splash or sickness (e.g. communicable diseases such as Hepatitis A and norovirus infections).
Fungi (mycotoxins)	Warm, moist environmental conditions that allow mould growth in the field or during storage which can result in toxin formation.

3.3.4 Microbiological survival on produce

Preventing microbiological contamination is the best way to ensure produce is safe to eat. However, if contamination does occur, the likelihood that it will cause illness partly depends on the magnitude of the contamination and the physical attributes of the produce, how it is prepared and eaten and the potential for further growth between the point of contamination and the point of consumption. Conversely most pathogens are readily killed by normal cooking.

Questions to consider when assessing pathogen risk include:

- does the produce support the survival and growth of pathogens? For example, does it have:
  - » large, uneven surfaces that can trap pathogens and moisture (e.g. leafy vegetables)
  - » surfaces that support pathogen growth (e.g. netted skin of rockmelon)
  - » natural openings that allow pathogens to enter (e.g. open calyx of tomato; stem scar of mango; cracks in carrots)
  - » openings caused by damage, such as cuts, splits or cracks
  - » temperature of storage, distribution and retail display.
- how is the produce protected from pathogens transmitted by vermin/vectors (e.g. rats, flies, cockroaches, windborne dust) during the physical transporting process from farm to customer? [refer Chapter 12]
- how is the produce consumed, cooked or uncooked?
- what is the pH of the produce and does it have free water (e.g. juice) within it?
- what part of the produce is eaten?
- if the produce has inedible skin (i.e. the outer surface is not eaten) can the edible part be accidentally contaminated during peeling or cutting?
- how long will the produce be stored before it is eaten and under what conditions?

The part of the produce that is eaten and how it is consumed can significantly affect the risk of microbiological foodborne illness. Produce that is eaten uncooked presents the highest risk. Salad vegetables, fruits with edible skins and many other crops are in this category.

Cooking before consumption can eliminate the risk of illness in almost all cases, except where the microbiological contaminants produce heat-resistant toxins if they grow on or in the product. However, only products that require cooking to make them edible, such as potatoes or rhubarb are certain to have this kill step. Vegetables such as carrots, broccoli, asparagus and even eggplant may be eaten uncooked as well as cooked. It cannot be assumed that consumers will prepare produce in a specific way.

The inedible skin of some produce prevents direct contact of contaminated water with the edible part. This reduces the risk of foodborne illness but doesn't eliminate it. The risk can still be significant if the skin is used in meal preparation (e.g. orange rind) if cutting during preparation contaminates the edible part (e.g. watermelon) or if consumer handling causes cross contamination between fresh produce and other foods.

Resources

NSW Department of Primary Industries (NSW DPI) (2022). *Managing food safety risks associated with toxic weeds in leafy vegetables*. Primefact 22/1365, December. New South Wales Department of Primary Industries.

CHAPTER 4

Where Contamination Can Occur in the Supply Chain

Overview

Contamination of produce with food safety hazards can occur at any step in the supply chain, from planting the crop to delivery to the end customer.

Preparing a flow chart of the supply chain process steps will assist the business to identify potential sources of food safety hazards. Contamination sources which could affect your produce may be physical, chemical (including allergen) and/or microbiological hazards.

Examples of fresh produce supply chain process steps and the inputs which could contain food safety hazards are outlined in Figures C4.1, C4.2, C4.3 and C4.4. The actual process steps and their order will vary depending on the type of produce and business. Chapters 5 to 16 provide good practice guidelines for managing the inputs and potential hazards.

Inputs that should be considered and managed include:

- fertiliser and soil amendments [Chapter 6]
- water used in irrigation, chemical applications, cleaning, processing and storage [Chapter 7]
- chemicals [Chapter 8]
- containers and packaging materials [Chapter 11]
- planting materials [Chapter 15]
- allergens [Chapter 16].

Food safety hazards that are required to be managed may also be associated with:

- the growing site and surrounding land uses [Chapter 5]
- weeds [Chapter 5]
- facilities and infrastructure [Chapter 9]
- equipment and tools [Chapter 10]
- vehicles [Chapter 12]
- pests, animals and birds [Chapter 13]
- people [Chapter 14].

Food safety hazards can also be present and contaminate produce during wholesale and retail handling and display of fresh produce. These hazards and their potential risk during that part of the supply chain are not considered within the scope of this document.

Produce can become contaminated with food safety hazards at any step in the supply chain.

4.1 Potential sources of contamination in crop production

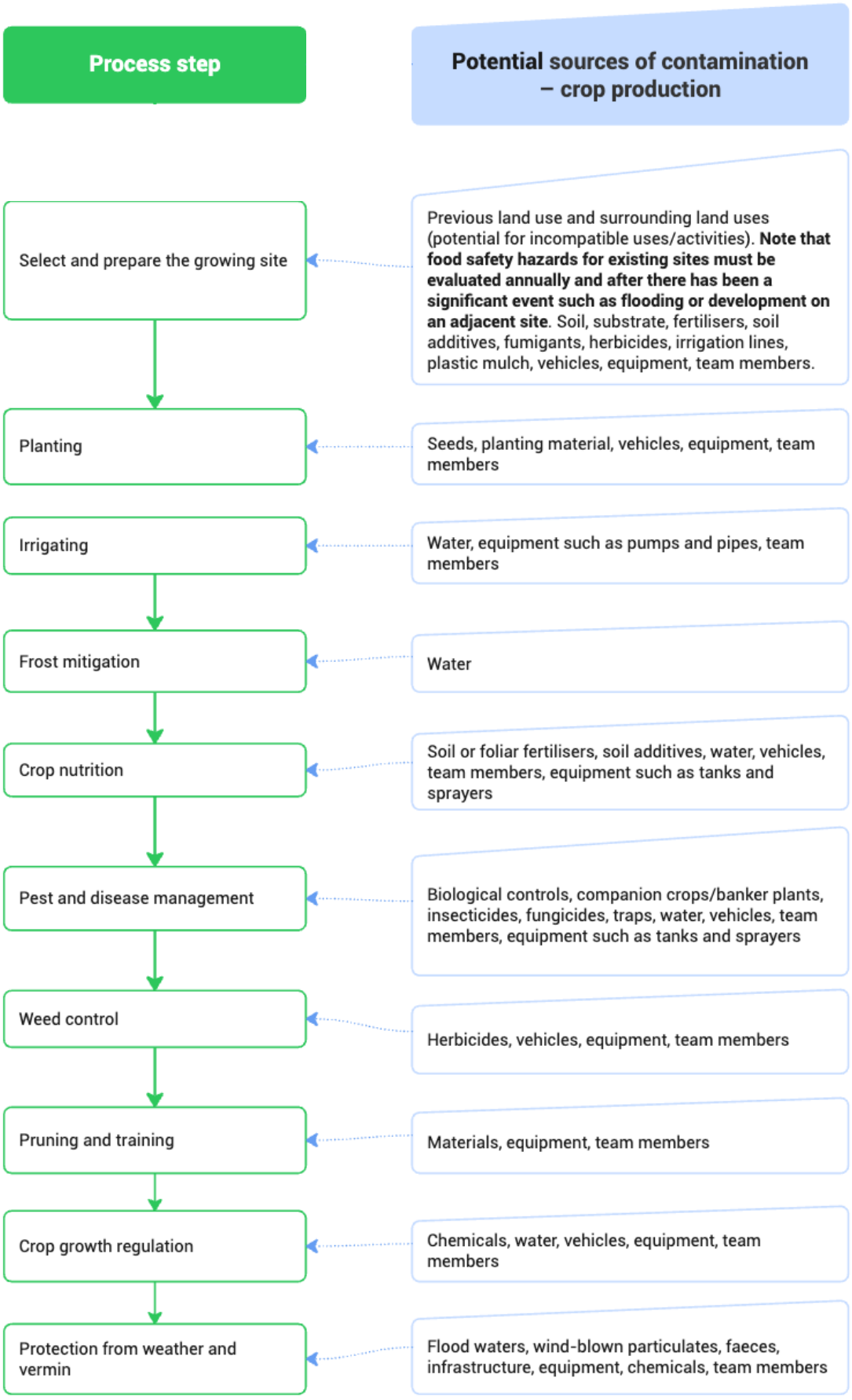


Figure C4:1 | Process steps during crop production and potential sources of contamination.

Image C4:1 | Plastic mulch can reduce soil contact and suppress weeds, but if not properly managed can be a source of physical contamination (foreign body).

Image C4:2 | If not properly managed, hydroponic systems can spread microbiological contamination via recirculated water.

Image C4:3 | Overhead irrigation (sprinklers) can directly wet edible portions of the crop, increasing the likelihood of contamination if water quality is not adequately managed.

4.2 Potential sources of contamination in harvest and field packing

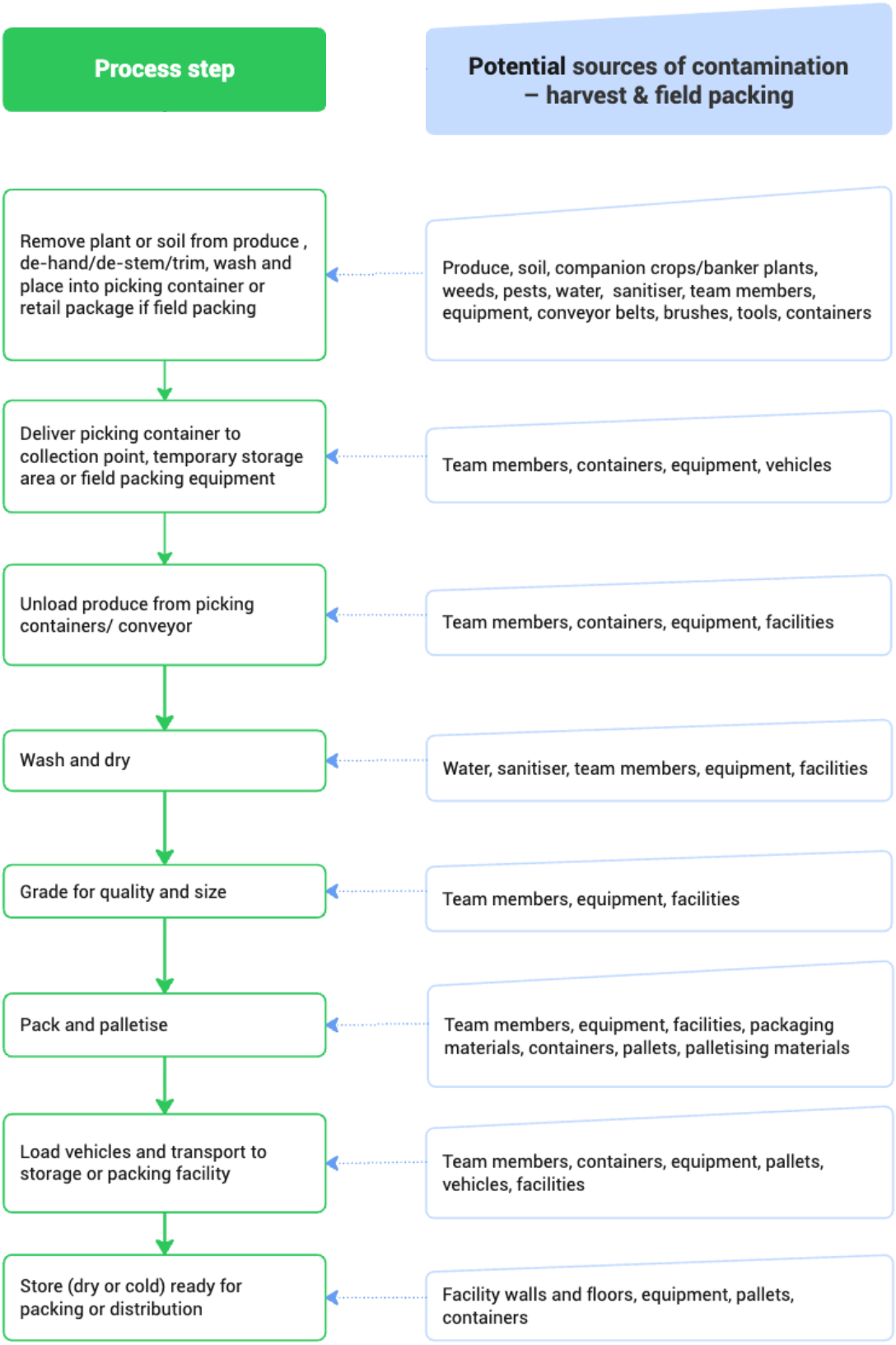


Figure C4:2 | Process steps during harvest and field packing and potential sources of contamination.

Image C4:4 | The hands of harvesting team members can pose a risk of microbiological contamination. Hands should be thoroughly washed with potable water, dried with a single use paper towel and sanitised before commencing work and after any activity that may compromise hygiene including toilet use, nose blowing, coughing or sneezing, eating, smoking, handling waste, performing maintenance tasks or taking breaks.

Image C4:5 | Harvesting containers can become a source of potential physical, chemical (including allergen) and microbiological contamination. Containers that come in contact with fresh produce should be food-grade, sourced from approved suppliers and kept clean and sanitary.

4.3 Potential sources of contamination in packing and storage

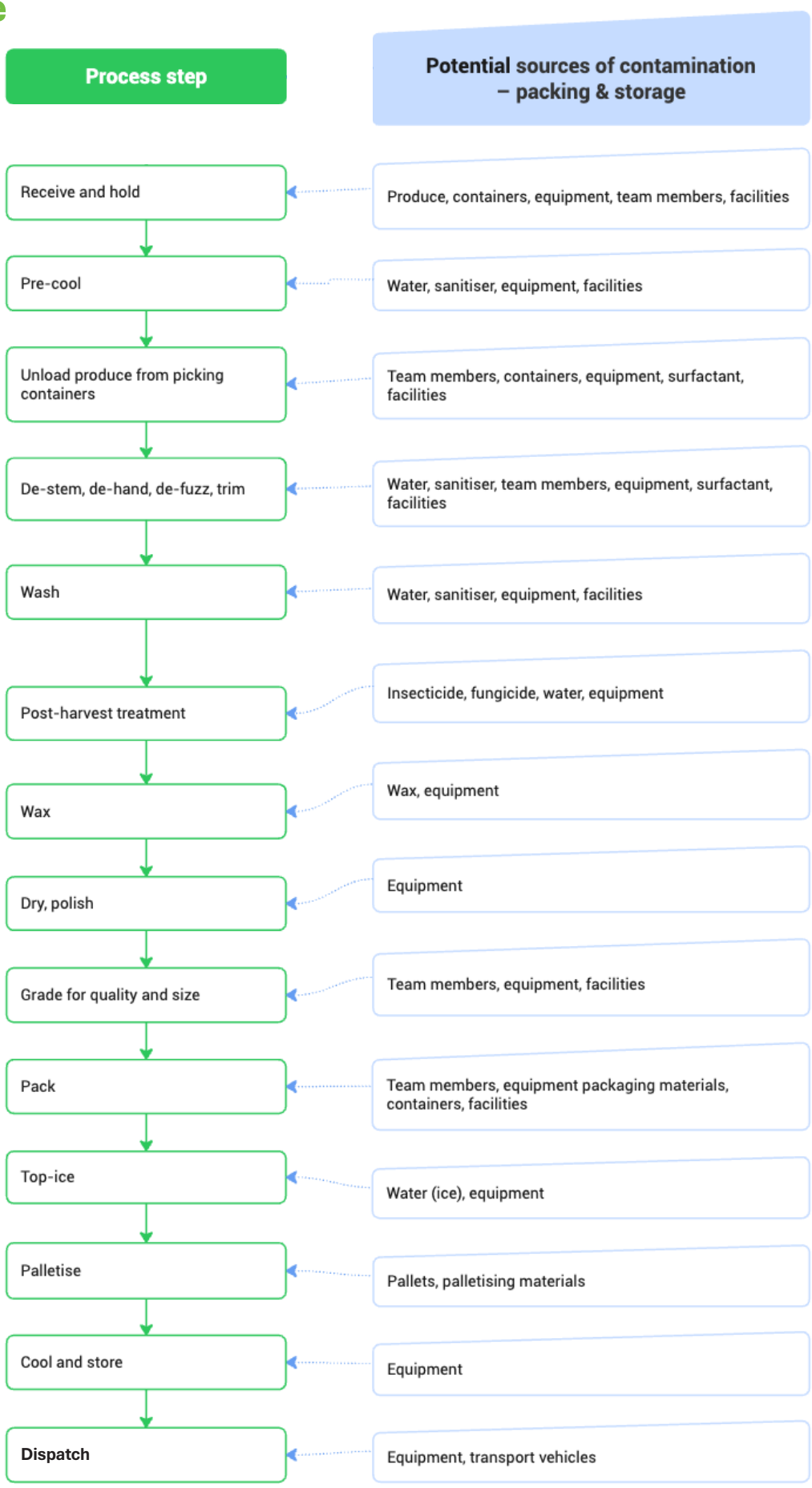


Figure C4:3 | Process steps in a packing and storage facility and potential sources of contamination.

Image C4:6 | The use of appropriate personal protective equipment (PPE) is essential for minimising physical and microbiological contamination risks posed by team members operating within packing and storage facilities.

Image C4:7 | Packaging materials used for fresh produce should be sourced from approved suppliers and where possible, hold recognised Global Food Safety Initiative (GFSI) certifications, such as Safe Quality Food (SQF) or Brand Reputation Compliance Global Standards (BRCGS).

Image C4:8 | Transport temperatures for fresh produce should be consistently maintained across all stages of the supply chain. Temperature verification should be conducted using monitoring devices such as data loggers.

4.4 Potential sources of contamination in distribution

Process step	Potential sources of contamination – distribution
Load/dispatch	Facilities, equipment, team members
Transport	Vehicles, other products
Unload/receive	Equipment, team members, facilities
Quality inspection	Equipment, team members
Re-grading (due to rots, damage, weight loss, carton damage, etc)	Facilities, equipment, team members
Storage	Facilities (water if humidified)
Ripening/conditioning	Facilities
Phytosanitary treatment	Facilities, chemicals
Order picking/restacking	Facilities, equipment, team members
Load/despatch	Facilities, equipment

Figure C4:4 | Process steps distribution and potential sources of contamination.

CHAPTER 5
Managing the Growing Site

Overview

Not all sites are suitable for growing fresh produce for human consumption. If the growing site is contaminated with significant levels of physical, chemical (including allergen) or microbiological agents, the produce grown there may also be contaminated. Surrounding land uses should also be considered for their potential to contaminate the growing site and fresh produce.

Growing sites include fields, orchards, buildings, greenhouses and shade houses. The suitability of the growing site should be evaluated before planting annual crops and during pre-establishment for perennial crops. The risk assessments should be conducted annually or when changes occur that may impact the significance of the hazard. Potential for contaminants to be introduced by dust, spray-drift and flooding from the surrounding environment should also be assessed.

The main hazards include:

- physical contamination from foreign matter
- high levels of metals or persistent chemicals
- contamination with human-infectious pathogens
- cross-contact with allergens.

5.1 Physical contamination

Physical hazards such as glass, metal, wood, plastic, roots, sticks and stones may be left on the site from previous uses. Metal, glass and oil can also be introduced from equipment. Team members may drop cigarette butts and other rubbish.

Weeds can physically contaminate produce, especially if the crop is mechanically harvested. Some weeds, such as stinging nettles, thornapple and deadly nightshade, have the potential to cause poisoning or allergic reactions.

Insects, frogs, rodents, spiders and other creatures can also become physical contaminants.

Factors increasing the likelihood that the site is physically contaminated include:

- growing site within 20 metres of a busy road
- previously used for landfill or dumping of waste
- previously used for industrial purposes
- previously used as a rifle range or for military purposes
- uncontrolled populations of spiders, insects or other pests present
- excessive amounts of roots, sticks and stones present
- poor attention to general site cleanliness.

Regular visual inspections and the use of sieve detectors during harvesting can assist identifying and removing physical contaminants.

The implementation of Good Agriculture Practices (GAP), including appropriate waste disposal and good equipment maintenance, can minimise the introduction of physical hazards.

Image C5:1 | Routine site inspections should be conducted to identify and remove these hazards, raising awareness and reducing the risk of physical contamination.

5.2 Chemical contamination

5.2.1 Persistent chemicals

Chemicals remaining in the soil from historical use should be evaluated during site selection and crop planning. This includes potential broad-scale contamination and 'hot spots' such as old dip sites, disposal or dumping areas, remnant building sites and areas near power poles.

Persistent chemical groups that may remain in the soil include:

- organochlorines (OC) and organophosphates (OP)
- polyaromatic hydrocarbons (PHBs)
- perfluoroalkyl and polyfluoroalkyl substances (PFAS).

How long persistent chemicals remain in the soil depends on their concentration, hydrophobicity and resistance to decomposition, as well as the soil type and local climatic conditions. Some chemicals can persist in the soil for decades. Soil testing is the only way to reliably determine if residues are present.

5.2.2 Metals

Metals such as arsenic, copper, cadmium and lead may occur naturally in soil. They can also be introduced in small amounts through:

- fertilisers (especially phosphate)
- soil amendments such as gypsum, biosolids and animal manure
- leaching from treated wooden poles and old sheep dips.

Broadacre cropping sites where persistent chemicals, particularly fungicides and insecticides, have been used may contain unacceptable levels of metals for some crop uses. Industrial land use on the growing site or neighbouring area is another potential source of metals.

FSANZ has established acceptable limits for the presence of metals in fresh produce. Information on Maximum Levels (MLs) for heavy metals in fresh produce is outlined in the Australia New Zealand Food Standards Code, Section 1.4.1 and Schedule 19. As MLs vary internationally, exporters may need to check those of the importing country.

Cadmium is the metal of most concern to fresh produce. Most naturally occurring cadmium (Cd) is at levels of 0.1-1.0 mg Cd per kilogram of soil. However, cadmium is also present in some fertilisers (especially phosphate and some trace element mixes) and soil amendments such as gypsum, animal manures, biosolids and composts.

Cadmium is normally present in an insoluble form, so uptake by plants is low. Uptake is increased in soils that are:

- very sandy
- saline or irrigated with salty water
- acidic
- low in zinc
- lacking organic matter.

Cadmium uptake varies considerably between different produce and even between varieties and cultivars. The probability is higher for:

- root and tuber vegetables (e.g. carrots, beetroot, some potato varieties)
- leafy vegetables and fresh herbs (e.g. spinach, silver beet).

Cadmium testing of produce is recommended when there is a reasonable likelihood of soil contamination and soil properties increase the potential for cadmium uptake.

If cadmium or other metal levels in the produce exceed the legal limit, a different site should be used or practices changed to minimise uptake. Alternatively, crops or crop varieties with low cadmium uptake rates may be selected (e.g. pumpkins, green beans, some potato varieties). Switching to a less salty irrigation water source or using fertilisers with low cadmium content (<1 mg/kg dry weight) can also reduce risk. Low-cadmium superphosphates are now available and may be used where reduced heavy metal content is required.

Lead is a heavy metal that can pose a risk to fresh produce. Although leaded petrol was phased out in New Zealand in 1996 and in Australia by 2002, contamination remains a concern near smelters and other large industrial processing sites.

As part of the risk assessment for heavy metal contamination, potential sources of both cadmium and lead should be evaluated (Figures C5:1 and C5:2).

Conduct risk assessments annually or when site conditions change.

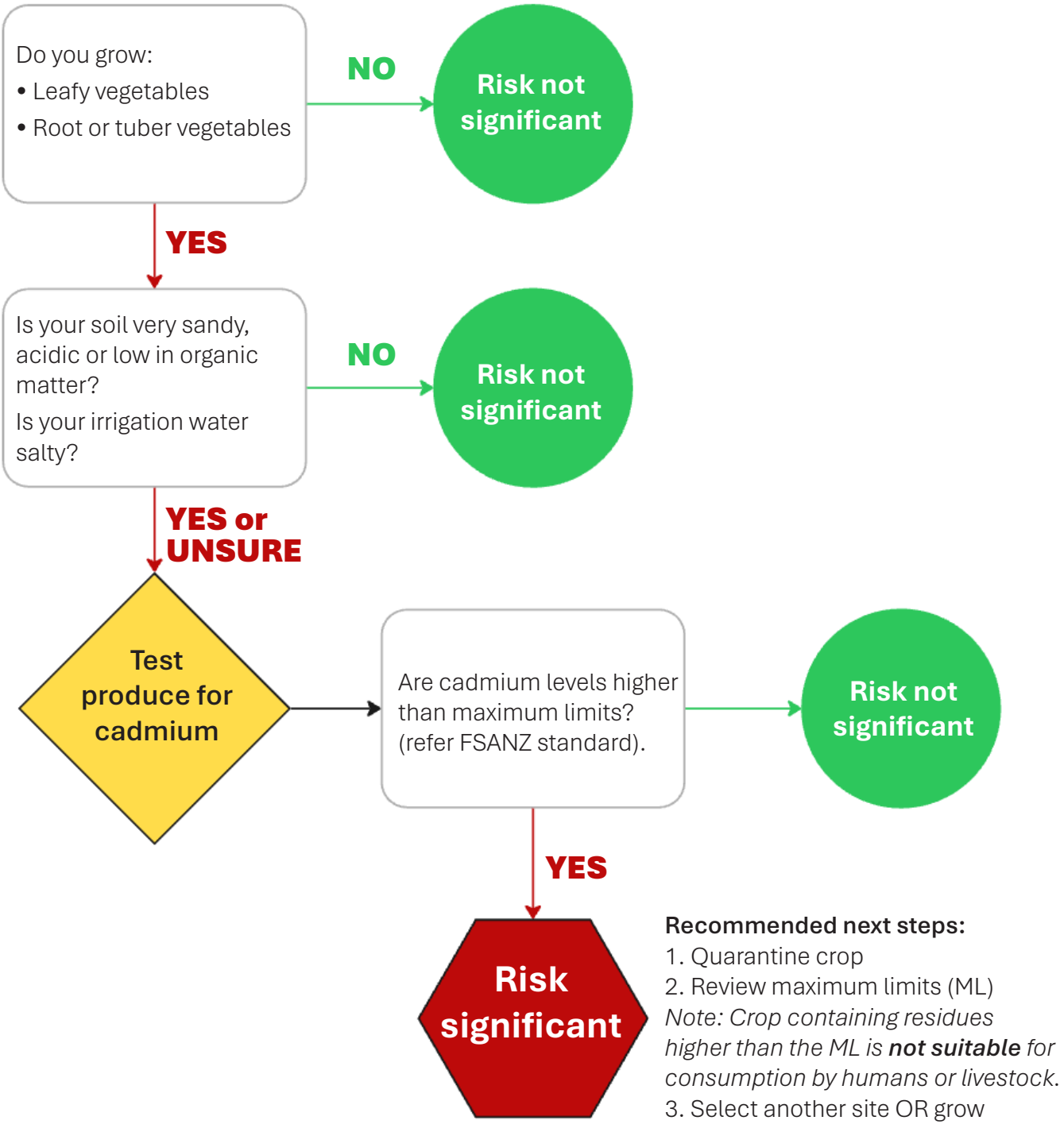


Figure C5:1 | Decision tree for assessing risk from cadmium.

The National Cadmium Minimisation Committee (NCMC) has developed a publication 'Managing Cadmium in Vegetables'.

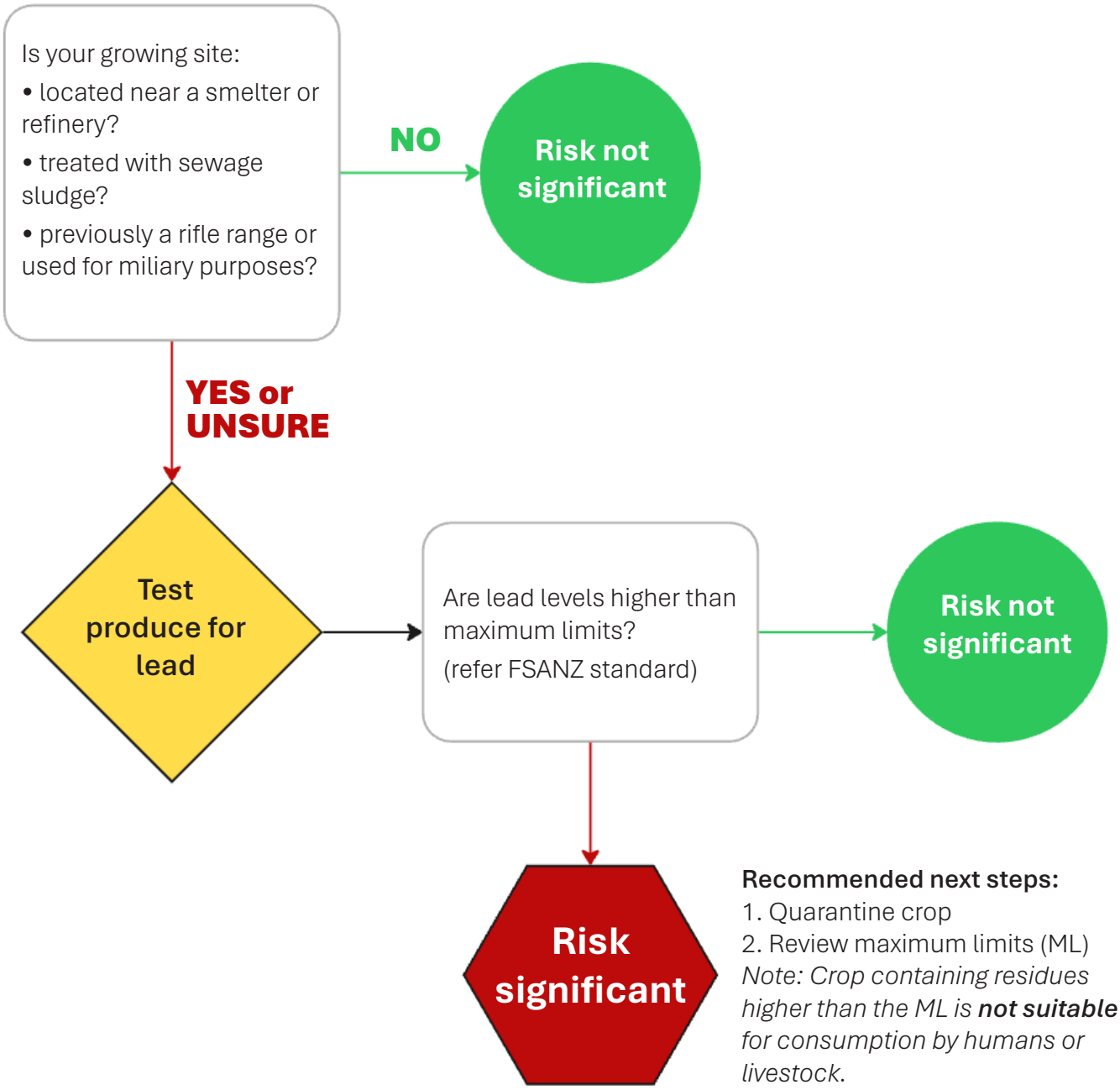


Figure C5:2 | Decision tree for assessing risk from lead.

5.2.3 External sources of chemical contamination

Growing sites may be accidentally contaminated through spray drift, chemicals leached into the water table or by runoff from adjoining areas. Past leakage from stored chemicals or disposal of pesticides can also contaminate growing sites, even if these events occurred many years ago.

Such sources of accidental contamination should be considered during site selection. If site history is unknown, visual indicators, such as redundant infrastructure and used chemical containers, may provide clues to past uses.

5.3 Microbiological contamination

Pathogen transmission is primarily associated with the faeces of humans and other warm-blooded animals (zoonotic sources). Untreated manure and inadequately processed compost used for fertilisation or soil conditioning may introduce pathogens into the production environment [refer Chapters 3, 6; Appendices 3, 4]. Microorganisms present in untreated organic materials can contaminate fresh produce through direct contact, application or dispersal via wind and water (e.g. splashes or flooding). Human effluent and biosolids from on-site wastewater systems also pose a risk of microbial contamination.

Appropriate steps should be taken if any of the following hazards have impacted the site:

- fertilisers or soil amendments containing inadequately treated manure, biosolids or composts made without verified processes have been applied to the site or nearby areas
- the site or nearby areas have been used for animal grazing, have had large flocks of wild birds feeding or have been used as a feedlot, piggery or for poultry production
- the site or nearby areas have been used for storage or composting of organic materials such as animal or poultry manure
- septic or sewage systems drain onto the site or adjacent areas
- human effluent, biosolids or reclaimed water have been used
- a fire or flood event has occurred on the site or in upstream water sources
- exclusion periods before planting and/or harvest may apply where the edible part is grown in contact with or close to the soil and the produce may be eaten uncooked [refer Chapter 6]
- produce testing may be required to assess the significance of any microbial contamination [refer Appendix 4].

Image C5:2 | Manure piles located near growing areas present a significant risk of pathogen transfer to fresh produce. To minimise this risk, manure should be stored at a safe distance from production zones, with appropriate containment measures and buffer zones in place.

Image C5:3 | Manure piles located upslope of irrigation dams pose a significant risk of pathogen transfer. To minimise this risk, manure storage areas should be sited away from water sources and positioned downslope or with adequate containment measures to prevent runoff.

5.4 Allergens

Allergens are covered in detail in Chapter 16. When assessing the potential for contamination with allergens, consider the following hazards on both the growing site and surrounding properties:

- residues of crops grown, processed or stored (e.g. lupin, peanut, soy, wheat)
- residues of inputs that contain allergens (e.g. mulches containing lupin or tree nuts)
- cross-contact with crops and species used in inter-planting or as cover crops (e.g. lupin, peanut, soy, wheat).

5.5 Good practice for managing the growing site

Table C5:1 | Summary of good practices for managing the growing site.

Hazard group	Good practices
Physical	Growing sites are assessed for potential physical contamination before and during land preparation. Areas close to roadways or with high levels of physical contaminants are avoided. Physical contaminants are removed or managed to minimise the risk of contamination. Weeds, especially those with the potential to cause poisoning or an anaphylactic response, are removed and controlled. Pests and other creatures that may hide in produce are removed and controlled. Team members are trained to identify and remove physical hazards. Rubbish and recyclables are collected and disposed of regularly. Equipment used on growing sites is regularly maintained and repaired.
Chemical	The presence of persistent chemicals and metals is assessed during site selection and crop planning. Potential contamination of the growing site by spray drift or dust is assessed. Where this is a potential risk, crops are planned to minimise the risk of contamination. Planting of wind breaks along property boundaries as well as within the property can assist with reducing spray drift. Guidelines for testing soil and produce are followed.
Allergen	Growing sites are assessed for potential cross-contact with allergens before planting [refer Chapter 16].
Microbiological	Human effluent or biosolids are not applied to growing sites or potential growing sites. Septic or sewage systems do not drain onto the site or adjacent areas. Ideally, these should not be located uphill from growing areas or irrigation water storage areas. The site or nearby areas are not used to store or compost organic materials such as animal or poultry manure. Fertilisers and soil amendments containing untreated manure are not used on the growing site within specific exclusion periods before harvest [refer Chapter 6]. Domesticated animals and pets (e.g. cows, sheep, poultry, dogs, cats, horses) are not permitted in growing sites [refer Chapter 13]. Wildlife (e.g. waterfowl, ravens, possums, kangaroos, wallabies, emus, skinks) are controlled at growing sites and in water sources. Biofilms are minimised on surfaces and in plumbing. If floodwater is in contact with produce, do not harvest. If floodwater impacts water supplies, test it before use [refer Chapter 7].
Overall	A property plan should be developed to identify areas of potential physical, chemical (including allergen) and/or microbiological contamination.

Resources

Food Standards Australia New Zealand (FSANZ) (2024). *Australia New Zealand Food Standards Code – Schedule 20 – Maximum residue limits*. Canberra: FSANZ.

International Organization for Standardization (ISO) (2017). *ISO/IEC 17025:2017 – General requirements for the competence of testing and calibration laboratories*. Geneva: ISO.

Ministry for Primary Industries (MPI) (2025). *Maximum residue levels for agricultural compounds: Food notice – 28 February 2025*. Wellington: MPI.

Fertiliser Association of New Zealand, n.d. *Code of Practice for Nutrient Management*.

CHAPTER 6

Managing Fertilisers and Soil Amendments

Overview

Fertilisers and soil amendments, particularly those containing animal excreta (e.g. manure), pose potential food safety risks. This risk is especially high for produce where the edible part comes into direct contact with soil and is consumed uncooked. Additionally, fertilisers can introduce heavy metals due to contamination from source ingredients.

6.1 Hazards and sources of contamination

Before using any fertiliser or soil amendments, the composition, treatment, application method and timing need to be considered, in the context of potential food safety risk.

Fertilisers and soil amendments include:

- inorganic (e.g. mineral fertilisers)
- foliar (e.g. liquid fertilisers and fertigation via irrigation)
- animal manures
- seaweed extracts
- composts and mulches including green waste (e.g. on-farm or off-farm sources)
- compost teas (e.g. liquid brews from compost) or vermicast
- sawdust
- fish and animal by-products
- rock phosphate
- lime
- gypsum
- coal/rock dust.

Table C6:1 | Potential hazards in fertilisers and soil.

Type of hazard	Hazard	Sources of contamination
Physical	Foreign objects such as microplastics and plastic fragments, metal shards, feathers, glass, stones.	Compost or soil amendments made from incompletely screened municipal green waste or poultry manure.
Chemical	Heavy metal residues in produce exceeding maximum levels (MLs).	Continued use of fertilisers, soil conditioners or soil amendments with high levels of heavy metals.
Microbiological	Human pathogens (bacteria, viruses and parasites) that may contaminate produce and potentially cause foodborne illness especially in susceptible consumers.	Direct or indirect contact between untreated fertilisers or soil amendments containing manure and the harvestable part of fresh produce. Run off or windblown contamination from stockpiles of untreated fertilisers and soil amendments containing manure.

6.2 Microbial contamination

The level of risk associated with microbial contamination depends on several factors, including environmental temperature and moisture, crop type, the treatment and composition of fertilisers or soil amendments, as well as the method and location of application.

6.2.1 Fertilisers and soil amendments containing manure

Products that contain animal manure, such as poultry, cow or horse manure, can provide essential plant nutrients and improve soil structure. In some cases, animal manure may also be present on the growing site as a result of grazing. However, untreated animal manures can harbour zoonotic pathogens such as *E. coli* and *Salmonella* [refer Appendices 3 and 4], posing a significant food safety risk. For crops marketed as ready-to-eat, treated manures, fertilisers and soil amendments are always the preferred option.

Pathogens present in untreated animal manure can contaminate fresh produce through direct contact with soil or foliage or indirectly via wind or water splash. The risk of contamination increases substantially if storms, equipment or pests damage the produce, as wounds on plant surfaces can create an ideal environment for pathogens by providing moisture, nutrients and shelter. Even applying manure-based fertilisers during crop growth (e.g. side-dressing) can introduce pathogens that survive in soil and sporadically transfer to produce, even if the amendments are treated. This practice should be carefully managed and avoided close to harvest to minimise risk.

Certain pathogens such as *Listeria monocytogenes* can persist, and in some cases proliferate, in manure amended soil or decaying plant matter and their presence is not necessarily indicated by *E. coli* levels. To minimise contamination risks, preventive measures should be implemented when there is a likelihood of crop exposure to inadequately treated manure.

These measures include:

- avoiding application of materials that contain insufficiently treated animal manure
- using only materials that have undergone treatment to eliminate human pathogens
- observing an exclusion period between application of the untreated material or grazing of livestock and harvesting of crops
- reducing contamination risk to crops further by incorporating manure into the soil, this limits surface exposure and helps pathogens die off more quickly
- only use agricultural teas made from properly composted materials and safe water. Teas made from untreated animal materials and/or contaminated water are high risk.

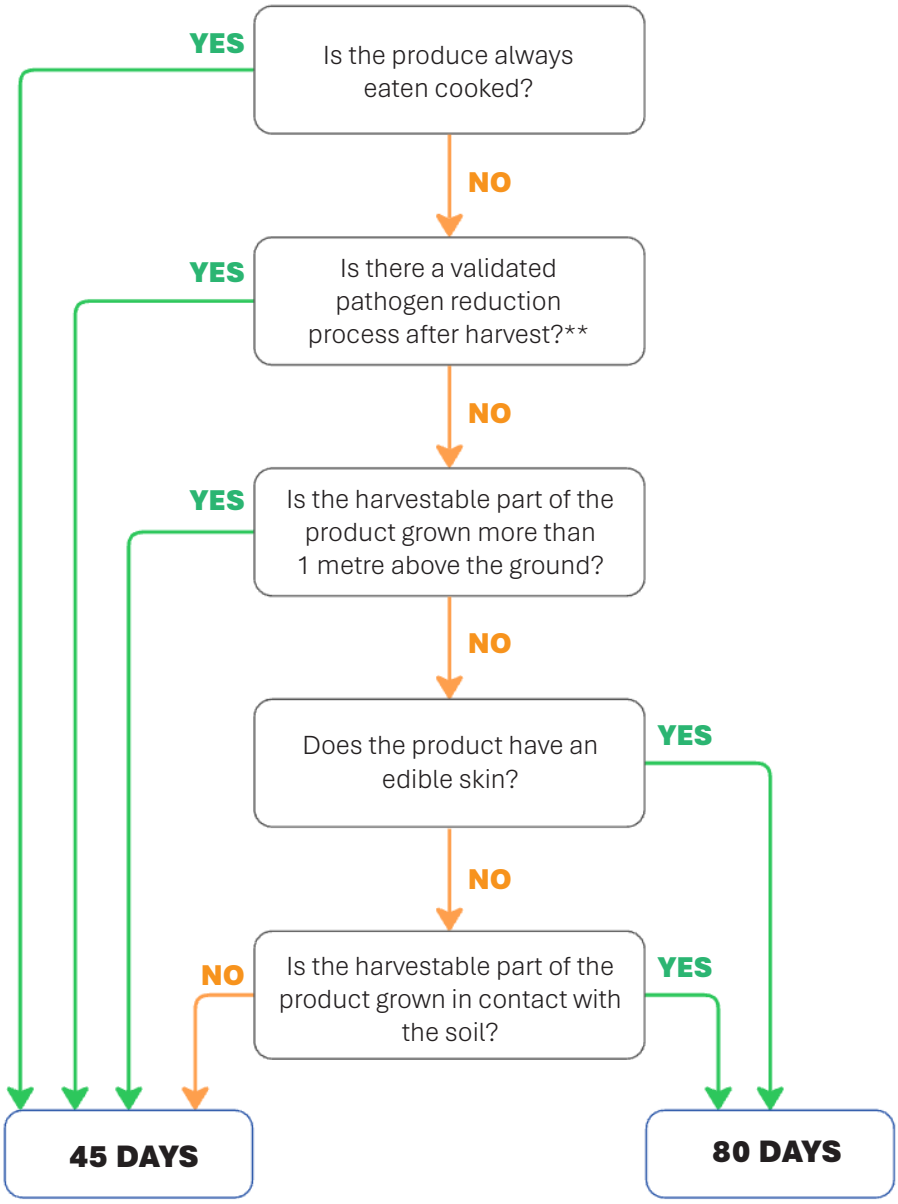
Pig manure or slurry is not recommended for any use in Australian and NZ horticulture. Unlike solid manures, slurry is highly fluid and behaves differently in the field, leading to increased runoff risks. Pig manure also contains a different microbial composition, typically harbouring higher loads of pathogenic bacteria, harmful viruses and parasitic cysts that can persist in the environment for extended periods. Furthermore, pig manure is a poor carbon source and contributes minimally to soil health. For these reasons it is not recommended for use in horticulture.

Untreated manure should not be applied to crops with short growing cycles or where the plant-to-harvest interval is too short to allow for a validated exclusion period. This includes crops such as leafy vegetables and herbs, where use of untreated manure poses an unacceptable food safety risk.

The exclusion periods outlined in Decision Trees 1 and 2 offer general guidance on the minimum time required between grazing of livestock or application of untreated animal manure and crop harvest. These guidelines are based on the mean maximum air temperature ranges at the crop location, reflecting evidence from peer-reviewed studies that show human pathogens generally die off more rapidly under warmer conditions and more slowly under cooler conditions. However, there are exceptions (e.g. *Listeria monocytogenes)* can persist or even grow in certain soil–plant environments at moderate temperatures (around 20–35 °C), especially when moisture and nutrients are available.

6.2.2 Decision Tree 1: Minimum time between grazing of livestock or application of untreated animal manure and produce harvest where mean maximum temperature is greater than or equal to 20°C

Mean maximum temperatures* from Bureau of Meteorology (BOM) can be used as guide to determine which of these decision trees should be used for your location. The number of days is how many days between grazing of livestock or application of untreated animal manure and crop harvest (i.e. exclusion period).



* Mean maximum temperature reached between grazing of livestock or application of untreated animal manure and crop harvest. Some standards mandate longer exclusion periods.

** Pathogen reduction steps after harvest may include:

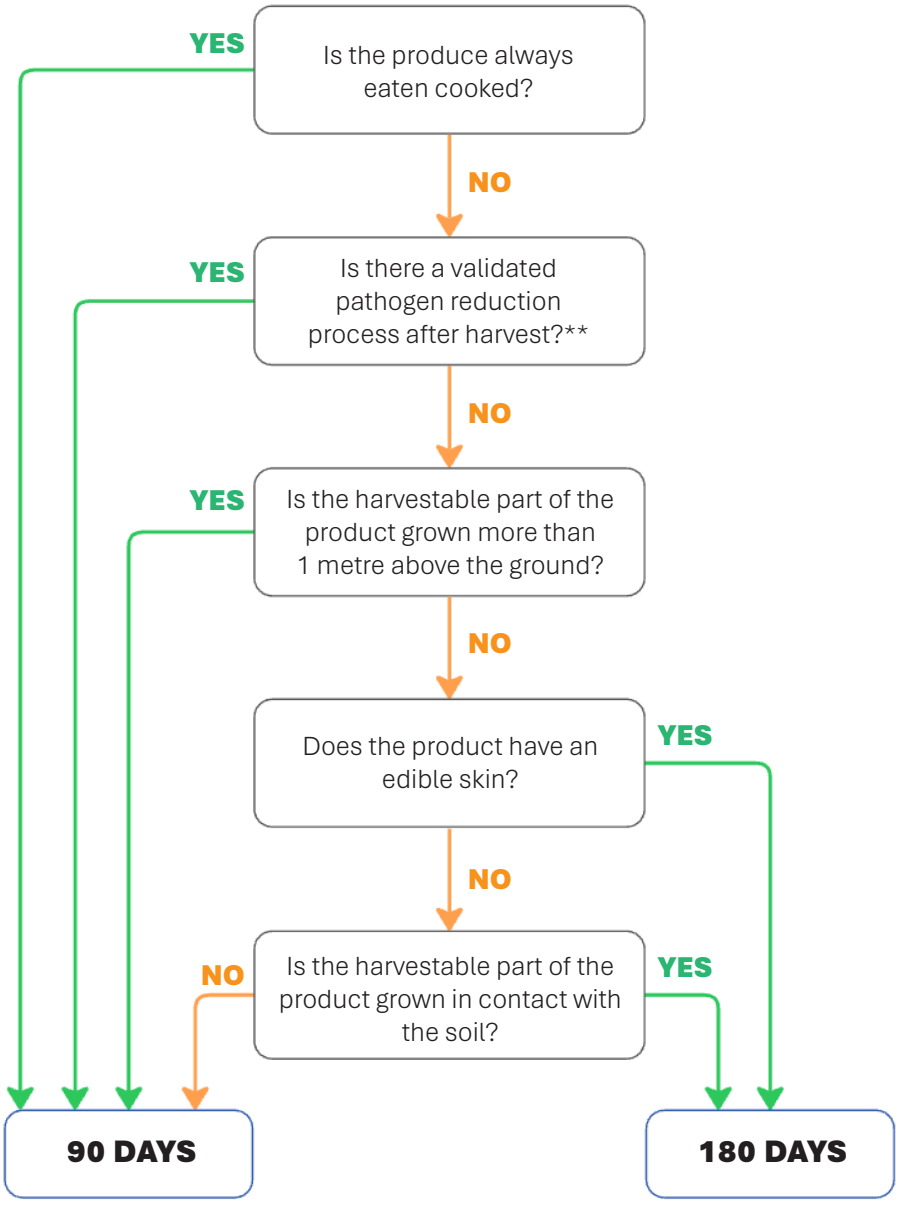
- Period between harvest and consumption
- Validated process that can achieve minimum 2 log reduction of human pathogens; water treated to achieve *E. coli* <1 cfu/100 ml.

Figure C6:1 | Decision Tree 1: Minimum time between grazing of livestock or application of untreated animal manure and produce harvest where mean maximum temperature is greater than or equal to 20°C.

These exclusion periods are based on a review of the peer-reviewed literature, as this has shown that human pathogens die off more rapidly under warmer environmental conditions and more slowly under cooler environmental conditions. However, there are exceptions, such as *Listeria monocytogenes*, that grows in warm soil-plant environments (20-35°C).

6.2.3 Decision Tree 2: Minimum time between grazing of livestock or application of untreated animal manure and produce harvest where mean maximum temperature is less than 20°C

Mean maximum temperatures* from Bureau of Meteorology (BOM) can be used as guide to determine which of these decision trees should be used for your location. The number of days is how many days between grazing of livestock or application of untreated animal manure and crop harvest (i.e. exclusion period).



* Mean maximum temperature reached between grazing of livestock or application of untreated animal manure and crop harvest. Some standards mandate longer exclusion periods.

** Pathogen reduction steps after harvest may include:

- Period between harvest and consumption
- Validated process that can achieve minimum 2 log reduction of human pathogens; water treated to achieve *E. coli* <1 cfu/100 ml.

Exclusion periods in Decision Trees 1 and 2 are based on the upper 99th percentile.

Figure C6:2 | Decision Tree 2: Minimum time between grazing of livestock or application of untreated animal manure and produce harvest where mean maximum temperature is less than 20°C.

6.2.4 How to calculate maximum mean temperature for your location

Australia

To determine the decision tree relevant to your growing conditions, you should first establish the mean maximum air temperature where the crop is grown by following the steps below:

1. Visit: https://www.bom.gov.au
2. Choose your state along the top right menu. Under the heading past weather, click on data and graphs.
3. Under the heading text search, select temperature from the first drop-down menu.
4. Under the heading observations, click on the button next to monthly and select mean maximum temperature from the drop-down menu.
5. Select a weather station in the area of interest by typing in the name of your location in the search box, then clicking on the find button. A number of bureau stations will appear.
6. Click the name of the location nearest to you, then click on the name of the closest bureau station.
7. Click get data and select the year.
8. Scroll to the bottom of the table and look at monthly mean.
9. The figures to use are the monthly mean temperatures listed in the last row of the table.

Screenshots from the BOM website indicating how to navigate to mean maximum temperature for a location and identifying the monthly mean maximum temperature.

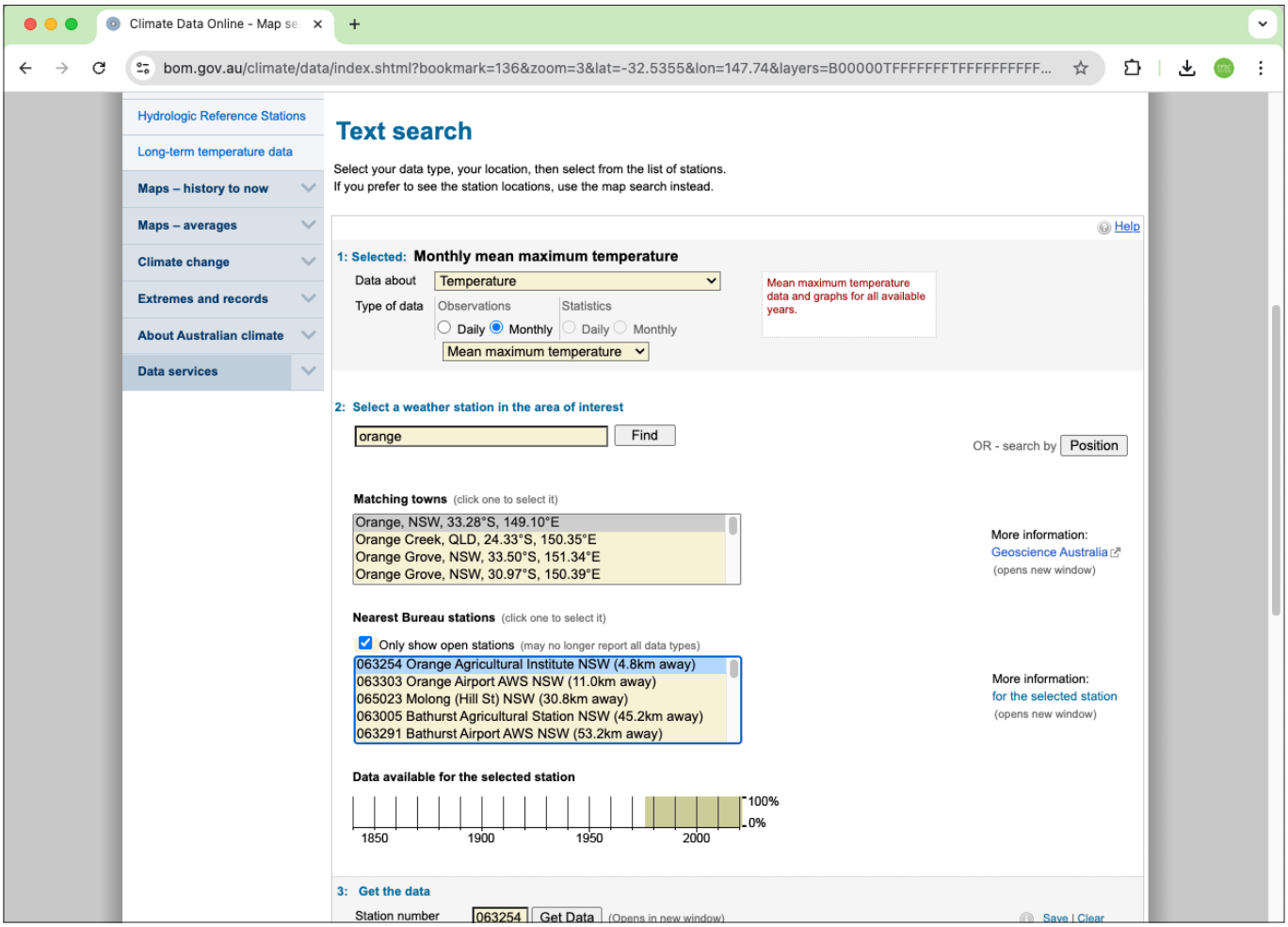


Figure C6:3 | A screenshot from the BOM website.

New Zealand

The MetService for New Zealand: https://www.metservice.com/ (search town, past weather, historical data).

6.2.5 Examples of how to use the Decision Trees

Example 1:

Grower Jane grows spinach in Camden. She plants her autumn crop in early April, with harvest expected in May. She would like to apply untreated chicken manure to her crop. To determine what exclusion periods apply to her situation, Jane should first work out which decision tree applies to her.

To do this, she should first work out the mean maximum air temperature for April and May. She checks the BOM website and notes that the monthly mean temperature for Camden airport i.e. her closest site is 23.6°C for April and 20.3°C for May. Based on this data, she should refer to decision tree 1, as the mean maximum temperature for her growing area is greater than or equal to 20°C.

Working through the questions on Decision Tree 1 (Figure C6:1), she establishes the following:

1. Is the product always eaten cooked? No, spinach is often eaten uncooked.
2. Is there a pathogen reduction step after harvest? No, she knows that it's important to get the harvest to the processor quickly and that there's no kill step used for spinach.
3. Is the harvestable part of the product grown above the ground i.e. typically more than 1 metre? No, spinach is grown close to the ground.
4. Does the product have an edible skin? No, although it is edible, it's not an edible skin, like what an apple or pear has.
5. Is the harvestable part of the product grown in contact with the soil? Yes, the spinach is grown in the soil and often has soil that needs removing from the leaves.

Result = 80 day exclusion period.

An 80-day exclusion period means that Jane should not apply raw, untreated manure or have animals graze on her land where she plans to grow the spinach for at least 80 days prior to her crop harvest. As she plans to harvest her crop around 30 May, she cannot apply raw manure at any point after 11 March (i.e. 80 days prior).

Example 2:

Grower Francesco harvests strawberries in Devonport, Tasmania, from October through to May. He checks the BOM website for Devonport Airport his nearest bureau station for the months of August through May. He finds that the monthly mean air temperatures for the months of harvest are:

Table C6:2 | Monthly mean temperatures for Francesco's location.

Month	Monthly mean maximum air temperature ºC
August	13.7
September	14.7
October	16.7
November	18.1
December	20.8
January	22.5
February	22.6
March	21.6
April	19.1
May	15.2

This is a 10-month growing window and Francesco works out that the average is 18.5°C (i.e. the total of the monthly means is 185, divided by 10 months), which means that decision tree 2 (Figure C6:2) is relevant to his situation because he has grown the crop in an area with a mean maximum air temperature of less than 20°C.

Working through the questions on Decision Tree 2, he establishes the following:

1. Is the product always eaten cooked? No, most people don't cook strawberries.
2. Is there a pathogen reduction step after harvest? No, he's sure there is not.
3. Is the harvestable part of the product grown above the ground i.e. typically more than 1 metre? No, while many of his fellow berry growers grow on tables, his are grown in the soil.
4. Does the product have an edible skin? Yes, it does have an edible skin.

Result = 180 days exclusion period.

A 180-day exclusion period means that Francesco should not use raw or untreated manure for 180 days (i.e. 6 months), before harvest. As he plans to harvest his first berries in October, having an exclusion period of 180 days means that any raw untreated manures should be applied to his crop before April.

6.3 Treated fertilisers and soil amendments

Materials containing animal manures are considered 'treated' if they have been subjected to validated time and temperature conditions proven to eliminate human pathogens.

When purchasing treated fertilisers and soil amendments, it is essential to obtain documented evidence of their treatment. A certificate of conformity (CoC) with Australian Standard AS 4454-2012 or New Zealand Standard NZS 4454-2005: Composts, soil conditioners and mulches provides suitable verification. Treating materials containing manure significantly reduce microbial risk. It is important to obtain evidence the treatment is effective. For detailed composting procedures, refer to the relevant national standards AS 4454-2012 or NZS 4454-2005.

For non-certified compost suppliers, evidence should include detailed information on the treatment process and microbial testing results (e.g. CoA) for each batch). It is also recommended to check whether the supplier holds any other relevant food safety certifications.

For on-farm treatment of fertilisers and soil amendments containing animal manure, appropriate composting techniques should be followed. A compliant compost standard, provides specific guidelines for both on-farm and off-farm composting, ensuring that composted material is free from human pathogens.

The process outlined below is intended to explain the principles behind pathogen reduction, not to serve as a full composting guide.

For composting to destroy human pathogens:

- the materials should be kept aerated and outer layers turned into the centre (Figure C6:4)
- the compost pile or windrow should reach a temperature of at least 55°C for three consecutive days (Figure C6:4)
- the materials should then be turned and this time plus temperature combination repeated four times, ensuring all materials are thoroughly treated.

Image C6:1 | Turning a windrow.

Image C6:2 | An in-vessel static composting system.

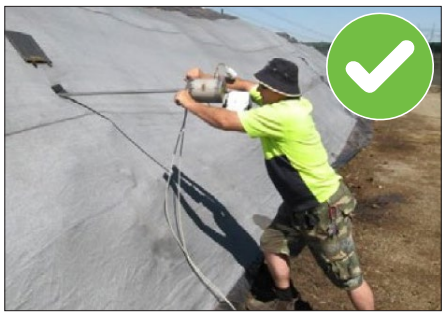


Image C6:3 | Measuring temperature inside a compost window.

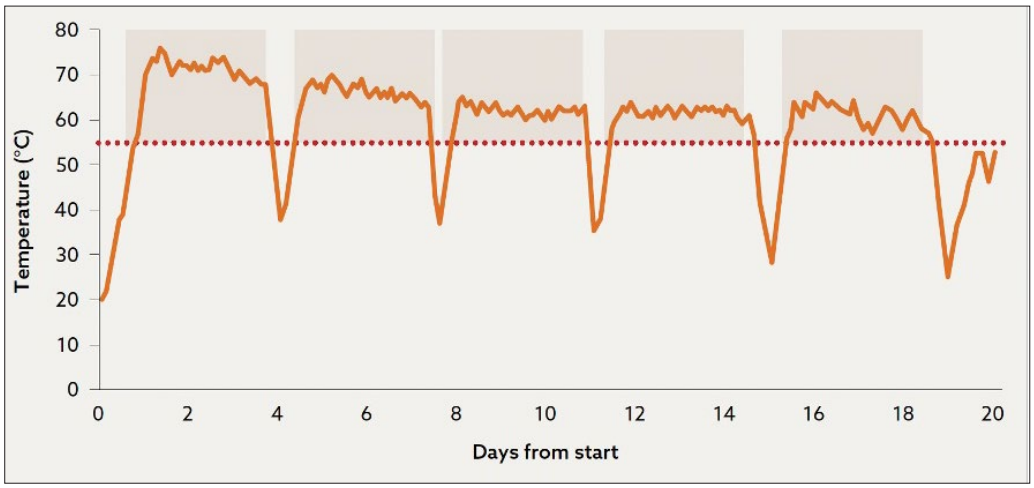


Figure C6:4 | Indicative temperature profile during composting, with five heating events consisting of three days at >55°C, the windrow being turned in-between heating events (i.e. which is when the temperature temporarily declines).

Figure C6:4 provides an example temperature profile during composting. Treatment times may be reduced if temperatures are higher and the material kept well aerated, as can be achieved during in-vessel composting (e.g. mushroom compost production).

Ageing is different to composting, as it involves leaving the material in a static pile for an extended and often undefined period. Depending on environmental conditions, at least six months of ageing may be required to reduce microbial populations. This benchmark is supported by studies detailing that *E. coli* O157:H7 can persist for ≥12 months in manure piles and that pathogens such as *Salmonella* can survive for over 200 days in manure-amended soils. However, even after six months, some human pathogens may remain in cooler or less biologically active parts of the pile. The critical factor in inactivating pathogens present in animal manure is achieving a sufficient temperature (at least 55 °C) for a sustained period of several days, as specified in validated composting protocols. For this reason, aged materials containing animal manure are considered untreated and should not be used where treated compost is required. Pelletised animal manure products are not always treated to destroy human pathogens and should not be assumed pathogen-free.

6.3.1 Biosolids

Biosolids can contain heavy metals, persistent chemicals and human pathogens able to survive normal composting processes.

In Australia biosolids are derived from treated human sewage and industrial waste. In Australia, biosolids and compost containing biosolids should not be used on sites where fruits or vegetables are grown. These materials can contain heavy metals, persistent chemicals and human pathogens that may survive standard composting processes. If biosolids have been applied to a site, fresh produce should not be planted for at least 12 months and checks for persistent chemical residues should be carried out before planting.

In New Zealand Grade A biosolids may be used without restriction if they meet contaminant limits and are approved by the regional council. Grade A biosolids should also contribute no more than 200kg of nitrogen per hectare per year.

These limits include:

- *E. coli* < 100 cfu/g
- *Campylobacter*: Not Detected in 25 g
- *Salmonella*: Not Detected in 25 g
- Enteric viruses: Not Detected in 4 g
- *Helminth ova*: Not Detected in 4 g.

Grade A biosolids should also contribute no more than 200 kg of nitrogen per hectare per year.

Grade B biosolids may be used under specific controls, including soil incorporation and withholding periods. Future restrictions may apply to persistent contaminants such as per- and polyfluoroalkyl substances (PFAS). Adverse health effects from PFAS exposure are not expected if blood concentrations remain below 2 ng/ml.

Biosolids can contain heavy metals, persistent chemicals and human pathogens able to survive normal composting processes.

6.3.2 Considerations for organic soil amendments

When using organic soil amendments, it is important to assess the potential for microbial risks, including the survival, persistence and transfer of pathogens during field production. Key factors influencing these risks include soil temperature, soil moisture and other environmental conditions. The sampling method used to assess microbial safety should also be appropriate to the type of amendment and application method.

6.4 Heavy metal contamination risks

Heavy metals occur naturally in many soils but can also accumulate through repeated use of fertilisers and soil amendments. Phosphate-based fertilisers and some soil conditioners, such as gypsum or trace element blends, may contain elevated levels of heavy metals.

Cadmium is the heavy metal of greatest concern. It can be present in a range of fertilisers, trace element mixes and soil amendments. Excess cadmium exposure has been linked to kidney disease, respiratory issues, skeletal damage and is considered a potential carcinogen. Other heavy metals such as lead and mercury may also be present in soil amendments and can contribute to chemical contamination.

If soils already contain elevated levels of cadmium or other heavy metals, fertilisers or amendments that could increase contamination should be avoided. Chemical residues, including heavy metals, can persist in soil and pose a long-term risk to food safety.

All soil inputs, including fertilisers, composts and conditioners, should be assessed for potential chemical risks and sourced from reputable suppliers [refer Chapters 5 and 15].

6.5 Physical contamination risks

All soil amendments and fertilisers, including compost, manure and soil conditioners, present a potential risk of physical contamination. Once applied, any foreign material remains in the production environment and may pose a hazard to fresh produce during growth or harvest.

Sources of physical contamination can include microplastics, glass, plastic fragments, metal, feathers or other non-organic debris, especially when materials are made from inadequately screened municipal green waste or poultry manure.

Before applying any soil amendment:

- check for the presence of visible foreign matter or insoluble materials
- avoid applying materials that contain fragments or contaminants that cannot be broken down or removed
- keep application equipment clean and well-maintained to avoid introducing foreign objects
- consider wearing a dust mask or other personal protective equipment (PPE) during application, especially in dry or dusty conditions.

Physical contaminants do not break down in the soil and may remain in the soil for years. Careful inspection and sourcing of clean, well-screened materials is essential to prevent persistent risks.

6.6 Reducing pathogen survival in manure-amended soils

The survival of pathogens such as *E. coli* in manure-amended soils is influenced by a range of environmental and management factors. Warmer temperatures, exposure to sunlight (UV) and moderately dry, well-aerated soils with active and diverse microflora tend to accelerate pathogen die-off. In contrast, cool, wet or waterlogged conditions can extend survival times by limiting oxygen and slowing microbial competition and breakdown processes. Soil type also matters. Sandy soils with low nutrient availability support faster pathogen decline than clay-rich or highly organic soils.

The form and handling of manure also impact survival (e.g. solid manure that is incorporated into the soil tends to result in quicker reduction of pathogens than surface-applied slurry).

Fertilisers, including those containing manure, should not be applied to soggy or waterlogged soils. These conditions may increase the risk of pathogen persistence and runoff, particularly in the absence of plant cover. Weather conditions at the time of application and immediately after should be considered to avoid unintended contamination.

Table C6:3 | Factors associated with reduced pathogen survival (e.g. *E. coli*) in manure-amended soil.

Area	Factors associated with reduced survival of pathogens (*E. coli*)
Soil properties	High pH (e.g. liming). Sandy soil with low clay content. Low nutrient availability, particularly assimilable carbon and nitrogen. Moderately dry, well-aerated soils. High aluminium and/or iron oxide levels. Saline soils (i.e. high electrical conductivity). High microbial diversity and activity (i.e. protozoa, fungi).
Water	Avoid application to wet or waterlogged soils, which can extend pathogen survival. Consistent moderate soil moisture supports microbial activity but excess water reduces oxygen and slows natural pathogen decline. Water pH and quality also influence soil microbial dynamics.
Manure properties	Aerated (i.e. turned manure prior to application).
Application method	Solid manure incorporated into soil (i.e. not left on surface). Applied when site is fallow, reducing plant contact risk.
Climate	High and/or fluctuating temperatures. High levels of ultraviolet light. Open field application (i.e. not protected cropping). Protected cropping environments may reduce UV exposure and air movement, which can affect how long pathogens survive in soil. Reduced UV light limits natural inactivation and lower airflow can increase humidity, creating more favourable conditions for pathogen survival. Heavy rainfall and subsequent waterlogging, even in protected systems, can allow pathogens to persist longer. Saturated soils reduce oxygen availability and slow natural microbial breakdown processes, which can extend survival times for pathogens such as *E. coli* and *Salmonella*. Floodwater or contaminated run-off entering a protected cropping system can also introduce new pathogens.

6.7 Good practice for managing fertilisers and soil amendments

Table C6:4 | Summary of good practices for managing fertilisers and soil amendments.

Management area	Good practices
Avoid contamination	Do not use human effluent in fresh produce production. Use biosolids only where permitted under national and regional regulations and apply with appropriate controls. Only use fertilisers and soil amendments with low or non-detectable levels of heavy metals. Store fertilisers and soil amendments in a way that prevents contamination of soil, water or produce. When using manure, follow hygiene and cross-contact controls as outlined in Chapters 7, 9, 10, 11 and 15.
Reduce risk	Never use untreated manure on growing sites where minimum exclusion periods cannot be met (Decision Trees 1 and 2). Avoid applying untreated manure near crops where edible portions are exposed. Maximise the time between manure application and harvest to allow for pathogen die-off. Do not apply untreated manure during rainy or windy weather and incorporate into soil immediately to reduce runoff and dust. Only use manure-treated products within exclusion periods if they meet the following microbiological criteria: • *E. coli* < 100 cfu/g • *Salmonella*: Not Detected in 25 g. Keep composted materials covered and away from waste and rubbish to prevent recontamination by birds or rodents. Apply properly composted materials during pre-planting or early growth stages. Apply near the roots and incorporate into the soil. Wear gloves when handling soil amendments and always wash hands after application.
Record keeping	Keep records of all fertiliser and soil amendment applications, including: • date of application • location or treated area • produce used • application rate and method • name and signature of the person applying the material.

Resources

Codex Alimentarius Commission (2003). Code of hygienic practice for fresh fruits and vegetables: CXC 53-2003. Rome: FAO/WHO.

eCFR (2025). 40 CFR Part 503 – Standards for the Use or Disposal of Sewage Sludge. United States Environmental Protection Agency.

EPA NSW (n.d.). Resource recovery orders and exemptions for biosolids. New South Wales Environment Protection Authority.

FA NSW (2016). Microbiological quality guide for ready-to-eat foods. New South Wales Food Authority.

Jiang, X., Morgan, J. and Doyle, M.P. (2002). Fate of *Escherichia coli* O157:H7 in manure-amended soil. Applied and Environmental Microbiology, 68(5), pp.2605–2609.

Kudva, I.T., Blanch, K. and Hovde, C.J. (1998). Analysis of *Escherichia coli* O157:H7 survival in ovine or bovine manure and manure slurry. Applied and Environmental Microbiology, 64(9), pp.3166–3174.

Water Quality Australia (2012). *National Guidelines for Biosolids Management*. Canberra: Department of Sustainability, Environment, Water, Population and Communities.

CHAPTER 7
Managing Water

Overview

Water is used extensively across the fresh produce supply chain, from growing through to post-harvest activities. At each stage, it can be a potential source of physical, chemical and microbiological contamination if not effectively assessed and managed. To ensure food safety, all water that comes into direct contact with produce should be clean and meet acceptable chemical and microbial criteria. Where appropriate, approved sanitisers should be used to reduce microbial contamination risk.

Regular evaluation of environmental conditions and water systems, along with routine monitoring of water sources, is essential as water quality is dynamic and can shift from safe to contaminated within a short timeframe.

7.1 Hazards and sources of contamination

It is necessary to manage water at all stages of the supply chain to ensure the delivery of safe produce to consumers. Water has the potential to carry human pathogens and chemical contaminants, including microplastics and other water-mobilised particulates.

Microbial pathogens associated with water include bacteria, viruses and parasites [refer Chapter 3 and Appendix 3]. Chemical contamination of water can occur through spills, leaks or leaching of agricultural or industrial chemicals into the water source (Table C7:1). Adoption of the recommended safe practices for storage and application of chemicals will minimise the risk of contamination of water sources on the property [refer Chapter 8].

Water can introduce contamination either directly through contact with produce or indirectly via its use in cleaning containers, equipment, tools, facilities, vehicles and team member hands. To manage this risk effectively, a water risk assessment should be conducted as an initial step. This assessment informs appropriate water uses and determines the level and frequency of monitoring required to maintain food safety.

Entire batches of fruit or vegetables may be contaminated if waterborne microbes infiltrate the produce or adhere to the produce surfaces. Many of the foodborne illness outbreaks that have occurred globally have been traced to the use of contaminated water.

7.2 Source of water

Common water sources used in fresh produce operations include public supplies, dams, bores, rainwater tanks, natural waterways (i.e. rivers and creeks) and agricultural water schemes (i.e. channels and piped systems). Reclaimed water, including non-potable water derived from sewage treatment systems or industrial processes, may be suitable for use during production under controlled conditions. However, it should not be used during harvesting or packing activities, even if treated, due to the elevated risk of contamination.

Businesses should consult the relevant Australian state or territory or New Zealand regulations before using reclaimed water for any purpose beyond irrigation. Emerging evidence suggests that microbes associated with reclaimed water may exhibit higher levels of antimicrobial resistance (AMR) compared to those found in potable water. Where pathogens grow following the use of reclaimed water, they are more likely to display AMR traits in any produce they contaminate. However, to date there is no conclusive evidence that AMR linked to produce has posed a public health concern in Australia or New Zealand. As pathogen contamination events have occurred and water sources vary in quality and change over time with seasonal events, increased AMR-pathogen risk would seem inevitable over the longer-term.

Water quality is dynamic, regular evaluation of environmental conditions and water systems, along with routine monitoring of water sources, is essential to manage contamination risks.

Water quality may change with environmental variation such as heavy rain and droughts:

- during drought water may become more saline or be affected by toxic algal/cyanobacterial blooms
- if drought is followed by heavy rain, then animal manures/sewage may contaminate the water supply, which is not always signalled by an increase in water turbidity.

Generally, the risk of contamination is highest for surface water supplies, less for ground water supplies and lowest for domestic or public potable water supply. Factors to consider when assessing the risk of contamination are:

- type of water source (e.g. surface water, ground water or domestic supply)
- rainfall level
- topography of surrounding land
- likelihood of run-off
- proximity of source to septic or sewage systems
- proximity of water sources to pollution such as garbage dumps, manure storage, manured areas or intensive livestock (e.g. feedlots, poultry farms, dairies, piggeries, horse stables)
- uses of adjacent land
- bird, reptile, amphibian or other animal activity.

Image C7:1 | Waterbirds may introduce contaminants in open water sources.

Image C7:2 | Livestock and other animals can compromise water quality through direct or indirect contact.

Table C7:1 | Potential sources of water contamination.

Water source	Hazard	Sources of water contamination
Waterway or agricultural water scheme (creek, river, channel, pipe)	Physical	Microplastics and fine/flocculant sediments transporting pathogens and chemicals.
	Chemical	Accidental spillage, run-off or leaching of chemicals from industrial or agriculture sites. Spray drift. Roof and rainwater water tank coatings. Mining activity, both current and historic.
	Microbial	Water flows near an intensive livestock area such as a feedlot, dairy, poultry farm or piggery. Water flows near or downstream from populated areas. Blooms of toxic cyanobacteria (i.e. blue-green algae) in stagnant or nutrified water bodies used for irrigation.
Dam	Chemical	Seepage from septic systems or from intensive livestock production or agistment (e.g. horse stables) in catchment areas. Accidental spillage or leakage from chemical storage areas or spray equipment or from chemical filling and washing areas.
	Microbial	Surface run-off from manure storage. Livestock and/or birds in or near the water. Cyanobacterial bloom (i.e. producing toxins).
Bore	Chemical	Leaching of chemicals through the soil profile. Accidental spillage or leakage from chemical storage areas or spray equipment or from chemical filling and washing areas.
	Microbial	Seepage of water run off during periods of rainfall/flooding introducing microbes from environmental and animal sources.
Tank (rainwater and/or domestic water storage)	Physical	Accumulated sediments providing a niche for growth of opportunistic pathogens and preserving enteric pathogens.
	Chemical	Water tank coatings.
	Microbial	Faeces from birds, rodents or other animals washed from the roof and gutters where water is collected. Contamination from birds or animals entering an unsealed tank.

To ensure food safety, water should be tested before initial use and then retested at regular intervals based on risk assessment. The appropriate testing frequency depends on several key factors:

- the likelihood of water quality fluctuations over time
- the frequency of irrigation on the specific type of produce being cultivated
- high risk crops (e.g. leafy vegetables) require more frequent monitoring than produce typically cooked prior to consumption.

Water testing provides useful insights, but it has notable limitations. Results can fluctuate between samples and reflect only the water quality at the exact time of collection, not the broader or continuous conditions. Generally, more frequent testing is required for variable quality water sources such as waterways, channels, dams and groundwaters impacted by surface waters. Events such as heavy rainfall can increase the risk of contamination of these water sources. Maintain ongoing records of water test results to establish a historical profile of the microbial quality of the water sources. For businesses operating year-round, more frequent testing may be necessary compared to those with seasonal operations.

Water for testing should always be collected at the point of use (e.g. a tap, spray nozzle, hose nozzle or shower) after allowing it to run for one to two minutes. This flushes away any contaminants from the fitting, ensuring that the sample reflects the water quality itself, not residues from the outlet [refer Chapter 18]. More than one water source may be available and each used for different purposes (e.g. irrigation water may be lower quality than water used during washing and packing processes).

Water may flow directly from its source to the point of use or be stored in tanks prior to use. Water pipes and tanks are potential sources of microbial contamination. Good practice includes:

Water pipes:

- water pipes are well maintained and free from breaks and cracks that might allow entry of microbes
- backflow devices installed as necessary to prevent contaminated water entering the main system
- application points, such as spray nozzles are regularly cleaned
- when not in use, water pipes should be stowed at an angle so that water does not collect in the pipes but drains away by gravity.

Storage tanks:

- the tank is constructed to prevent entry of pests, wild and domestic animals and birds
- if rainwater is collected, roofs and gutters are clean and maintained
- a filter is fitted to prevent plant material and other debris entering the tank
- annual removal of accumulated tank sediments

7.3 Water used during growing

During growing, water may be used for irrigation, hydroponics, fertigation, spraying and overhead cooling misting. Team members also use water for handwashing. The risk of microbial contamination varies with the mode of water delivery and use. Water that does not directly contact the edible part of the crop is considered a low risk. The risk is highest if water directly contacts the edible part of the produce. An important exception involves water contaminated with cyanobacteria, as their toxins are highly persistent and may be absorbed through plant roots, accumulating in edible crop tissues.

Water used in hydroponics can pose a significant risk of microbial contamination if the water contacts the edible part of the crop. An example is the nutrient film technique used for growing leafy vegetables. The nutrient solution recirculates, constantly contacting the roots and potentially splashing the leaves during harvest and packing. To reduce risk, the nutrient solution needs to be sanitised and monitored to maintain water quality. Run-to-waste systems generally pose a lower risk, as the nutrient solution does not contact the edible part of the crop.

Research has shown that the risk of produce contamination from pre-harvest water is reduced as the time from last water contact to harvest increases. The surfaces of leaves and fruit are generally not favourable for growth of human pathogens (*Listeria* on melons being an exception). Generally, human pathogens decline rapidly after contamination of these surfaces. Water potentially containing human bacterial pathogens that is applied more than 48 hours before harvest poses minimal food safety risk, but longer withholding times may be relevant for higher loadings, particularly if human viruses or parasitic protozoa are potentially present (Table C7:2).

Table C7:2 | Exclusion period (hours) between irrigation or spray application and crop harvest if water contains *E. coli* >100 cfu/100 ml but <1,000 cfu/100 ml (Table C7:4).

	Always consumed cooked	May be consumed uncooked
Water contacts the harvestable part during irrigation or spray application	N/A	48 hours
Water does not contact the harvestable part	N/A	N/A

Note that human pathogens can survive longer within damaged crops, such as if impacted by storms, insect feeding, equipment or people. Contaminated water should not contact the harvestable part of the crop if it has been recently damaged. Several factors can reduce survival of *E. coli* on plant surfaces following irrigation or spray application (Table C7:3).

Table C7:3 | Climate and crop factors that reduce survival of *E. coli* following irrigation or spray application.

Factor associated with reduced survival of *E. coli*	Example of Potential Cause
Climate	High incident radiation (e.g. ultraviolet light). Low relative humidity/leaves dry quickly after irrigation or spray application. High temperature. High variability in temperature.
Crop characteristics	Plants are undamaged. Open canopy. Hydrophobic, smooth or waxy surface. High leaf surface pH. Diverse indigenous microbes on leaf surface. Microbial predators present on leaf surface. Low availability of nutrients.

Image C7:3 | Water that directly contacts the harvestable part of the plant, such as during overhead irrigation, poses a higher risk. Ponding also increases risk of contamination.

Image C7:4 | Design recirculation systems to maintain water quality and prevent splashing onto edible leaves, reducing contamination risks (i.e. run-to-waste hydroponics).

Overhead irrigation systems pose a significant risk of pathogen transfer to crops, especially those consumed uncooked (Image C7:3). This direct contamination pathway is of particular concern for leafy vegetables, berries and other fresh produce, as pathogens can adhere to plant surfaces and enter through natural openings or persist in biofilms. Unlike subsurface methods that limit water contact with edible parts, overhead irrigation increases opportunities for pathogen attachment and survival, making water quality a critical factor in food safety.

All team members working at the growing site should wash their hands with soap for at least 20 seconds, followed by drying with paper towels [refer Chapter 14]. Water quality requirements:

- potable water should be used for handwashing by all team members
- where potable water is unavailable (e.g. in-field, hands should be thoroughly dried and then sanitised using an alcohol-based hand sanitiser containing at least 60% alcohol).

7.4 Water used post-harvest

During harvesting, cooling, processing and packing water may be used for:

- icemaking and cooling produce
- unloading/dumping of produce from picking containers
- transferring produce in flumes between locations
- washing produce
- trimming, de-sapping and de-fuzzing
- applying insecticides and fungicides
- applying wax
- cleaning equipment, containers, vehicles and facility structures.

Cooling produce as soon as possible after harvest not only preserves product quality but also inhibits the growth of human pathogens. Water can provide a fast and effective cooling medium and is used in hydrocooling and hydro-vacuum cooling as well as top icing after packing. It is also used to move produce through wet bin dumps and flumes and to apply post-harvest treatments (Image C7:5).

Water can also introduce and spread human pathogens. When warm produce contacts cold water the internal tissues cool and contract, drawing water and potentially microbes inside. Human pathogens in water have the potential to contaminate both the inside and outside of some produce.

Most contaminants are on the surface of produce and can spread to surrounding produce, increasing the hazard. Water can also be contaminated by bird or rodent faeces, dead animals in tanks or directly from the water source itself. Cooling towers and evaporators can also be a source of contamination if water from the equipment drips onto produce in open containers.

Water that is recirculated during post-harvest processes should be effectively sanitised to prevent cross-contamination. This requirement applies to systems involved in hydrocooling, hydro-vacuum cooling, bin dumping, fluming, dipping and waxing processes. Maintaining appropriate sanitiser levels and monitoring water quality are critical to ensuring food safety throughout these operations.

Water that is used for 'run to waste' purposes, such as to apply fungicide, insecticide or wax, may be the last water that contacts the product, so should not contain *E. coli* >1 cfu /100 ml.

Minimising water exposure during packing line design helps reduce contamination risk, especially on edible surfaces.

7.4.1 Cooling

Cooling systems that use water are generally recirculated and need to be sanitised. Water quality for ice-making should be of potable quality. However, not all sanitisers are equally effective at low temperatures. For example, peroxyacetic acid and chlorine-based products are more effective at low temperatures than some other sanitisers (Table C7.5).

7.4.2 Dump tanks and flumes

Water in dump tanks and flumes is often recirculated for extended periods, so should include an effective sanitiser. However, some sanitisers react with organic materials, rendering the sanitiser ineffective when the water becomes dirty. For example, chlorine-based and ozone systems lose activity quickly if high levels of organic matter are present.

The level of sanitiser should be maintained through regular monitoring or an automated monitoring and dosing system installed. Water should be replaced if sanitiser levels cannot be maintained.

Image C7:5 | Wet dumps and water flumes are widely used to transport produce during packing, but can be a significant source of pathogen cross-contamination if not properly sanitised.

When using chlorine-based sanitizers, pH monitoring is critical because chlorine effectiveness depends heavily on water pH. At pH levels above 7, chlorine products produce less hypochlorous acid (HOCl), which is the active biocidal compound responsible for pathogen inactivation. However, maintaining very low pH can increase corrosion of equipment and create other operational challenges. To balance antimicrobial effectiveness with practical considerations such as equipment protection, the recommended pH range for chlorinated water is 6.0-7.5.

7.4.3 Washing produce

Effective washing can be achieved when:

- washing is thorough and vigorous (i.e. the process should be sufficiently long and turbulent to remove soil, chemical residues and foreign materials from produce surfaces)
- mechanical action enhances cleaning (i.e. agitation or pressurised spray nozzles increase the physical force applied to surfaces, improving removal of microbiological and chemical contaminants)
- surface scrubbing provides additional benefits (i.e. brushes can be highly effective for certain produce types, but only when they are easily accessible for regular cleaning and sanitisation to prevent cross-contamination)
- water quality is maintained throughout the process (i.e. washing may involve single or multiple steps and should use potable water supplemented with an appropriate sanitiser or a run-to-waste system to minimise cross-contamination between produce).

Image C7:6 | A series of washes are more effective at cleaning the product than a single wash.

Image C7:7 | Water containing *E. coli* <1 cfu/100 ml should be used to apply fungicides and waxes.

Fungicides and insecticides are not intended to kill human pathogens, most of which are bacteria, yet some plant fungal pathogens belong to the same species as human pathogens (e.g. *Aspergillus fumigatus*) and are carried via water. Some sanitisers are incompatible with certain fungicides, rapidly losing activity when two or more such products are mixed together.

If pesticides or waxes are applied through a recirculating dip, but a sanitiser cannot be included, then consider minimising the size of the reservoir and change the solution regularly. Run to waste systems generally pose less risk than recirculating dips and should always use potable water.

7.4.4 Cleaning equipment, containers, vehicles and facility structures

Cross contamination can occur if contaminated water is used to wash picking containers or other equipment that contacts produce. Use only potable water for washing equipment, containers, vehicles and facility structures. Water droplets may be splashed or blown onto produce during cleaning of vehicles as well as the walls, ceiling and floor of the facility. Water used for cleaning should be discarded after use.

Potentially contaminated water should be disposed of using a method that avoids cross contamination of equipment or produce.

7.5 Water quality and treatment

7.5.1 Water quality

The microbial quality of water is assessed for faecal contamination using *E. coli*, a member of the coliform group [refer Appendix 4]. While most *E. coli* are harmless inhabitants of warm-blooded animal intestines, certain pathogenic strains called STECs (Shiga toxin-producing *E. coli*) have caused serious foodborne illness outbreaks [refer Chapter 3, section 3.1 and Appendix 3]. Despite these concerns, enumeration of total *E. coli* by culture remains the preferred indicator of microbial risk in water.

Further guidelines for chemical and microbiological quality of water used for irrigation of food crops is outlined in ANZG (2023), which also provides guidance on tolerable levels of *cyanobacteria* and *cyanobacterial* toxins.

The following water microbial criteria are recommended in Table C7:4.

Table C7:4 | Microbial criteria for water used in growing and harvesting.

Water microbial criteria	Suggested water use
E. coli <1 cfu/100 ml	May be used without restriction on any crop at any time as it is considered potable or highly treated.
E. coli <100 cfu/100 ml	May be used without restriction on any crop prior to harvest and for certain post-harvest applications (Table C7:5).
E. coli >100 but <1,000 cfu/100 ml	May be used any time pre-harvest if produce is always cooked before consumption. Is not used within 48 hours of harvest where water contacts edible portion of crop and produce may be consumed uncooked (Table 7:2).
E. coli >1,000 cfu/100 ml	Should not be used for irrigation or crop spraying where the water contacts the edible portion of produce that may be consumed uncooked.

Note: These limits do not apply to reclaimed water. Growers should check with Australian state/territory or New Zealand regulations before using reclaimed water for purposes other than irrigation.

Table C7:5 | Microbial criteria for water used in post-harvest applications.

	Type of produce	Use of water	Critical limit
Washing, cooling and treating produce	Always consumed cooked	Pre-washing to remove soil and debris.	N/A
		Final wash or single step washing. Water dumps and flumes. Hydrocooling, top icing. Applying fungicides, insecticides and waxes.	*E. coli* <100 cfu/100 ml
	May be consumed uncooked	Pre-washing to remove soil and debris.	*E. coli* <1 cfu/100 ml
		Final wash or single step washing. Water dumps and flumes. Hydrocooling, top icing. Applying fungicides, insecticides and waxes.	E. coli <1 cfu/100 ml
Cleaning and sanitising facilities, equipment and containers	All	Cleaning and sanitising containers and equipment surfaces that contact produce. Handwashing.	*E. coli* <1 cfu/100 ml
		Cleaning vehicles, floors, walls and ceilings. Cleaning equipment that doesn't contact produce. Handwashing if followed by application of alcohol hand sanitiser with minimum of 60% alcohol.	*E. coli* <100 cfu/100 ml

7.5.2 Water treatments

If water is potentially contaminated and no cleaner alternative is available, it should be treated to minimise the microbial risk. It is important to remember that the purpose of sanitising water is to eliminate or reduce harmful microorganisms like bacteria, viruses and parasites, preventing them from contaminating the produce. However, different water sanitisers interact with materials differently. Ozone or chlorine can be very corrosive to some metals and alloys, including parts within water pumps and various fixtures. Hence, it is important to have compatible infrastructure, which may initially be more expensive to purchase, but less expensive in the long run to minimise corrosion damage and maintain system integrity.

Once produce is contaminated it is difficult to significantly reduce the microbial load, the only completely effective methods are gamma-irradiation or cooking before consumption. *Cyanobacterial* toxins and bacterial exotoxins are particularly challenging to eliminate from water as they are highly stable and resist removal through conventional methods. They are not destroyed by cooking temperatures and cannot be eliminated by standard water disinfectants (e.g. chlorine or basic filtration systems). Effective removal requires advanced treatment technologies, including activated carbon filtration or advanced oxidation processes using specialised chemicals.

There are numerous chemical sanitisers and non-chemical sanitising methods that can be used to treat water. Options include:

- chlorine-based chemicals: calcium hypochlorite, sodium hypochlorite, bromo-chloro compounds, chlorine dioxide. These are ineffective against Cryptosporidium oocysts, where UV or Ozone is preferred
- peroxyacetic acid
- iodine
- ozone
- UV irradiation
- advanced oxidation, generally H_2O_2-UV or H_2O_2-ozone and free radicals
- nanobubbles, typically 50–200 nm bubbles generated on nanosilver or nano-titanium dioxide materials with ozone, which generate reactive oxygen species (free radicals) that persist in association with neutrally buoyant nanobubbles.

Factors that need consideration when selecting the best sanitising method to use, include:

- type and number of pathogens likely to be present
- amount of organic material in the water
- water pH and presence of salts or sediment
- water temperature
- sanitiser concentration
- duration of contact between the sanitiser and the produce.

Each method of sanitising water has advantages and disadvantages as well as different ways to monitor concentrations and effectiveness (Table C7:6). Sanitiser selection may also be affected by local regulation of water disposal and the methods approved for use by the destination market.

Monitoring is essential to verify that the sanitising treatment remains effective in reducing water borne microbes (i.e. that the concentration of the active component remains high enough and that correct operating conditions are being maintained). Checking microbiological levels before and after treatment is the best way to monitor effectiveness [refer Chapter 18]. Some sanitising methods, such as application of chlorine dioxide, bromo-chloro compounds, peroxyacetic acid and iodine, can be automated. In such systems the level of the active ingredient in the water is constantly monitored and adjusted, as required.

Table C7:6 | Comparison of sanitising methods.

Sanitising method	Advantages	Disadvantages	Monitoring	Suitable uses
Calcium hypochlorite **Sodium hypochlorite**	Relatively inexpensive and easy to use. Effective against most microbes. Provides residual control.	De-activated by organic matter. Requires pH control (6.0-7.5). Corrosive to metal.	Test strips, meters or fully automated systems to measure pH and dose chlorine.	All water used during harvesting and packing.
Bromo-chloro compounds	Less affected by organic matter and pH than calcium/sodium hypochlorite. Provides residual control. Low corrosion.	Often generated on site.	Automated analyser.	All water used in a packing facility.

Chlorine dioxide	Effective at low concentrations. Not affected by organic matter in water. Less affected by pH than calcium/sodium hypochlorite. Provides residual control.	Should be generated on site. Explosive at high concentrations. Relatively expensive. Requires good ventilation to avoid irritation to team members.	Redox probe. Method recommended by the manufacturer.	All water used in a packing facility.
Peroxyacetic acid (PAA)	Stable in high organic loads. Produces biodegradable by-products.	Hazardous at high concentrations. De-activated at high temperature and high pH.	PAA test strips. Automated analyser.	All water used in a packing facility.
Iodine	Stable in high organic loads. Effective at broad pH range. Some fungicidal activity.	Corrosive to metal.	Automated analyser.	All water used in a packing facility.
Ozone	Highly effective in killing microbes.	De-activated by organic matter. No residual control. Concentrations may be variable and cannot be easily monitored. Corrosive to metal. Should be generated on site. Requires good ventilation to avoid irritation to team members.	Automated analyser.	Non-recirculated water used in a packing facility. Not suitable for dirty water or water in dump tanks and flumes.
Electrolysed water	Salt (NaCl) input required. Low electricity usage. Multiple antimicrobial oxidants produced. Solution is stable and can be stored. No team member safety issues unless the pH becomes too low.	High capital cost.	Automated analyser.	All water used in a packing facility. Research underway on pre-harvest applications.

7.6 Good practice for managing water

Table C7:7 | Summary of good practices for managing water.

Growing	
Assessment	Environmental conditions and water systems are regularly evaluated to ensure ongoing suitability and safety. Routine monitoring of water sources is conducted to assess risk of contamination and ensure water meets quality requirements. Historical water data is tracked across seasons, with adverse weather events documented to support trend analysis and risk assessment.
Reducing risk	Potable water is used for handwashing. Water that meets relevant quality criteria is used in production, depending on how the produce is consumed (e.g. uncooked) and timing of application (e.g. within 48 hours of harvest). Irrigation water is not applied to the edible portion of the crop (especially for high-risk crops that are consumed uncooked like leafy vegetables). Nutrient solution used in hydroponics is sanitised and monitored to maintain water quality. Water pipes and storage tanks are well maintained. Water sources contaminated with toxic algae or *cyanobacteria* are not used if pre-harvest water directly contacts the edible portion of the produce. If pre-harvest water contacts the edible portion within 48 hours of harvest: • water quality requirements are assessed • each water source is tested at least monthly • testing is conducted during periods of highest risk • water quality meets specified limits and/or a validated pathogen reduction step is applied post-harvest. Where water contacts edible portion of the crop and produce may be consumed uncooked, water containing *E. coli* >100 cfu/100 ml is not used within 48 hours of harvest. Produce that has come into contact with flood water is not harvested for human consumption, due to the difficulty in eliminating contamination and verifying safety [refer Appendix 19]. Potentially contaminated water does not contact produce with recent physical damage.
Post-harvest	
***E. coli* limits**	Water meets or is treated to achieve the critical limit of *E. coli* <1 cfu/100 ml of water unless: • the produce is always consumed cooked • the water is used to pre-wash produce immediately before a final wash in higher quality water. Water sources are tested for *E. coli* monthly during the period of use. Outlets supplying water not verified as *E. coli* <1 cfu/100 ml are clearly marked (e.g. 'not for drinking or handwashing').

Reducing risk	Select, manage and maintain water sources, storage equipment and infrastructure to minimise potential contamination from: • human activities • livestock and domestic animals • wildlife, where applicable • adjacent land use or operations. Do not use water sources contaminated with toxic algae. Sanitise, monitor and refresh water in recirculation systems, water dumps, flumes and treatment tanks at appropriate intervals to maintain hygiene and effectiveness.
Hazard analysis	Complete a process flow diagram to map where water is sourced and how it is used throughout production. A hazard analysis is conducted for each water source to assess the risk of microbial contamination of produce and a record of this analysis is maintained. Key factors considered in the hazard analysis include: • type of produce • method of consumption (e.g. uncooked or cooked) • potential sources of contamination • likelihood of water contamination • intended use of the water.
Sanitation	If hazard analysis identifies a high-risk water source, either a safe alternative is used or the water is treated to reduce microbial load. Sanitation treatments are monitored to verify effectiveness and ensure operating conditions are maintained. Monitoring is conducted at a frequency aligned with the level of risk and all results are documented.

Resources

ANZG (Australian and New Zealand Guidelines) (2023). *Water quality for irrigation and general water uses: Background information*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand governments and Australian state and territory governments, Canberra.

Environment Protection and Heritage Council, Natural Resource Management Ministerial Council and Australian Health Ministers' Conference (2006). *Australian guidelines for water recycling: Managing health and environmental risks*.

CHAPTER 8
Managing Chemicals

Overview

To protect crops, maintain hygiene and control pests, a range of agrichemicals (including cleaning, sanitising and pest control chemicals) are used during production, harvesting, packing and storage of fresh produce. Good chemical management practices are essential for ensuring food safety, environmental sustainability and regulatory compliance.

To minimise risks, all pesticides, cleaners, sanitisers and other chemicals should be applied according to the label's instructions and relevant regulations, ensuring compliance with Maximum Residue Limits (MRLs) and safe handling practices. Adequate storage, labelling and disposal are also critical to prevent contamination, chemical spills and environmental hazards.

This section outlines good practices for the safe and responsible use of chemicals, including regulatory requirements, application guidelines and risk management strategies.

8.1 Chemical use in production and post-harvest handling

Chemicals may be used on or around fresh produce during:

- production, harvest, packing and storage
- cleaning and sanitation of processing facilities and equipment
- pest control in production and storage areas.

Agrichemicals such as pesticides, fungicides, herbicides, finishing sprays and bud set sprays may be applied pre-harvest. Additionally, fumigants, liquid fungicides and insecticides may be applied post-harvest to control pests and diseases.

Water used for washing fresh produce often contains sanitisers to inactivate microorganisms and prevent cross-contamination.

8.2 Regulations on chemical residues

The list of approved agrichemicals and sanitisers and their maximum residue limits (MRLs) are set by:

- Australian Pesticides and Veterinary Medicines Authority (APVMA) in Australia
- Ministry for Primary Industries Agricultural Compounds and Veterinary Medicines Group (MPI ACVM Group) in New Zealand.

These regulations are published in the Food Standards Code. In New Zealand, MRLs are set via the *Maximum residue levels for agricultural compounds notice* issued under the Food Act 2014. Since MRLs and approved chemicals vary internationally, exporters are required to confirm compliance with importing country regulations.

If an MRL is not specified for an agrichemical or sanitiser, it is generally accepted in Australia that no detectable residue is permitted on the produce. In New Zealand where there is no MRL specified, a default MRL of 0.1mg/kg applies. In some instances in New Zealand, the limit is set as the limit of analytical quantification (e.g. 0.01 mg/kg) meaning use of the substance on that produce is not permitted and any residue detection is considered a breach.

The ways in which fresh produce can contain pesticides which exceed MRLs or become contaminated with unapproved chemicals are outlined in Table C8:1.

Table C8:1 | Ways fresh produce can exceed MRLs or become contaminated with unapproved chemicals.

Cause	Potential sources of contamination
Incorrect use of an approved agrichemical	Not reading or understanding label instructions. Incorrect application and /or application rate. Expired products. Incorrect mixing (e.g. too high concentration). Failure to observe withholding periods. Use of uncalibrated dispensing/application equipment.
Cross-contamination	Spray drift from neighbouring crops. Persistent agrichemicals in soil from previous applications. Residue in picking bins or crates. Unclean equipment. Using postharvest treatments not approved for the specific use.
Accidental exposure	Spray drift from industrial sites. Use of unapproved pest control chemicals. Chemical spills (e.g. fuel, oil, sanitisers) near produce or packaging. Use of non-compliant waxes (e.g. morpholine- based waxes) which are banned in the EU.

8.3 Good practice for chemical management

Good practices for chemical management in fresh produce production and post-harvest handling are outlined in detail in Table C8:2.

Table C8:2 | Summary of good practices for chemical management.

Management area	Good practices
Purchasing and procurement	Chemicals should be sourced from suppliers approved by the national regulator (e.g. Agsafe in Australia or MPI in New Zealand). Chemicals must be provided in original, intact containers, with legible labelling that clearly identifies the product and its intended use. Second-hand agrichemicals should not be purchased for food crop use. Deteriorating chemical labels should be replaced immediately with a legible copy to prevent misidentification. Chemicals with deteriorated or missing labels should not be purchased or used. Material Safety Data Sheets (MSDS) / Safety Data Sheet (SDS) are legally required to be readily available to all team members using the chemicals and easily accessible in case of an emergency.

Management area	Good practices
Storage of chemicals	Chemical storage areas should: • be located and designed to prevent contamination of fresh produce, water sources, equipment and packaging materials • be designed to contain leaks and spills (e.g. bunded areas) • be structurally sound, ventilated, well-lit and protected from direct sunlight and weather exposure to maintain chemical stability • contain an appropriate spill kit for immediate response to leaks or accidental exposure • be secured with restricted access for authorised and trained team members only and designed to prevent chemicals being misused • not used for storing non-compatible materials such as fuels, fertilisers or flammable substances. Adequate chemical storage protocols include: • chemicals being stored in designated areas, separated by category (e.g. insecticides, fungicides, sanitisers, herbicides) to avoid cross-contamination • chemicals remaining in their original containers, unless transferred to an approved storage container (e.g. Dangerous Goods-certified containers) with an attached copy of the original label and batch number • annual checks being conducted to identify and segregate expired or deregistered chemicals for disposal. Records being maintained on disposal activities, including: • date of inspection • names and quantities of chemicals being identified for disposal • methods of disposal (e.g. registered collection agency or approved off-farm disposal area) • unusable chemicals and empty containers are required to be disposed of legally, using registered collection agencies (e.g. DrumMuster and ChemClear in Australia or Agrecovery in New Zealand).

Image C8:1 | Chemicals should not be left on the ground. They should be stored securely to prevent spills or contamination.

Image C8:2 | Chemicals should not be transferred into containers that lack adequate labelling.

Management area	Good practices
Training and competency	To ensure the safe handling, application and disposal of chemicals in accordance with regulations, supervisors and team members handling chemicals are required to complete recognised training such as: • ChemCert in Australia • Growsafe in New Zealand
Chemical use	All chemicals are required to be applied in strict accordance with: • regulatory and customer requirements • label directions • off-label permits issued in Australia by APVMA or local State and Territory requirements. In New Zealand by MPI Agricultural compounds and Veterinary Medicines (MPI ACVM) or New Zealand Environmental Protection Agency (NZEPA). Copies of current chemical labels and off-label permits are required to be retained, permits can be accessed via the APVMA website. Pre-harvest pesticides are required to follow withholding periods (WHPs), which range from one day to several months. Post-harvest pesticides are required to be approved and applied according to label instructions. Before use, each new chemical container should be checked for label updates to ensure compliance.
Chemical application and equipment calibration	Personal Protective Equipment (PPE) is required to be provided, when required. Chemical application equipment should be well maintained to ensure correct dosing and MRL compliance it should be calibrated regularly, at least annually or per manufacturer recommendations or regulatory requirements. Calibration should be carried out following the manufacturer's instructions or an approved calibration method, by trained team members. Calibration should be rechecked immediately after replacing spray nozzles to ensure accurate dosing. Records should be kept for all calibration activities, including: • date and team members responsible for calibration • description of the calibration method used • results of the calibration test.
Mixing and handling of chemicals	Chemical mixing areas should be located away from fresh produce and water sources to prevent contamination. For measuring volumes and weights, calibrated equipment is required to be used. Leftover chemical solutions should be disposed of according to label directions, or in a way that minimises the risk of contaminating produce.

Management area	Good practices
Record keeping and documentation	To ensure traceability and compliance, detailed records of all chemical treatments should be maintained, including: • crop and treatment location (site address) • date and time of treatment • target pest or purpose of treatment • product name and active ingredient • batch number and expiry date • rate and quantity applied • equipment and application method used • withholding period (WHP), if applicable • operator's name and certification details • weather conditions at the time of application (e.g. humidity, temperature, wind direction and speed).
Testing, certification and compliance	Packed produce should undergo random sampling and testing, at minimum once per year, to ensure that chemical treatments comply with Maximum Residue Limits (MRLs). Testing programmes should be designed to consider seasonal differences in the use of chemicals. Chemical residue testing should include: • a multi-screen test covering commonly used pesticides and agrichemicals to ensure that it covers all chemicals that the grower uses. Analysis by a laboratory accredited by National Association of Testing Authorities Australia (NATA Australia) or International Accreditation New Zealand (IANZ New Zealand) to International Organisation for standardisation (ISO)/ International Electrotechnical Commission (IEC) ISO/IEC 17025 standards • in New Zealand, the laboratory is required to be approved by the Ministry for Primary Industries (MPI) for residue analysis • results should be documented to verify compliance with Food Standards Australia New Zealand (FSANZ) MRLs and in NZ the MRL Food Act notice, customer-specific requirements, importing country regulations.
Standards	NZS 8409:2021 Management of Agrichemicals provides practical and specific guidance on the safe, responsible and effective management of agrichemicals, including plant protection products (such as herbicides, insecticides, fungicides), veterinary medicines, fumigants used in rural situations and agricultural use.

Image C8:3 | Chemicals should be stored within the original containers, adequately labelled and kept in a designated storage area.

Image C8:4 | The chemical store should be structurally sound, secure, adequately lit, well ventilated, constructed to protect chemicals from direct sunlight and weather exposure.

Image C8:5 | The chemical store should be equipped with a spill kit to contain and manage chemical spills

8.4 Surface coatings

Surface coatings, such as waxes, may be applied to fresh produce to reduce moisture loss and enhance appearance. However, these coatings should:

- be approved for use in the destination market (e.g. morpholine-based waxes, which are commonly used are prohibited in the European Union)
- be applied strictly according to regulatory requirements to prevent contamination and ensure compliance with food safety standards
- comply with FSANZ allergen labelling requirements (refer Chapter 16)
- follow good practice procedures for purchase, storage, application and disposal.

Image C8:6 | Waxes should be appropriate for the destination market.

8.5 Cleaning, sanitising and pest control chemicals

Cleaning, sanitising and pest control chemicals are essential for maintaining hygienic processing environments, preventing microbial contamination and ensuring food safety. To minimise risks:

- all cleaning, sanitising and pest control chemicals are required to be approved for their intended purpose and used strictly according to the manufacturer's instructions
- storage and application should prevent contamination of produce, vehicles, equipment, containers and packaging materials
- secure, vented storage areas should be designated for cleaning and pest control chemicals to:
  - » prevent cross-contamination with fresh produce, food-contact surfaces and raw materials
  - » ensure chemicals are kept separate from production, handling and storage areas
  - » comply with regulatory requirements for storage.

Image C8:7 | Up-to-date safety data sheets (SDS) are maintained and readily accessible for reference.

Image C8:8 | Bait stations are securely placed to prevent tampering and accidental cross-contamination.

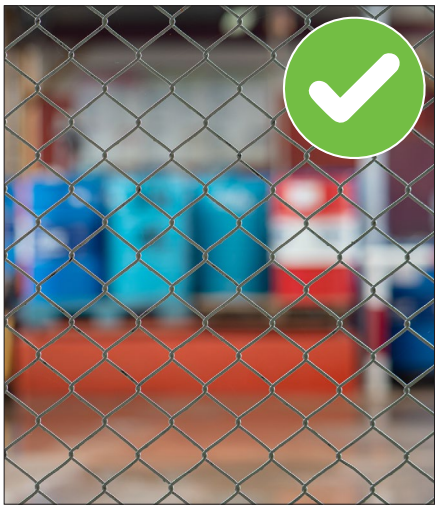


Image C8:9 | Chemicals are stored in locked, restricted-access areas to prevent contamination and unauthorised use.

Resources

Food Standards Australia New Zealand (FSANZ) (2024). *Australia New Zealand Food Standards Code – Schedule 20 – Maximum residue limits*.

International Organization for Standardization (ISO) (2017). *ISO/IEC 17025:2017 – General requirements for the competence of testing and calibration laboratories*. Geneva: ISO.

Ministry for Primary Industries (MPI) (2025). *Maximum residue levels for agricultural compounds: Food notice – 31 July 2025*.

CHAPTER 9
Managing Facilities

Overview

Well-designed facilities prevent contaminants moving from early to later process steps and minimises the risk of produce contamination. Facilities should also be designed for ease of cleaning, maintenance and to avoid accumulation of water and debris.

9.1 Introduction

Facilities vary according to the type of business. The facility may be a simple farm building used to store empty picking containers and hold produce ready for dispatch. At the other end of the scale, it can be a building with capacity to pre-cool, treat, grade, pack, ripen and store produce. Facilities include:

- growing sites (e.g. glasshouse, tunnel, net house)
- produce storage areas
- structures used to store packaging materials and other inputs
- buildings used for cooling, grading, washing, treating and packing
- cold rooms, ripening or conditioning rooms
- disinfestation or quarantine structures (e.g. fumigation chambers)
- distribution centres
- market stands.

Other chapters that should be considered with this chapter include:

- Chapter 10: Managing Tools and Equipment
- Chapter 11: Managing Containers and Packaging
- Chapter 12: Managing Vehicles
- Chapter 13: Managing Animals

9.2 The outside environment

Movement from outside areas into the facility increases risk of produce contamination from external sources (Table C9:1). Wind, water runoff and mud can transfer microbes and chemicals into the facility. Additionally, pests (including rodents, birds, insects and spiders) may inhabit surrounding areas, particularly if perimeter weeds are not properly controlled. Contaminants may also be carried on or be spread by vehicles, machinery, equipment and containers or team members.

Image C9:1 | Good practice example of a tidy and clean area outside a facility.

Image C9:2 | Unacceptable practice example with external areas that are not adequately maintained, creating conditions that may harbour pests and increase risk of contamination.

Table C9:1 | Potential external sources of contamination of facilities.

Source	Potential type of contamination
Water source and storage conditions	Facility water source is non-potable and potentially contaminated by animal faeces or dead animals.
Drainage area	Microorganisms (e.g. *Listeria*) from puddles and poorly drained areas enter the facility directly by runoff or carried in on machinery, equipment and team members. Water pooling encourages insect infestations to occur.
Roads and paths	Soil and dust enter the facility on the wind, equipment and team members.
Farm machinery and vehicles	Soil and pests enter the facility on tractors and forklift wheels.
Equipment and containers	Transfer of soil and plant debris into the facility on equipment and containers used during growing and harvesting.
Livestock and pests	Entry of birds, rodents, insects and other animals into the facility. Human pathogens from manure enter the facility directly on dust and in runoff or carried in, on machinery, equipment and team members.
Storage areas for fertiliser, manure or chemicals	Microorganisms and chemicals enter the facility directly by wind and runoff or carried in on machinery, equipment and team members (storage not well separated from the facility).
Facility surrounds	Weeds and plant waste near the facility harbour pests.
Toilets and team member meal areas	Sewage and wash water seep into the facility water source or runoff directly into the facility. Failure to wash and sanitise hands properly (transfer of human pathogens or allergens from team members' hands).

9.3 Inside the facility

It is important to eliminate design features and materials that enable harbourage and cross-contamination of hazards to produce during storage, processing and packaging. Table C9:2 provides a summary of potential contaminants and their sources inside facilities.

Image C9:3 | Good practice example of a well-maintained internal environment that helps minimise contamination risks and supports compliance with hygiene standards.

Image C9:4 | Unacceptable practice example with untidy or inadequately maintained internal areas that may harbour pathogens and attract pests.

Table C9:2 | Potential sources and types of contamination inside packing and storage facilities.

Source	Potential type of contamination
Structures (e.g. walls, ceilings, posts, bearers, mezzanine floors, walkways, stairs)	Paint flakes, rust and dirt on structures fall into open containers or packed product. Faeces of birds, rodents and other animals accumulate on structures and drop onto produce, equipment, containers and packaging. Water drips or splashes from structures during cleaning, due to condensation or from leaks during heavy rain. Electric insect killers attract and kill flying insects which then drop into grading equipment or onto produce.
Cool rooms, ripening rooms	Condensation, dripping of water from dirty ceilings, walls and cooling units into open containers. Discharge from defrost and condensate lines. Splashing of water onto produce during cleaning.
Drains	Pathogens such as *Listeria* and *Salmonella* can survive in drains and contaminate product and equipment through splashback and overflow.
Dirty food contact surfaces	Microbiological contaminants such as *E. coli* and *Listeria* can survive on dirty surfaces and in biofilms, potentially leading to repeated contamination of produce.
Lights	Glass from broken lights falling onto produce, equipment, containers or packaging materials.
Storage of equipment, materials and product	Faeces of birds, rodents and other animals accumulating in storage areas. Broken glass, hard or brittle plastic, ceramic or similar material fragments falling onto produce, equipment, containers and packaging.
Chemical storage	Spillage or leakage of chemicals into areas where produce is handled and/or packaging is stored. This includes all agrichemicals, maintenance chemicals, fuel, oil and grease.
Fertiliser storage	Spillage or leakage of fertilisers into areas where produce is handled and/or packaging is stored [refer Chapter 6].
Workshop	Metal shavings and other foreign objects from a workshop located close to areas where produce is handled and/or packaging is stored.
Team members	Jewellery, hair, adhesive plasters/bandages and/or disposable Personal Protective Equipment (PPE).

To minimise risk, key considerations include:

9.3.1 Improved facility design

Contamination potential may be higher at entry to the facility than at the exit. Facility layout should prevent contaminants from earlier steps transferring to later steps in the process. To achieve effective control, consideration should be given to the following elements of facility design:

- process flow
- air flow
- traffic (vehicle) flow
- people movement
- flooring (materials, slope and maintenance)
- water drainage (so that water flows from areas of high hygiene control to areas with lower hygiene control)
- infrastructure to prevent condensation
- storage of unused equipment
- location of repair and maintenance activities.

Ideally, the facility will be described in zones, whereby the level of sanitary control is determined by the type of activities in the zone and the feasibility of implementing controls.

Specific attention should be given to the site, design and maintenance of drainage systems which are high risk for potential product contamination. Critical considerations for drainage include:

- construct using food safe, corrosion resistant materials
- the number and capacity of drains should prevent water accumulation
- ensure waste flows from high-risk to low-risk areas
- prevent backflow
- keep clean and free of blockages with a documented and monitored cleaning schedule
- prevent pest entry using grates or mesh.

For further information refer to the Food Standards Code Standard 3.2.3 Food premises and equipment.

9.3.2 Separation of materials

Areas used for handling and storage of produce should be separated from areas used to store equipment, packaging, chemicals, fuel, oil, grease, fertilisers and other materials. Crates, bins and other containers should be identified for in-field use or facility use (e.g. colour coding). If, in small facilities, clear separation is not feasible then prevention of cross-contamination should be achieved through separation of activities by time, team training and control of workflow. Contamination risks vary depending on the type of produce being produced/packed. The inherent level of risk from the volume and type of produce and the processes used should be considered.

9.3.3 Operate a risk-based cleaning and sanitising programme

The frequency of cleaning, sanitising and maintenance activities depends on the risk of contamination. For example, cleaning and maintenance may be required daily during peak periods of operation, weekly during infrequent operation or annually prior to seasonal operation. A cleaning and maintenance plan should be prepared, detailing the structure or area to be cleaned or maintained and the type and frequency of the activity. A record should be kept of all cleaning and maintenance activities to confirm they have been completed correctly and as scheduled.

The required frequency of cleaning and sanitising can be determined, for example, from the results of environmental monitoring, which also verifies the effectiveness of cleaning and sanitising performed. Guidance on environmental monitoring programmes is available in the FSANZ Compendium of Microbiological Criteria for Food (2025) and UFPA Guidance on Environmental Monitoring for *Listeria* Control in the Fresh Produce Industry, 2nd Edition (2018). As an example, production zones in the facility will determine cleaning regimes as outlined in Table C9:3.

Table C9:3 | Facility zones and cleaning frequencies.

Zone	Cleaning regime
A	Clean and sanitise daily, with possible mid-production sanitation.
B	Clean and sanitise daily.
C	Generally, clean and sanitise daily, but less frequent cleaning of some areas may be appropriate.
D	As appropriate for maintenance of facility hygiene.

This zoning is also used to plan the monitoring programme as shown in **Figure C9:5**.

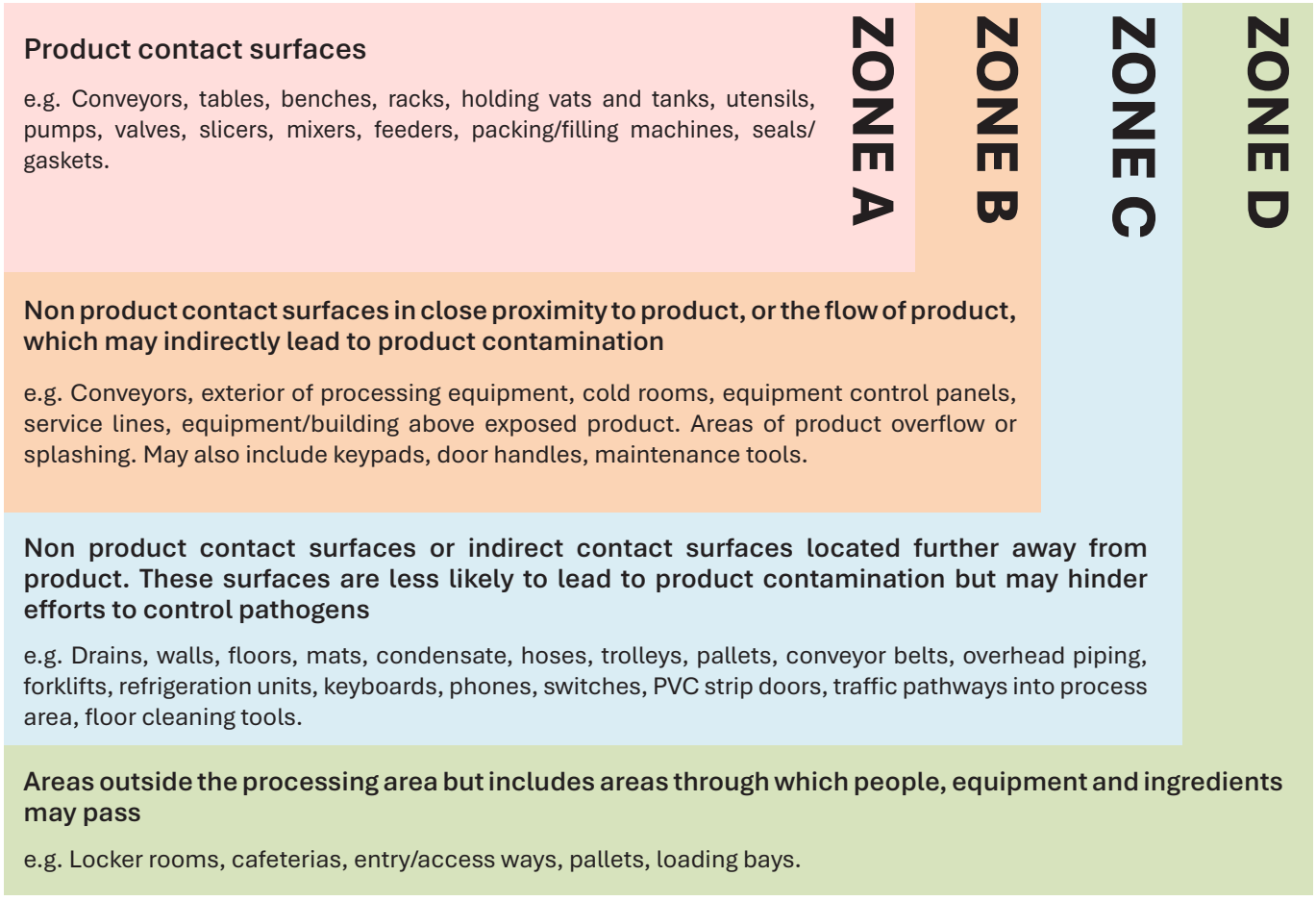


Figure C9:1 | Example environmental monitoring zones and sites (Adapted from FSANZ Compendium of microbiological criteria for food 2025).

Environmental monitoring programmes need to be business specific based on contamination risks (i.e. a risk-based plan should be established) [refer Chapter 18].

The formation of microbial biofilms on food contact surfaces (Figure C9:2) can pose a significant hazard to food safety (food contamination with human pathogens) and food quality (food contamination with spoilage microorganisms).

Biofilms are a community of microorganisms and associated extracellular products (polysaccharides, eDNA, proteins, lipids) growing on a surface. The extracellular matrix (slime layer) enhances the survival of the microbes in hostile environments and increases their resistance to sanitisers and other stressors (UV, heat, drying).

To minimise or potentially prevent biofilm formation, the food facility should have developed an efficient cleaning and sanitising programme, noting that these programmes can fail due to the development of microbial dormancy among biofilm-associated cells. To prevent this, cleaning and sanitising programmes should be limited to sanitisers that have a growth-independent mode of action (i.e. the sanitiser will kill or damage microbes whether or not they are in an active growth phase).

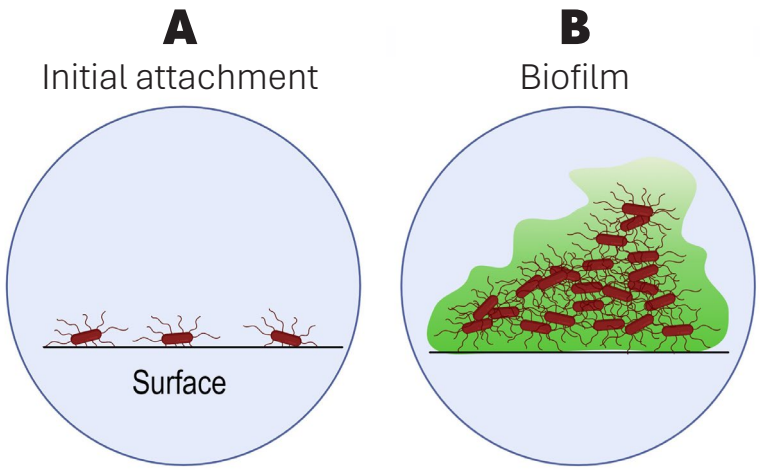


Figure C9:2 | Diagram of a microbial biofilm. Biofilms may form on equipment surfaces resulting from ineffective cleaning and sanitising if inappropriate processes and chemicals are applied (Adapted from Vidovic et. al, 2024).

9.4 Good practice for facility management

Table C9:4 | Summary of good practices for facility management.

Management are	Good practices
Design	Hygienic design principles should be considered at the design stage of any new facility to be constructed.
Exclusion	Entry of soil, dust, water and other potential contaminants from the outside should be minimised or managed. A pest control program outside and inside the facility should be implemented and monitored (refer Image C9:5).
Structure	Facility structures should be kept clean, free of vermin and well maintained.
Separation	Produce should be separated from storage areas for chemicals, fuel, fertilisers or other potential contaminants. Containers and equipment used in the field should not be used or located in finished product areas.
Layout	The layout of the facility should prevent contaminants from earlier steps in the process (e.g. arrival and pre-wash), transferring to later steps in the process (e.g. packing and storage).

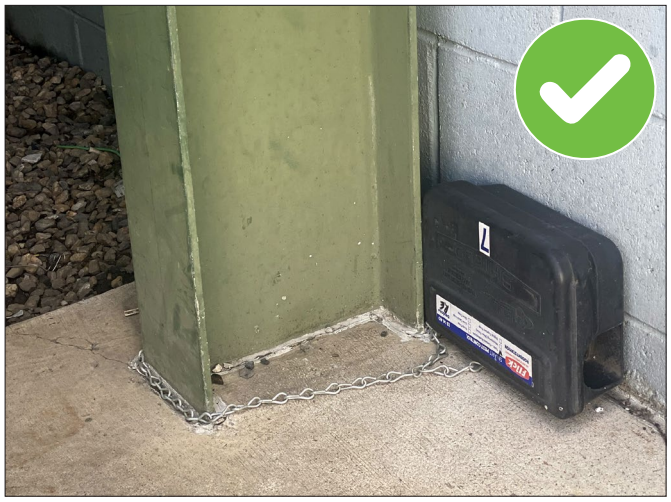


Image C9:5 | Good practice example of a numbered bait station, secured in place to prevent movement and maintain effective pest control.

Image C9:6 | Good practice example of under-building mesh, providing protection from pests.

Image C9:7 | Good practice example of a meshed window, providing protection from flying insects.

Image C9:8 | Good practice example of ultraviolet light used to attract flying insects, which are then captured on glue boards instead of being electrocuted. These are widely used in packing sheds and protected cropping environments due to their low risk of insect fragmentation (unlike electric zappers).

Resources

European Hygienic Engineering and Design Group (EHEDG), (2018). ***Doc. 8, Hygienic Design Principles***. 3rd ed. Frankfurt: EHEDG.

Food and Agriculture Organisation (FAO), (2012). ***Good practice in the design, management and operation of a fresh produce packing-house***. RAP Publication 2012/04. Bangkok: Food and Agriculture Organization of the United Nations.

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Schmidt, R.H. and Erickson, D.J., (2005). ***Sanitary design and construction of food equipment***. FSHN0409. Gainesville, FL: IFAS Extension, University of Florida.

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Vidovic, S., Gupta, S., Paturi, G. and Fletcher, G. (2024). Lifestyle of *Listeria monocytogenes* and food safety: Emerging listericidal technologies in the food industry. ***Critical Reviews in Food Science and Nutrition***, 64, pp.1817–1835.

CHAPTER 10
Managing Tools and Equipment

Overview

Tools and equipment are essential for the growing and production of fresh produce but can also be sources of physical, chemical (including allergen) and microbiological contamination.

Careful selection, design, maintenance, cleaning and sanitising of tools and equipment is essential to minimise these risks and ensure food safety.

Guidelines for maintaining, cleaning and sanitising vehicles (including harvesters) are provided in Chapter 12, while guidance for facilities is outlined in Chapter 9.

Considerations:

- equipment and tools should be designed for easy inspection, cleaning and sanitising, particularly when they come into direct contact with produce
- regular maintenance helps prevent accidental contamination and ensures equipment remains in optimal condition
- cleaning and sanitising, along with maintaining tools and equipment are fundamental practices to ensure the delivery of safe produce to consumers
- the likelihood of contamination is influenced by several factors, such as design, material composition, function, maintenance history, type of produce, location of use and level of cleanliness
- implementing good practices in equipment management will help safeguard food safety and reduce contamination risks in production and processing environments.

10.1 How tools and equipment can act as sources of contamination to produce

Equipment surfaces that come into contact with produce pose the highest risk of microbial contamination, especially when wet or soiled.

These surfaces include picking bags, buckets, tanks, water flumes, spray nozzles, brushes, rollers, conveyors, filters and flaps. Contamination can occur when tools and equipment from one area are transferred to another without first being cleaned and sanitised. Consideration should be given to having dedicated tools for critical or especially dirty areas or for each zone the produce passes through (e.g. outside the facility, inside holding area, preliminary washing zone and packing area).

Potential ways in which tools and equipment can act as sources of contamination to produce are outlined in Table C10:1.

Table C10:1 | Ways in which tools and equipment can act as potential sources of contamination.

Hazard group	Potential sources of contamination
Physical	Metal shavings, bolts, nuts, glass, plastic fragments, knife blades and other foreign objects from damaged tools and equipment. Poorly maintained or damaged equipment introducing foreign objects into produce.
Chemical	Grease and other lubricants coming into contact with produce. Use of inappropriate cleaning and sanitising products on equipment or tools. Accidental spillage of pesticides, fuel, oil and other chemicals.
Allergen	Inadequate allergen control can result in equipment surfaces, picking bags or buckets becoming contaminated with allergens, which may then cross-contaminate fresh produce [refer Chapter 16].
Microbiological	Presence of faeces from birds, rodents and other animals. Contaminated produce, soil or other debris. Use of contaminated water for cleaning tools and equipment. Dripping of contaminated water from equipment. Splashing of contaminated water during cleaning of tools and equipment.

10.2 Equipment design, maintenance, cleaning and monitoring

Good practice for the way in which equipment is designed, operated, maintained and cleaned is outlined in Table C10.2. Adhering to these principles ensures tools and equipment remain in optimal condition, reducing contamination risks and enhancing food safety.

For monitoring the effectiveness of cleaning microbial testing or Adenosine Triphosphate (ATP) test kits can be used. ATP is a molecule found in all living cells, including microorganisms and organic matter. The presence of ATP indicates the presence of biological material, which can be an indicator of contamination. ATP test kits can quickly assess the cleanliness of surfaces or equipment by measuring the amount of ATP present.

10.3 Good practice for managing tools and equipment

Table C10:2 | Summary of good practices for managing tools and equipment.

Management area	Good practices
Design	Equipment should be easily disassembled for thorough inspection and cleaning, including enclosed components. Surfaces that contact produce should be made of material that can be easily cleaned and sanitised. Do not use porous materials like wood or carpet. Conveyor guides, splash guards and safety guards should be designed for easy cleaning. Avoid hollow structures that can trap water and debris, making them difficult to clean and inspect. Conveyors should not have roll-under edges, creases, gaps or open seams, where contaminants can accumulate. Welds should be smooth and continuous to prevent the accumulation of debris. Equipment should not have sites (ledges, ends) where product and debris can accumulate. Plumbing should not have dead ends where soil can collect and where turbulence and sanitiser concentrations are low which enables microbes to survive or multiply.
Installation	Equipment should be positioned at least 200 mm above the floor to enable effective cleaning and reduce the risk of contamination from floor surfaces. Food safety standards widely support this guideline, with industry best practices recommending elevations between 150 mm and 300 mm (Codex Alimentarius, HACCP, GMP, ISO 22000, FSANZ).
Maintenance	Equipment and tools should be designed and constructed to facilitate regular cleaning and maintenance. All equipment food contact surfaces should be free from damage or defects that could trap bacteria, hinder effective cleaning or create a source of physical contamination. A documented preventive maintenance plan should be in place, detailing: • areas and equipment covered • specific maintenance procedures • frequency of maintenance • responsible person ensuring completion. Equipment should be stored properly to minimise contamination risks. Lubricants should be applied carefully and not excessively to prevent accidental contact with produce.

Management area	Good practices
Cleaning	A documented cleaning and sanitising plan should be followed for equipment and tools that come into contact with produce. A documented cleaning plan should be in place, detailing: • areas and equipment requiring cleaning • specific cleaning and sanitising products and methods • frequency of cleaning and sanitising • responsible person ensuring completion. Food contact surfaces should be cleaned at least daily or at product or shift change over. Only approved chemicals for food contact surfaces should be used following manufacturer instructions. Storage of cleaning and sanitising materials should be carefully managed to prevent contamination of produce [refer Chapter 8]. Tools used for cleaning floors should never be used on food contact surfaces. Label cleaning tools clearly or apply a colour-coding system that corresponds to the zone where they are used.
Monitoring	To ensure cleaning and sanitising are effective, verification should be carried out through visual inspection, microbiological swab sampling or ATP testing [refer Chapter 18]. Monitoring outcomes should be carefully documented and evaluated.

Image C10:1 | Good practice example of a packing line constructed from smooth rubber; a non-absorbent, durable material.

Image C10:2 | Good practice example of a packing line constructed from stainless steel. This surface is easy to clean and maintain, reducing the risk of contamination.

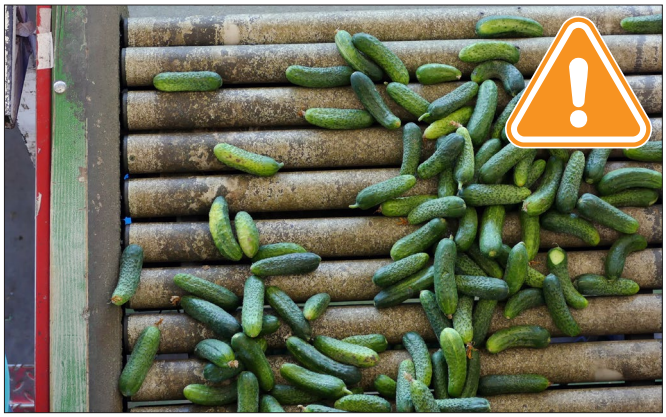


Image C10.3 | Unacceptable practice example of a packing line using absorbent or deteriorating materials. Wooden rollers are difficult to clean and could harbour pathogens.

Image C10.4 | Unacceptable practice example of a packing line with rust and flaking paint which can introduce a potential hazard.

10.3 Cleaning and sanitising regimes

Cleaning and sanitising are distinct yet complementary processes, typically involving different chemical agents and application methods. These procedures are intended to eliminate physical, chemical (including allergen) and microbiological hazards, thereby minimising the risk of surfaces becoming sources of contamination.

10.3.1 Cleaning

The purpose of cleaning is to remove soil, debris and residual organic matter from surfaces. This process also removes the majority of microorganisms and their potential sources of nutrients.

Cleaning can involve the use of detergents to dissolve and remove dirt, dust and debris from surfaces. However, physical methods such as dry brushing, sweeping, high pressure washing or steam cleaning can also be effective alternatives, depending on the type of contamination and the surface being cleaned. It is important that high pressure washing is only carried out in a location or manner that ensures that the aerosols generated do not spread contamination to other parts of the facility. By eliminating dirt and organic matter, cleaning reduces the number of microbes present, but by itself cleaning does not ensure that the surfaces are free of pathogenic bacteria. Cleaning should be followed by an effective sanitising step.

To ensure effective cleaning, several factors should be considered:

- type of detergent – selecting the appropriate detergent for specific contaminants
- type of surface to be cleaned – ensuring compatibility between detergent and surface material
- method of detergent application to optimise coverage and effectiveness – ensuring detergent is applied from the base upwards to achieve complete surface coverage
- quality of water used – evaluating the effectiveness of the detergent in the available water and determining if amendments are required to alter the hardness or pH of the water
- water velocity and flow – to ensure that all surfaces to be clean are exposed to the desired degree of mechanical action (turbulent flow or direct impingement) and do not contaminate other surfaces through splashing.

10.3.2 Sanitising

The objective of sanitising is to eliminate any pathogenic microorganisms that remain on the surface following the cleaning process.

The following active constituents are commonly used in sanitisers:

- chlorine/chloro-bromo products
- iodine
- quaternary ammonium compounds (QACs)
- peroxyacetic acid
- acid anionics
- carboxylic acids.

Cleaning and sanitising procedures are designed to eliminate physical, chemical (including allergen) and microbiological hazards.

10.3.3 Key factors for effective sanitisation

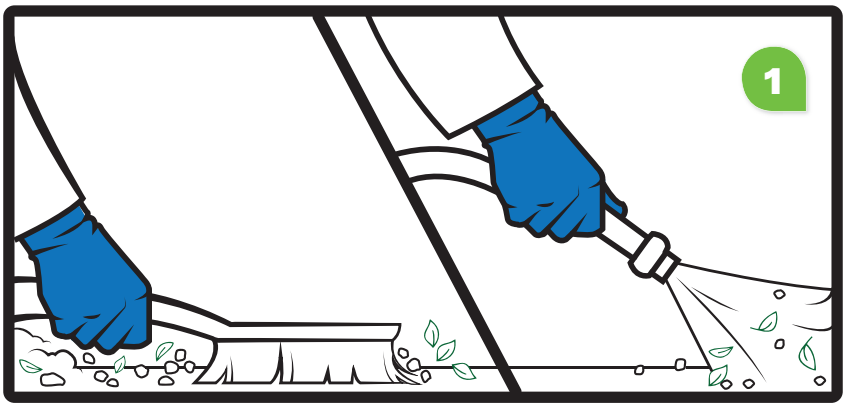
To maximise the effectiveness of sanitisation, the following factors should be considered:

- surfaces should be physically cleaned before sanitising, as sanitisation is only effective on surfaces that have already been cleaned
- direct contact between the sanitiser and the surface is essential, ensure complete and even coverage
- maintain the temperature within the range specified by the manufacturer for optimum performance
- follow the manufacturer's instructions regarding concentration and contact time to ensure adequate dosage and sufficient exposure time for effective results
- consider the pH and water properties
- the quantity and types of microorganisms can influence sanitiser selection, use products suited to the targeted organisms.

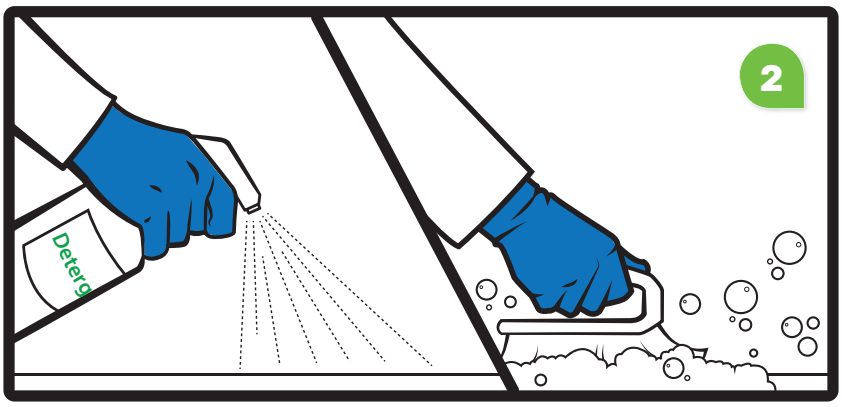
Figure C10.1 | Key factors for effective sanitisation.

10.3.4 Selecting and using cleaning and sanitising agents

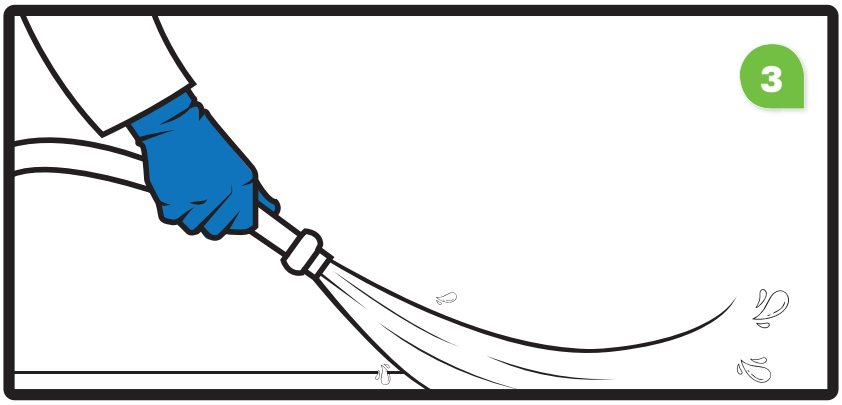
Both detergent and sanitiser selection should align with their intended use and all chemicals should be approved for food-contact surfaces. A rinsing step is usually required between the detergent and sanitiser step. Even when using approved products, precautions should be taken to prevent detergent or sanitiser residues on packed produce. For example, while QACs are permitted in food preparation areas, some markets impose zero tolerance for QAC residues on fresh produce. Appropriate storage, correct application and compliance with manufacturer guidelines are essential.



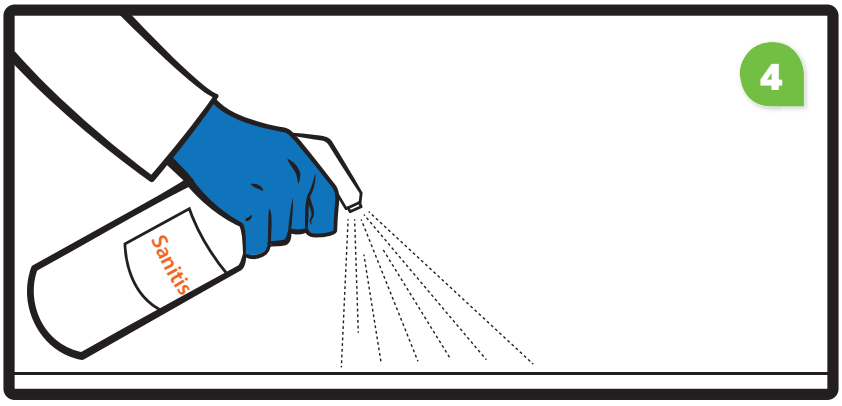
Remove dirt and debris.



Apply appropriate detergent, then scrub thoroughly.



Rinse the surface thoroughly with clean water.



Apply adequate coverage of a sanitiser approved for use on food contact surfaces.

Figure C10:2 | Good practice cleaning and sanitising procedure.

10.3.5 Cleaning and sanitising frequency

The frequency of cleaning and sanitising should be determined for each piece of equipment. Good practices include:

- ensuring all equipment is thoroughly cleaned and sanitised before the start of the season or when changing farms or produce
- implementing regular cleaning and sanitising schedules throughout the season, tailored to specific equipment needs
- using water analysis and surface swab tests (or ATP) to assess microbial presence and adjust cleaning frequencies accordingly.

By adhering to these guidelines, cleaning and sanitising processes can effectively reduce contamination risks and ensure food safety throughout the production cycle.

10.4 Physical contamination

The risk of physical contamination can be minimised through proactive measures, such as covering facility lights to prevent breakage and ensuring equipment is properly maintained.

If physical contamination occurs (e.g. glass breakage, a broken knife blade) operations in the affected area are halted immediately. Any potentially contaminated produce and packaging are identified and safely disposed of. The affected area and equipment are then be thoroughly cleaned to remove all traces of foreign objects.

All foreign objects should be carefully collected and where possible, reassembled to confirm that the entire broken item has been accounted for. Breakage kits (which are required under certain quality assurance food safety and customer standards) can assist in this process by ensuring appropriate recovery and documentation. The incident is recorded and an authorised manager should verify that the area has been cleaned to an acceptable standard and cleared before operations resume.

10.5 Management of hand tools

Hand tools used by team members such as knives, secateurs and temperature probes should be properly managed. This includes ensuring they are clearly identifiable, regularly maintained, thoroughly cleaned, sanitised and calibrated where necessary to ensure accuracy and effectiveness.

Knives should have solid, non-breakable blades (e.g. not breakable-blade utility knives) and should only be issued to team members by an authorised manager.

In high-risk situations, knives should be individually numbered and their issuance details, including date and time, recorded in a dedicated logbook. After use, all knives should be returned to the appropriate manager, inspected for damage, cleaned and securely stored. Any lost or damaged knives must be promptly reported, documented and appropriate corrective actions implemented in accordance with internal procedures. Their condition, return date and time should be accurately logged for accountability.

CHAPTER 11
Managing Containers and Packaging

Overview

Containers and packaging materials that come in contact with produce should be of food-grade quality, sourced from approved suppliers and kept clean and sanitary. Damaged containers should not be used. Reusable containers should be washed and sanitised, or produce should be placed on a food-grade liner.

Various types of containers are used during harvesting and handling. These may include picking bags, trays, crates, bulk bins, containers used for cooling and storage, containers used to pack the final product and containers used for holding reject produce, waste and other materials.

Pallets and packaging materials should also be considered when assessing the risk of food safety hazards during harvesting and packing.

Packaging materials are used to protect and maintain product quality and improve presentation. They include plastic liners, bags, packing inserts, punnets, trays, foam pads, bubble plastic, socks and labels.

11.1 Hazards and sources of contamination

Containers and packaging can become a source of contamination from physical, chemical (including allergen) and microbiological contaminants (Table C11:1). The level of contamination risk depends on factors such as:

- the type of produce
- the age and type of container/packaging
- the composition of the container/packaging (what it's made of)
- how the container/packaging is used.

Table C11:1 | Potential sources of contamination from containers and packaging materials [refer Chapter 8, 13 and Appendix 3].

Food safety hazard	Potential sources of contamination
Physical	Fragments from damaged containers and packaging materials. Splinters and nails from wooden pallets and bins. Torn packaging material. Pest contamination during storage and harvest (e.g. cockroaches, frogs, moths). Environmental contaminants (e.g. dust, stones, organic matter).
Chemical	Containers and packaging that contains recycled materials that are untested or purchased from a non-approved supplier. Using containers previously used to store chemicals, fertilisers or waste materials, for produce intended for human consumption. Accidental spillage or application of pesticides, fuel, oil or other chemicals into containers or packing materials. Chemical and fertiliser spillage onto pallets and the bottom of containers. Use of inappropriate cleaning and sanitising products.

Food safety hazard	Potential sources of contamination
	Container and packaging materials that contain toxic substances such as PFAS and MOH: • Per- and polyfluoroalkyl (PFAS) substances are a large group of man-made chemicals. They are known for their ability to repel grease, water and stains, but they also persist in the environment and can accumulate in the human body. In food safety, PFAS are a concern because they can contaminate food through various pathways, including contaminated crops, animals, food packaging and processing equipment. • Mineral oil hydrocarbons (MOH) are a diverse group of chemical compounds found in food, primarily derived from petroleum. These substances can enter food through various pathways, including environmental contamination, machinery lubricants and food contact materials [refer Chapter 3].
Allergen	Containers or packaging materials that have been in contact with allergens (e.g. cross contact with other crops or crop by-products such as lupin, soy, wheat, tree nuts or peanuts). Packaging, films or inserts made-from or containing materials that are allergens (e.g. peanuts, soy, tree nuts, crustacea, fish, molluscs, milk, egg, lupin, sesame, wheat or sulphites). Labels may introduce risks from incorrect information (e.g. undeclared allergens), the use of food-grade adhesives, or cross contact with allergens during printing or application.
Microbiological	Faeces of birds, rodents, insects and other animals dropping onto containers and packaging. Soil, manure and faeces adhering to the bottom of containers and pallets. Reusable containers that have not been cleaned and sanitised. Containers cleaned incorrectly or with contaminated water. Containers are considered correctly cleaned when all visible dirt and organic matter are removed and an appropriate cleaning agent is used and the surface sanitised with an approved sanitiser (where applicable). Pathogens such as Shiga toxin-producing ***E. coli*** (STEC) may persist on surfaces of harvest equipment, reusable crates and conveyor belts if not properly cleaned and sanitised between use.

Image C11:1 | Good practice example of picking containers kept off the ground to prevent dirt from the bottom of containers placed on top of others contaminating harvested product underneath.

Image C11:2 | Damaged pallets and packaging should not be used as broken surfaces may be a source of physical contamination (wood splinters, plastic fragments).

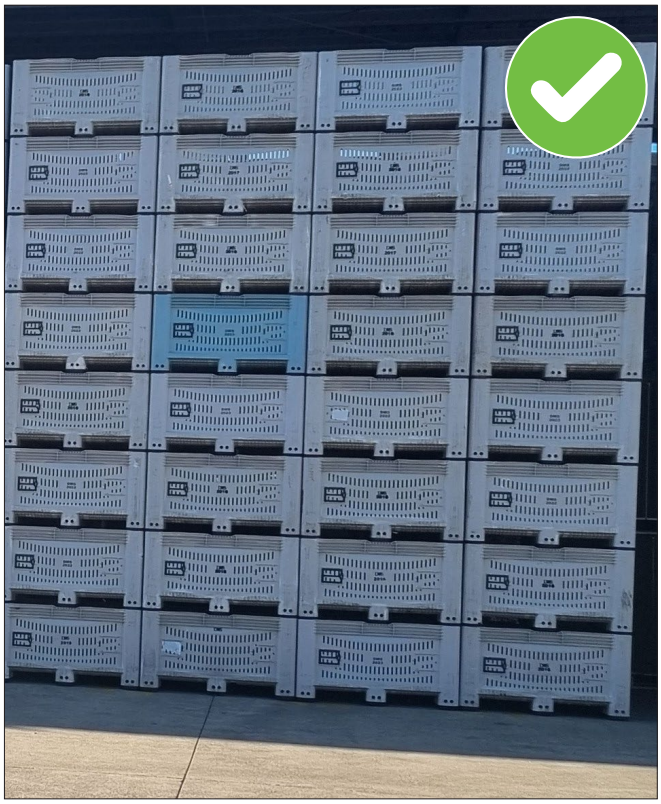


Image C11:3 | Good practice example of correctly cleaned and stored harvesting containers.

Image C11:4 | Containers, liners and packaging should be of food grade quality.

11.2 Good practice for maintaining containers and packaging

Table C11: 2 | Summary of good practices for managing containers and packaging.

Management area	Good practices
Supply	A list of approved suppliers with agreed specifications for containers and packaging is maintained and reviewed annually. Containers and packaging materials are sourced from an approved supplier and thoroughly inspected when delivered with records of inspections kept. Keep purchase records for containers and packaging materials that may present a food safety risk. Records should detail the supplier, purchase date and batch number (if applicable) for each product. Containers and packing materials are made of food grade substances, designed and constructed to allow regular cleaning and maintenance.
Storage	Empty reusable containers, new containers and packaging materials are stored in clean dry areas that are segregated from chemicals or other hazardous products and free of pest or animal infestation. Containers and packaging materials are stored off the ground, away from walls and checked for cleanliness and pest infestation before use. Dirty containers or packaging materials are not used. Containers used for storing waste, chemicals or dangerous substances are clearly identified and not used for produce.
Cleaning and use	Reusable containers such as harvest bags, trays, crates and bins are easy to clean and maintain. Picking containers are kept up off the ground to avoid contact with the soil. Containers and packaging materials are routinely inspected for damage, cleanliness, foreign objects, pest infestation. They are cleaned, rejected or covered with a protective material as required. Cleaning agents and sanitisers are appropriate for the purpose and approved for use on food contact surfaces. Food grade liners are used when recycled packaging cannot be effectively cleaned. Wooden bins and pallets are checked for cleanliness, foreign objects, pest infestation and protruding nails and splinters. Where risk is identified, bins and pallets are cleaned, repaired, rejected or covered with a protective material.

11.3 Emerging technology

UV irradiation of packaging material: Decontamination methods such as UV irradiation are increasingly being trialled for reducing surface contamination on containers and packaging. UV irradiation refers to the application of short-wavelength UV-C light to destroy or inactivate microorganisms. When evaluating such technologies, it is important to compare them with conventional cleaning and sanitising methods to ensure efficacy and suitability. UV irradiation has been found to be effective in reducing Salmonella contamination on surfaces of horticulture products and food-contact surfaces (Lim and Harrison, 2016). This technology is also considered an environmentally friendly and low-cost method of disinfecting food packaging materials.

Active packaging: Some packaging films and inserts contain chemicals that modify the atmosphere inside the package (e.g. oxygen scavengers and/or carbon dioxide generators) or inhibit microbial growth (e.g. antimicrobial peptides, essential oils or silver ions). Active packaging extends the shelf life of packed food or improves the safety of food products. Many of these products contain naturally derived substances and are subject to regulatory requirements, particularly where antimicrobial agents or functional amendments are involved.

New edible films and coating: These are often made from naturally derived biodegradable substances including plants, animals, algae and microorganisms and may have antimicrobial properties. Some are made from products or proteins that are allergens such as milk, wheat, gluten and soy. Chitosan, which is derived from the exoskeletons of crustaceans is also being explored for future application.

Recycled packaging: As many businesses incorporate recycled packaging to support sustainability goals, it is essential to ensure that these materials are suitable for food contact and do not pose a food safety risk from contaminants, allergens or chemical migration.

Other: Packaging containing natural materials that are biodegradable and/or compostable are becoming increasingly popular. Consideration should be given to the composition of the packaging and any potential migration of chemical substances or allergenic proteins into the packed produce.

Emerging technologies such as UV treatment, active packaging and edible films offer potential benefits for extending shelf-life and reducing contamination. However, food safety considerations including chemical migration, presence of allergens and regulatory compliance should be evaluated alongside their benefits.

Resources

Arvanitoyannis, I.S. and Kotsanopoulos, K.V. (2014) 'Migration phenomenon in food packaging: Food–package interaction mechanisms, types of migrants, testing and relative legislation—A review', *Food and Bioprocess Technology*, 7, pp. 21–36.

Lim, W. and Harrison, M.A. (2016) 'Effectiveness of UV light as a means to reduce Salmonella contamination on tomatoes and food contact surfaces', *Food Control*, 66, pp. 166–173.

CHAPTER 12
Managing Vehicles

Overview

Vehicles, tractors, trailers, harvesters and other equipment used to transport produce should be well-maintained and kept free of physical, chemical (including allergen) and microbiological hazards. Preventive maintenance and regular cleaning should be implemented to minimise contamination risk. Food contact surfaces on harvest vehicles should be hygienically designed to allow effective cleaning and sanitisation.

12.1 Hazards and sources of contamination

The risk of produce becoming contaminated while on vehicles, machines or trailers depends on:

- the type of produce
- how the produce is contained and protected/covered
- the type and condition of roadways (e.g. sealed or unsealed)
- type, age, and maintenance of the vehicles, machines or trailers
- how the vehicles, machines or trailers are stored and cleaned
- other tasks the vehicles, machines or trailers are used for.

Potential sources of contamination are listed in Table C12:1 [refer Chapter 3].

Table C12:1 | Potential sources of contamination from vehicles used to transport harvested produce.

Food safety hazard	Source of contamination
Physical	Metal shavings, bolts, nuts, glass, plastic fragments and other foreign objects from damage or unacceptable maintenance. Foreign objects from damaged crates or bins.
Chemical	Accidental spills of pesticides, fuel, oil or other chemicals. Overspray or spray drift from surrounding operations. Exhaust splatters and particulates.
Allergen	Cross contact contamination from shared transport of inputs such as soil improvers and produce. Ineffective cleaning and sanitising between different loads. Lubricants and greases used for vehicle maintenance may contain contact allergens.
Microbiological	Faeces of resident birds, insects or rodents. Animal faeces, soil or other organic matter carried over from previous tasks. Soil or mud attached to tyres, which may flick onto produce or contaminate the floor of processing facilities. Dust generated during transport that can settle on produce. Contaminated water used in cleaning. Build-up of organic material on or in harvesting equipment.

Image C12:1 | Vehicles and trailers used to transport harvested produce should be maintained and cleaned regularly.

Image C12:2 | Vehicles tyres entering holding, packing and processing facilities should be free of dust, dirt and mud to reduce the risk of transferring pathogens such as *Listeria monocytogenes* into the facility. When complete prevention is not possible, floor cleaning frequencies should be increased.

Where possible, avoid using vehicles, machines and trailers used to transport produce for transporting potential contaminants such as fertilisers, chemicals and soil amendments. Where this is not possible, a plan to verify cleanliness and prevent cross-contamination should be implemented. Table C12:2 gives some examples of how vehicles may be cleaned between loads. A risk assessment should be conducted to determine the type and frequency of cleaning between loads [refer Appendix 1].

Table C12:2 | Examples of approaches to cleaning based on goods transported.

Transportation use	Cleaning schedule
Produce only	General clean down of organic material after each load. Cleaning and sanitising weekly.
Produce, harvest bins, containers and packaging	Cleaning and sanitising after each load.
Produce and hazardous inputs (e.g. fertilisers, chemicals and soil amendments)	Cleaning and sanitising after each load and immediately after transporting hazardous inputs with no time delay.

Some pesticides and fertilisers containing ammonium nitrate are considered 'Dangerous Goods' and are required to be transported in accordance with government regulations (Australian Code for the Transport of Dangerous Goods by Road and Rail (2014); NZ Land Transport Rule: Dangerous Goods (2010)). Regulations require dangerous goods to be packaged, secured and segregated in a manner that prevents spillage and contamination.

Note:

Fresh produce and hazardous inputs should never be transported in the same load.

12.2 Product integrity during transport

Produce may require temperature control during transport to ensure that quality and safety are maintained. The need for refrigerated transport will vary. For example, produce undergoing short transit times, such as from the field to an on-farm packing shed after early morning harvest, is less likely to need temperature-controlled conditions. However, even in these circumstances, priority should be given to transferring produce to the appropriate storage temperature as soon as possible.

All fresh produce requires refrigerated transport for long transit times, recognising that the appropriate temperature for maintaining quality of different produce items varies are transported at 13°C for control of quality, whereas leafy vegetables are transported between 1 to 5°C to maintain quality and reduce microbial risk (e.g. cucumbers).

Transport temperatures should be controlled either by using refrigerated food vehicles or for smaller loads, insulated food carrier boxes with temperature regulators. Product temperature throughout the journey should be verified using monitoring equipment such as data loggers.

12.3 Good practice for managing vehicles

Table C12:3 | Summary of good practices for managing vehicles.

Management area	Good practices
Design	Vehicles, machines and trailers are designed to enable regular cleaning, sanitising and maintenance. Vehicles, machines and trailers are designed in a way that minimises the potential for contamination.
Storage	Vehicles, machines and trailers are stored in designated locations where contamination risks are controlled and minimised (e.g. pests controlled, covers used).
Use	Potential contaminants such as fertilisers, chemicals and soil amendments are not transported in or on vehicles, machines and trailers used to transport produce. Dust creation is considered when transporting produce on unsealed roadways. Vehicles with dirty tyres should remain outside storage and processing facilities; vehicles with clean tyres are used to move produce within. Refrigerated transport is used when appropriate and the temperature is monitored and verified.
Maintenance	A documented plan for preventive maintenance is followed. This plan describes the details and frequency of maintenance and the team member responsible for ensuring it is completed.

Management area	Good practices
Cleaning and sanitising	A documented plan for cleaning vehicles, machines and trailers is followed. The plan describes: • areas and items to be cleaned • cleaning and sanitising products and methods • frequency of cleaning and sanitising between loads, after exposure to hazards or severe weather • name of the team member responsible for ensuring cleaning and sanitising is completed. Dedicated vehicle-cleaning chemicals and equipment are used. Records of cleaning and sanitising maintained, between loads, after exposure to hazards or to severe weather. Label instructions are followed and chemicals are stored safely to minimise the risk of contaminating produce. Greases, degreasers and oils should be food grade where potential contamination of produce exists.

Resources

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CHAPTER 13
Managing Animals and Pests

Overview

Pests, wild animals and domestic animals are potential sources of physical and microbiological contamination. Effective control and management measures are essential to minimise their presence in all areas where produce is grown, packed, stored and distributed including containers and transport vessels.

13.1 Hazards and sources of contamination

Animals can be a source of microbiological contamination either directly, through contact with produce, or indirectly via contaminated structures, vehicles, equipment, water, containers, packaging materials and team members. They can also serve as physical contaminants (e.g. spiders or insects) or introduce contaminants such as hair, feathers and nesting materials. Animal contamination sources include domestic animals, livestock (e.g. cattle, sheep, pigs and poultry), pests (e.g. rodents, insects and spiders), domestic pets (e.g. dogs and cats) and wildlife (e.g. frogs, birds, kangaroos and possums).

Wild and domestic animals are the main reservoir for a broad range of human pathogens such as *Salmonella spp.*, *Escherichia coli* (including Shiga-toxin producing strains), *Campylobacter spp*, *Cryptosporidium spp*, and *Giardia spp*. These pathogens may enter the food chain primarily through faecal shedding and complex environmental transmission routes.

Rodents such as deer mice have been shown to shed high levels of *Giardia* and *Cryptosporidium* in agricultural environments and their proximity to leafy vegetables increases the risk of contamination. Wild rodents also play a role in the dissemination of *Salmonella* and *E. coli* O157:H7, particularly in regions where biodiversity is low or rodent densities are high. Studies have confirmed the presence of *E. coli* O157:H7 and other zoonotic pathogens in the urine of domestic mice, representing a potential route for contamination of fresh produce through contact with surfaces or packaging materials.

Pest control should focus on areas prone to harbourage, including storage zones for harvesting equipment and vehicles, as well as inside and around packing and storage facilities. Control measures should combine baiting, trapping and removal of pest refuges.

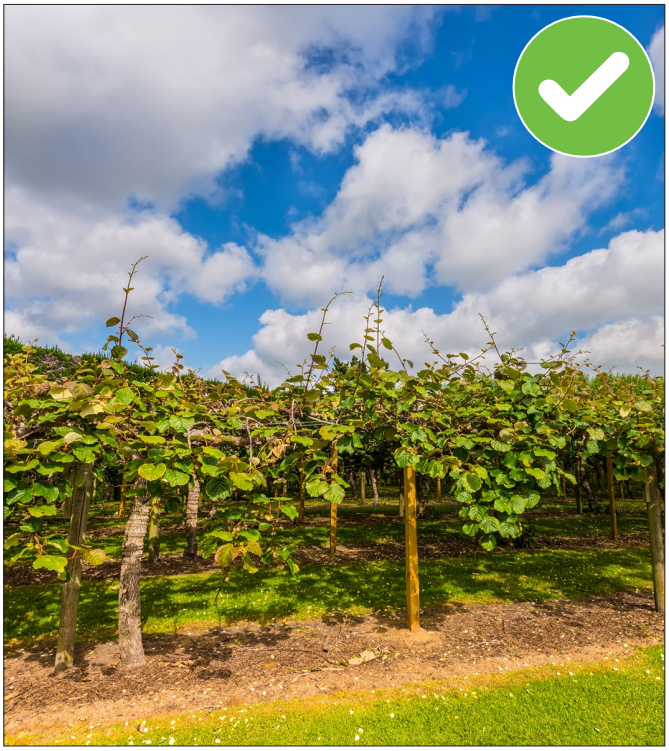

Image C13.1 | Good agricultural practice example of a clean and well-maintained growing site that is less likely to attract animals and pests, therefore minimising contamination risks.

Image C13.2 | Unacceptable agricultural practice example of a growing site with waste material and uncontrolled vegetation that can attract animals and pests.

13.2 Good practice for managing animals and pests

Practical actions include:

- a documented plan for managing pests and animals should be developed and implemented across all relevant stages, including where produce is grown, packed, stored and where packaging is packed, stored and used. This plan should also extend to distribution systems, including containers and vessels
- regularly inspecting equipment, vehicles and facility perimeters for signs of pest and animal activity
- discourage roosting of birds
- keeping facility doors closed when not in use; self-closing doors are recommended and regularly check buildings for any holes or gaps that would allow pest entry
- storing materials and equipment off the floor
- keeping all packaging materials dry, ventilated and covered
- removing waste daily, storing it securely covered and disposing of it frequently
- cleaning behind and under equipment regularly, including container and packaging storage areas
- storing cleaned containers upside-down after cleaning.

Pests including rodents and insects with unhygienic breeding behaviours such as flies, cockroaches and coprophagic beetles represent efficient vectors of human enteric pathogens. Flies can carry pathogens in their gut or on their body surfaces. Studies have found wild-caught flies contaminated with *Salmonella enterica*, *Listeria monocytogenes* and *Cronobacter spp*. Flies have also been shown to transmit large quantities of *E. coli* to food in field conditions. Although pollinators can also transfer pathogens, their role is less significant than that of unsanitary insects.

To minimise the risk of contamination from pest control activities:

- use chemical blocks instead of pellets
- only use chemicals that are suitable for use and used according to manufacturer's instructions
- baits are appropriately stored with access to the Safety Data Sheets (SDS)
- construct physical barriers or place baits inside protective containers with restricted access to trained team members only
- ensure bait and trap locations are clearly shown on facility maps
- monitor and maintain traps regularly to ensure continued effectiveness
- ensure that team members are trained on risks and prevention of contamination.

Image C13.3 | All team members should have appropriate training to identify pest and animal activity and the method for reporting sightings.

Wildlife can also act as a natural reservoir of foodborne pathogens. These animals carry pathogens in their gastrointestinal tract and by faecal excretion, the food chain can be contaminated. In Australia, *Salmonella* and Shiga-toxin producing *Escherichia coli* have been isolated from wildlife such as kangaroos, wallabies, snakes, lizards, turtles and crocodiles.

Domestic animals, including dogs, cats and horses, should not be allowed in growing, packing or storage areas. These animals can introduce pathogens, dirt, plant debris and pests. Team member interaction with pets increases the risk of physical and microbial contamination.

Birds should be excluded from facilities. If exclusion is not feasible, ensure they cannot roost in areas where produce, containers or packaging materials are handled or stored. Keep windows and doors closed to prevent pest entry and remove unnecessary materials to reduce potential harbourage. A tidy environment is easier to clean and less attractive to pests.

Where operations involve mixed farming (e.g. livestock and produce) appropriate risk assessment and mitigation strategies should be implemented. Zoonotic pathogen transfer has been documented between domestic livestock and wildlife such as feral pigs, with water, manure and bioaerosols acting as vectors.

Growers should consider buffer zones, tool separation and composting to reduce contamination risks. Additionally, where practical, growers should engage with neighbouring operations to share food safety practices and better understand adjacent land use activities that may affect risk.

Images C13.4-6 | A combination of physical, electric and pond fencing is used to restrict access by livestock (e.g. cattle) and native wildlife (e.g. kangaroos) reducing the risk of faecal contamination and crop damage.

Table C13:1 | Summary of good practices for managing animals and pests.

Management area	Good practices
Animal and pest control plan	Use an animal and pest control plan to manage, monitor and minimise contamination risks from animals and pests. Clearly define the scope of the animal and pest control plan (e.g. growing area, incoming raw materials, on-site processes, storage areas and transport systems such as trucks, containers, shipping vessels). In the event of contamination or suspected contamination, conduct an investigation, with root cause analysis and implement corrective actions [refer Appendix 1]. Segregate and destroy affected product if necessary.
Records	A documented plan is followed to minimise the presence of animals and pests in and around growing areas, harvesting equipment, vehicles, packing and storage areas. The plan describes: • location of baits and traps • chemicals and methods used • frequency of checking baits and traps • name of the person responsible for pest management. Pest control measures are monitored to ensure they are effective and a record is kept.
Exclusion	Domestic animals and birds are excluded from all food producing areas. Wildlife and livestock are excluded from areas where produce is grown, harvested, packed and stored to the greatest extent practicable.
Control	Only pest control chemicals approved for use in food handling areas are used and in accordance with manufacturer's instructions. Baits and traps are securely placed to prevent chemical contamination. Edible plant parts should not come into contact with pest control chemicals. Where baits contain potential allergens (e.g. wheat-based) their use should be assessed for allergen cross-contamination risk.

Figure C13:1 | The most effective way to prevent entrance of animals and pests into food processing facilities. Adapted from Sanikleen Group Australia (SGA).

Resources

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CHAPTER 14
Managing People

Overview

Team members are a significant potential source of contamination, particularly microbiological. Team members should maintain good personal hygiene, refrain from handling produce while sick, and be trained to prevent physical, chemical (including allergen) and microbiological contamination of packed produce.

14.1 Hazards and sources of contamination

Team members, contractors and visitors can all be sources of physical, chemical (including allergen), and microbiological contamination. Microbiological contamination may be caused by team members who are infectious during or after sickness or who have poor personal hygiene. Several outbreaks of foodborne illness have been traced back to a contaminated team member handling produce.

Humans can spread microbes including bacteria (e.g. *Staphylococcus aureus, Shigella spp.*, *Salmonella spp.*) and viruses such as Hepatitis A. These microbes may be present anywhere on the body, with higher concentrations around the anus, nose, mouth and in open sores. Activities such as using the toilet, blowing the nose, sneezing, coughing, eating or smoking can transfer pathogens to team members' hands and subsequently to produce.

Table C14:1 | Potential sources of contamination from team members, contractors and visitors.

Food safety hazard	Source of contamination
Physical	Hair, jewellery, tools, clothing and other personal items (e.g. rings or buttons falling into packed produce). Bandages and gloves falling into packed produce.
Chemical	Team members not cleaning their hands after handling chemicals. Cross contamination from dirty clothing.
Allergen	Contaminated clothing. Hands not washed after consuming foods containing allergens. Handling growing media that may contain allergens.
Microbiological	Not properly washing and drying hands after: • using the toilet • eating food • smoking • sneezing, coughing or spitting into hands • touching domestic animals/pets • handling pests. Contaminated water used for washing hands. Contaminated rags and towels used for drying hands. Gloves not discarded after use or effectively cleaned. Team members with infectious diseases touching produce. Unacceptable practices including touching produce with uncovered or bleeding wounds and spitting, coughing or sneezing onto produce.

14.2 Training

Personal health and hygiene starts with company management. Management is responsible for providing and maintaining a safe and clean working environment. This means ensuring equipment is safe as well as implementing policies and procedures that promote safe and hygienic work habits by team members [refer Chapter 20].

Team members need to understand they are responsible for producing safe food. They should be trained so that they understand potential food safety hazards and sources of contamination. The level of training should be appropriate to the level of risk of the duties performed. Team members should be informed of the personal hygiene standards required and instructed in important practices such as correct handwashing.

Food safety training should be included as part of induction for new team members and refreshed annually. The content and format of the training needs to be appropriate to the literacy skills of the team member. Written instructions and signs in appropriate work areas and facilities will reinforce and remind team members of personal hygiene standards and inform contractors and visitors about the standards of personal hygiene required. Photographs, diagrams and cartoons can convey simple and clear messages. Supervisors should monitor team members and facilities to check that the personal hygiene standards are followed.

Image C14:1 | Hygiene signs should be easy to read, using team members' native language and include clear graphics to ensure the message is communicated effectively.

14.3 Personal hygiene

Team members, contractors and visitors can transfer human pathogens to produce from their hands and other body parts and clothing.

Inadequate personal hygiene practices, such as spitting, coughing, sneezing or exposure to blood can lead to produce contamination. To reduce the risk of physical contamination, it is essential to maintain good personal hygiene standards, minimise or cover jewellery and wear suitable personal protective equipment (PPE).

14.3.1 Handwashing and sanitation

Hands should always be washed with soap and potable water (i.e. contains no more than 1 cfu of *E. coli* per 100 ml) and then dried thoroughly using single-use paper towels. Contaminated hands can infect or contaminate produce or product contact surfaces. Using potable water reduces the risk of contamination of hands with harmful microbes and human pathogens [refer Chapter 7].

When handwashing with non-potable water is unavoidable, hands should be thoroughly dried and then sanitised using an alcohol base product containing at least 60% alcohol.

Where air dryers are used instead of paper towels, team members should ensure their hands are thoroughly dry before applying hand sanitiser.

Hands should be washed:

- before starting work
- after each visit to the toilet
- after blowing the nose, coughing or sneezing into hands
- after eating or smoking
- after touching domestic animals or handling livestock
- after handling rubbish or performing maintenance on equipment
- after any break from work.

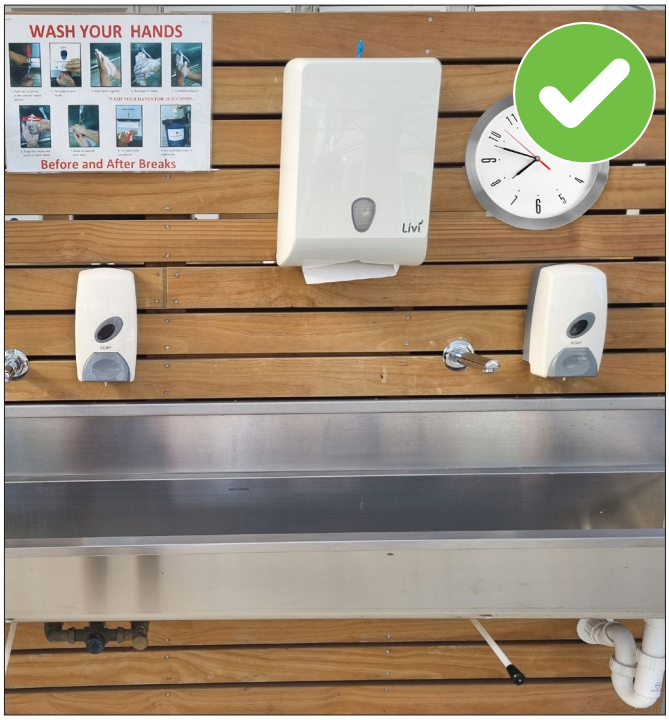

Image C14:2 | Handwashing stations should be clean, clearly signed and stocked with soap and single-use paper towels. A visible 20-second timer should be provided to support effective hand hygiene. Any glass or hard plastic items used for timing should be recorded in the glass and hard plastic register.

Image C14:3 | Inadequate handwashing and drying facilities increase the risk of produce contamination by team members (e.g. unhygienic or not hands-free).

Washing hands for the correct length of time is the best way to ensure handwashing has removed pathogens. There are many online resources from public health authorities including videos to support the training of team members in effective handwashing.

Spending twenty seconds washing the hands, including scrubbing fingernails, interlocking fingers and cleaning to the wrist, will ensure that washing has been effective. This is about the same time as it takes to hum the 'Happy Birthday' song from beginning to end, twice.

Soap contains surfactants that help lift soil and microbes from the skin and team members are more likely to wash for 20 seconds if using soap. Warm water is no more effective at removing microbes than cold water, but it does encourage longer time spent washing hands.

Hands should be washed and dried before using sanitisers, as dirt can shield microbes from being killed. Without adequate cleaning, the sanitiser is ineffective, increasing the risk of cross contaminating the produce with harmful pathogens.

Hands should be washed and dried before using sanitisers, as dirt can shield microbes from being killed.

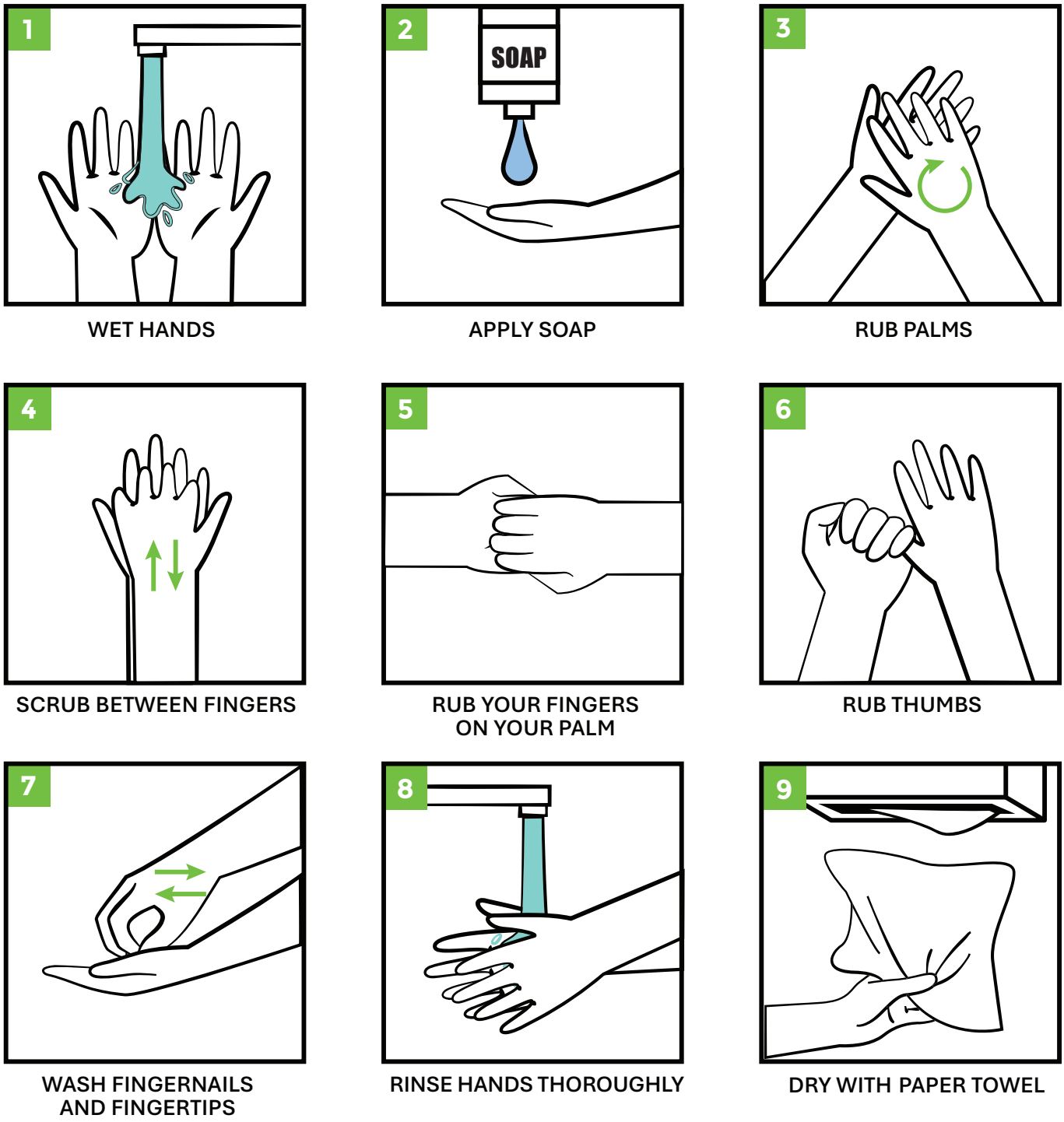

Figure C14:1 | Effective hand hygiene includes thorough washing with soap for at least 20 seconds (steps 3 to 7) followed by drying with clean disposable paper towel to reduce the risk of spreading contaminants.

14.3.2 Wounds and injuries

Cuts, minor wounds and sores should be covered with secure, waterproof bandages or dressing, preferably blue and detectable by metal or x-ray. In wet environments, use waterproof coverings and where possible, cover dressings with a glove to prevent contamination.

Where wounds cannot be fully covered, the team member should be excluded from direct contact with produce, equipment and water that contacts the produce. Produce contaminated with blood and other bodily fluids should be discarded and contaminated equipment cleaned and sanitised. A dedicated kit should be available to carry out this task to prevent the risk of cross-contamination from general cleaning equipment. First aid kits with appropriate wound coverings should be readily available. These should be stocked with materials kept in sanitary and usable condition and which are within their expiry dates.

14.3.3 Gloves

Dirty gloves can be a source of microbial contamination. Disposable gloves are therefore preferable to reusable gloves. Disposable gloves should be removed, discarded and replaced with a new pair after visiting the toilet, blowing the nose, coughing or sneezing into hands, eating, smoking, handling rubbish or touching other contaminated surfaces. If reusable gloves are used, they should be washed and sanitised the same method as for hands.

Where reusable gloves are used, they should be kept in good repair and free of gross soiling to prevent contamination of the produce. Waterproof gloves will still need to be cleaned and sanitised in the same method as hands. Fabric gloves should be replaced if they are soiled to prevent spreading the soil onto the product. When cloth gloves are washed, consideration should be given to the perfumes and whiteners used in some laundry materials. Gloves need to be thoroughly rinsed and allowed to dry before returning them to use.

14.3.4 Hair

In produce packing facilities, hair and beards should be covered to prevent physical contamination. Hair nets, beard nets, caps or beanies may be used. Team members with long hair should tie it back securely.

14.3.5 Eating, drinking and smoking

Eating, chewing gum, smoking and drinking fluids other than water should not be allowed. These activities should be restricted to designated areas. All of these activities require hands to be washed and gloves to be replaced before returning to work.

14.3.6 Jewellery

Jewellery poses a contamination risk by collecting dirt and microbes or falling into produce. Items that may break or detach, such as charm bracelets or dangling earrings should not be worn. Ideally, no jewellery should be worn during packing, though a plain wedding band is generally acceptable. Any jewellery that cannot be removed should be securely covered.

Figure C14:4 | Blue adhesive bandages are easier to detect in packed produce than skin-coloured dressings.

Figure C14:5 | Gloves should be cleaned and sanitised using the same method as hands.

Figure C14:6 | Hair nets and beard nets should be worn when packing produce ready for retail sale.

14.3.7 Clothing

Contaminated clothing may carry microbes or chemicals. Team members should wear clean outer garments free of loose buttons, threads or attachments. Top pockets often cause physical contamination (e.g. pens) and should be avoided. In many facilities, team members, contractors and visitors may be required to wear single-use protective clothing (e.g. aprons) and change or clean shoes. Any such protective clothing should be removed before entering the toilet.

14.3.8 Verification of personnel hygiene practices

Hand swabs from team members can be collected to provide confidence that hygiene practices are being followed and are effective. Chapter 18 details specific requirements for collecting and testing samples from the environment, water or produce. For the purposes of training, hand swabs are an effective method to illustrate the importance of adequate handwashing.

Another technique involves applying 'UV Wash and Glow' gel to hands, which highlights the number of bacteria that can remain after inadequate washing.

Image C14:7 | Jewellery can trap dirt and microbes or become a physical hazard.

Image C14:8 | Cleaning and sanitising footwear before entering production areas reduces the risk of pathogen contamination.

Image C14:9 | Fluorescent traces under UV light reveals areas missed during handwashing, assisting to reinforce good hygiene practices.

14.4 Team member facilities

Team member facilities need to be separate from produce handling and storage areas and designed to be easily cleaned and sanitised. They include meal rooms, change rooms, toilets and handwashing facilities at harvesting sites and in packhouses. Locating facilities near the entrance to the packhouse or harvesting area will make them more convenient to use, encouraging people to use them appropriately.

Providing accessible and hygienic toilet and handwashing facilities is critical to minimising the risk of contamination from field team members during harvest. To support food safety outcomes, growers should ensure that facilities are adequate, appropriately located, stocked and maintained in clean, working order throughout the harvest period.

Toilet facilities should be of adequate number for the people working in the field and in compliance with any local regulations. For a crew of approximately 30 team members, a minimum of two toilets and handwashing stations is generally recommended. Handwash stations should be equipped with potable water (*E. coli* less than 1 cfu/100 ml), non-perfumed liquid soap and single-use towels, with signage and hand-free operation preferred.

Image C14:10 | Portable toilets provided on-farm support team member hygiene and reduce the risk of field contamination.

Image C14:11 | Portable handwashing stations located near work areas support good hygiene practices.

Toilets and handwash facilities should be located within 500 m (less than a 7 minute walk) of the work area. However, greater than 200 m is recommended for ready-to-eat crops or adverse field conditions. The shorter distance helps maintain hygiene standards, reduce in-field relief and improve labour efficiency.

Toilets should be located an appropriate distance from any water sources (e.g. streams, ponds, boreholes and tanks) and not in areas prone to flooding. Waste and wastewater from the toilets and handwash stations should be captured for disposal in a way that does not contaminate the land and crop.

Growers should conduct a hygiene risk assessment to determine the appropriate number, location and servicing frequency of sanitary facilities, considering crew size, crop type, terrain and site accessibility.

14.5. Illness

Team members, contractors or visitors suffering from intestinal illness (e.g. gastroenteritis, Hepatitis A) can potentially contaminate produce, either directly or indirectly. Team members who have suffered from communicable diseases with symptoms such as diarrhoea, vomiting, fever or jaundice should not harvest produce or work in packing and storage facilities until they are fully recovered.

It is worth noting that people can remain infectious even after they have started to recover. As a guideline, team members need to be symptom-free for at least 48 hours before returning to work following vomiting and/or diarrhoea. Ideally, they should be cleared by a doctor before returning to work as high-risk illnesses share similar symptoms to more benign issues.

Recovering team members should be reassigned to other duties rather than being stopped from coming to work. This will encourage them to advise their manager or supervisor that they are or have been ill.

Team members with a respiratory illness, such as a cold, should not handle produce directly. They should take extra precautions (wearing masks) to prevent contamination of the environment and equipment from sneezing, coughing and blowing the nose. Tissues should be discarded after single use and increased handwashing and/or wearing of gloves is recommended.

Public health agencies are an excellent source of advice about specific illnesses and food safety risks.

14.6 Intentional contamination

Deliberate and malicious tampering with fresh produce to introduce a physical, chemical (including allergen) or microbiological hazard can cause injury or illness to consumers. Tampering is a criminal offence in Australia and New Zealand. If a tampering case is suspected, it should be reported to senior management to investigate immediately.

Deliberate produce tampering can occur in both field and packhouse settings. Incidents may be premeditated and targeted or entirely opportunistic. Motivation can include revenge, jealousy, media attention, extortion, disenchantment or boredom. Similar risks may also occur from suppliers and cause-driven groups.

There are several practical steps growers and packers can implement to reduce the threat of intentional contamination including:

- ensure team members are treated well and paid according to the law
- create an open and transparent workplace culture supported by appropriate internal processes
- empower team members to report any issue or suspicious behaviour to management (directly or anonymously via the business's complaints procedure), no matter how minor or unusual
- install locks, alarms and cameras where appropriate and have a key register
- segregate work areas and restrict access areas, where possible
- restrict access to high-risk water supplies
- provide a sign-in register for visitors and contractors and ensure that it is used at all times
- pay attention if visitors or team members are in unauthorised areas
- listen for lunch room chatter or behaviour that may be suspicious
- ensure team members understand company policies, procedures and the consequences of non-compliance for the business, its people, the industry and consumers.

Intentional contamination issues reinforce the importance of effective product identification and traceability [refer Chapter 17]. It is also essential to keep inventories of key inputs such as chemicals, fertiliser, fuel and equipment. Ensure that physical contaminants such as pins and staples are not present where fresh produce is harvested or packed.

14.7 Good practice for managing people

Table C14:2 | Summary of good practices for managing people.

Management area	Good practices
Induction	Workplace induction for team members, contractors and visitors includes guidance on essential basic food safety and hygiene, such as: • requirements for personal cleanliness and management of hair, clothes and jewellery • instructions on hygiene in the workplace (e.g. handwashing) and what to do if unwell. Training is supported by clear written instructions in appropriate languages and pictorial guides that are prominently displayed and easily accessible. Refresher training is provided at least annually.

Management area	Good practices
Training and awareness	Training is appropriate to the literacy level and duties of team members. Supervisors monitor handwashing and hygiene compliance. Visual aids (e.g. photographs, cartoons, UV "wash and glow" gel) are used to demonstrate effective handwashing and highlight missed areas. Hand swabs may be used to verify hygiene standards and reinforce training outcomes.
Personal hygiene	Hands are washed with potable water and soap for at least 20 seconds and dried using single-use paper towels. Handwashing occurs before starting work and after breaks, toilet visits, eating, smoking, coughing, sneezing or handling animals or waste. Where potable water is unavailable, hands are dried and sanitised using an alcohol-based product containing at least 60% alcohol. Wounds are covered with waterproof, blue metal detectable dressings and gloves are worn over the dressings. Jewellery is minimised or securely covered, with a plain wedding band acceptable. Clean outer garments are worn, free of loose items and single-use aprons or protective clothing are used, as required. Eating, smoking and drinking, except water are restricted to designated areas. Hair and beards are covered in produce handling and packing areas.
Glove use	Disposable gloves are preferred and replaced after contamination risks such as toilet use, eating or sneezing. Reusable gloves are cleaned and sanitised as for hands and replaced if soiled or damaged.
Facilities	Team member facilities e.g. meal rooms, change rooms, toilets and handwashing need to be separate from produce handling and storage areas and designed to be easily cleaned and sanitised. Toilets and handwashing stations are clean, well equipped and conveniently located (i.e. within 500 m of work areas or less than 200m for ready-to-eat crops). Facilities are supplied with potable water, non-perfumed liquid soap and single-use towels. Waste and wastewater are disposed of to avoid land or crop contamination. Facilities are located away from water sources and flood-prone areas and maintained in clean working order throughout harvest.
Illness management	Team members with illnesses such as gastroenteritis or hepatitis A do not handle produce until fully recovered and symptom-free for at least 48 hours. Recovering team members are reassigned to non-produce contact duties. Team members with respiratory illness (e.g. colds) do not handle produce directly, wear masks and practise increased hand hygiene.

Management area	Good practices
Intentional contamination prevention	Team members understand company policies, procedures and the consequences of non-compliance for the business, its people, the industry and consumers. Fair treatment of team members and compliance with legal employment standards are maintained. Access to work areas, water supplies and key inputs (chemicals, fertilisers, fuel) is restricted and controlled. Visitor sign-in registers are used and monitored. Locks, alarms and cameras are installed, where appropriate. Workplace culture encourages prompt reporting of suspicious activity. Physical contaminants such as pins and staples are excluded from harvesting and packing areas.

CHAPTER 15

Managing Suppliers of Inputs and Services

Overview

Inputs and service providers are potential sources of contamination. Specifications for inputs and services should be agreed with suppliers, documented and checked for compliance.

Inputs and services are potential sources of contamination. Hazard assessments should be conducted for inputs such as containers, packaging materials, equipment, vehicles, water, chemicals and planting materials. Examples of services that can create hazards include pest control, labour, maintenance contracting and transport.

If significant hazards are identified, measures should be taken to reduce or prevent their potential risk. Inputs or services should be clearly specified, agreed with the supplier and clearly documented. All inputs and services should be sourced from an approved supplier and inspected against a specification on delivery. A list of approved suppliers and their mode of approval should also be kept and reviewed annually.

Purchase records should be kept for inputs or services that may introduce a hazard. These should include a description of the goods or services, name of supplier and date of purchase, as well as a record of input or service inspections.

Image C15:1 | Conduct visual inspection of incoming goods at delivery, including packaging, labelling and temperature (if applicable) to verify input safety.

Image C15:2 | Review supplier documentation, such as Certificate of Analysis (COAs) to verify raw materials and inputs meet food safety requirements.

15.1 Chemical contamination via planting materials

Planting materials, such as seeds, seedlings, runners and cuttings can be a source of chemical contamination from the pesticides used to treat pests and diseases during their production.

To prevent residues in the produce from exceeding the maximum residue limits (MRLs), particularly relevant for baby leaf crops, all chemicals should be applied to planting materials in accordance with legislation in the destination market and the directions on labels or off-label permits.

Some chemicals have long withholding periods, so these should be checked before application, especially if they are applied to crops with a short cropping cycle. Records of chemical treatments during the production of planting material should be kept to verify that chemicals have been used correctly.

Suppliers of planting materials (e.g. vegetable seedlings) should disclose any chemical treatments that could result in residues exceeding MRLs in the harvested product.

15.2 Good practice for managing suppliers of inputs and services

Table C15:1 | Summary of good practices for managing suppliers of inputs and services.

Aspect of supplier approval	Good practices
Identifying inputs and services that have food safety, quality or authenticity significance.	Food safety and quality hazards related to the material or service. Significance to final produce safety. Quantities sourced. Related authenticity and food fraud concerns [refer Appendix 1]. Authenticity being the extent to which a food product is genuine and matches its description, ingredients and origin, without substitution, mislabelling or adulteration. Examples of food safety evidence for inputs could include seed lot documentation, chemical labels and SDS, supplier certificates, product specifications or declarations of compliance.
Specification documentation for inputs and services that have food safety, quality or authenticity significance.	Specifications to be agreed, documented and accessible to team members responsible for procurement and receivals.
Identifying and approving suppliers that present elevated risks to food safety, quality or authenticity risks.	Where applicable, supplier confidence may be supported by accreditation (e.g. ISO accredited laboratory), certification (e.g. to a Global Food Safety Initiative (GFSI) recognised assurance programme such as SQF or BRCGS), or registration (e.g. regulatory body register of approved agrichemicals) [refer Appendix 2]. Supplier audits should be conducted for suppliers that do not have a recognised approval. These supplier audits should ideally cover food safety, quality, authenticity, food defence and traceability. Additional considerations include: • supplier's reputation • supplier's historical performance • other supporting evidence may include third-party audit reports, regulatory compliance records (e.g. registration status, declaration of conformance or completed supplier questionnaires).
Receiving of inputs and services.	To ensure specifications are met, inputs and services should: • be sourced from approved suppliers that demonstrate compliance with the specification • inspected/assessed against the specification and a record of inspection kept • in some cases, depending on the input or service, the supplier may provide a Certificate of Analysis (CoA) with each batch to demonstrate compliance with the agreed specification.
Record keeping.	Maintain purchase records for inputs and services that may pose a food safety risk. Records include the name of supplier, date of purchase and inputs or service supplied. It is good practice to keep an up to date list of approved suppliers and their method of approval and to review this list regularly, ideally annually.

CHAPTER 16
Managing Allergens

Overview

Allergic reactions can be severe and sometimes fatal. Identifying and controlling allergens within the business production system is key to their management.

16.1 Types of allergens

Allergens are substances that, even in very small amounts, can cause a reaction in susceptible individuals. The severity of reactions can vary from mild to life-threatening. Reactions can involve respiratory, gastrointestinal and/or skin problems. Severe reactions (anaphylaxis) can also occur. Signs of anaphylaxis may include swelling of the tongue and airways, difficulty in talking and dizziness. This can be fatal if not treated immediately with adrenaline.

It is estimated that two to four percent (2-4%) of adults and five to ten percent (5-10%) of children are affected by a food allergy for which there is no known cure. The only completely effective way to manage a food allergy is to avoid foods containing the allergen. The food industry relies on allergen management practices and product labelling to manage this important food safety issue.

All allergens identified in Figure 16.1 are required to be declared in accordance with the requirements of the Food Standards Code when present in a product.

* Tree nuts include almond, brazil, nut, cashew, pecan, hazelnut, macadamia, pine nut, pistachio and walnut.

** Wheat (including its hybridised strains) and any of the following cereals if they contain gluten: wheat, rye, barley, oats, and their hybridised strains.

*** Added Sulphites in concentrations of 10 mg/kg or more.

Figure C16:1 | Allergens and their derivatives that are present in a food are required to be declared in accordance with regulatory requirements.

16.2 Cross-contact contamination

The risk of allergen cross-contact should be evaluated during food production. Cross-contact refers to the unintended presence of allergenic residue in foods that are not intended to contain them (Table 16.2).

Examples of cross-contact sources:

- tree nut waste materials or peanut shells used as mulch on crops
- fruit, vegetable or nut-in-shell waxes containing soy, casein (milk protein), peanut or sesame
- peanuts present during production, harvest or packing
- species used in crop rotation, cover crops and interplanting, as some commonly used crops (e.g. lupin, peanut, soy and wheat) are allergens
- shared equipment used for harvesting, storage and/or transport.

Image C16:1 | Tree nut waste materials, such as these peanut shells, can potentially introduce allergens if used as mulch.

Allergens can also be present if team members fail to follow good hygiene practices, such as washing hands before touching produce or refraining from eating while working during harvesting, packing or processing line.

Image C16:2 | Crop rotations, cover crops, and inter-planting with wheat, soy, peanuts, or lupin can potentially introduce allergens through cross-contact.

Image C16:3 | New products applied to produce, including food-based films and agronomic sprays, should be assessed to identify the presence of allergens.

16.3 Food Regulation

Standard 1.2.3 and Schedule 9 of the Australia New Zealand Food Standards Code require a mandatory declaration for the main foods and their products (Figure C16:1) that may cause an allergic reaction if present in ingredients or processing aids. In the absence of labelling, this information should be displayed on or in connection with the food display or provided to the purchaser on request.

There is currently no mandatory requirement for declarations in the event of unintended cross-contact for (e.g. “may contain” statements) [refer Appendix 2].

16.4 Sulphites

Sulphites in concentrations of 10 mg/kg or more, are required to be identified on labelling.

One of the most important issues relevant to the fresh produce industry is the use of sulphur dioxide (SO_2) release sheets in packed/stored grapes. The sheets slowly release SO_2, which controls fungal rots inside the plastic-lined package.

If you have sulphites in concentrations of 10 ppm (10 mg/kg) or more, you are required to comply with allergen labelling requirements.

Products containing sulphites, irrespective of if they require mandatory allergen labelling, may also be subject to food amendment labelling requirements, as outlined in Standard 1.2.4 Information requirements – statement of ingredients and in Schedules 7 and 8 of the Code [refer Appendix 2].

16.5 Good practice for managing allergens

Table C16:2 | Summary of good practice for managing allergens.

Management area	Good practices
Planning	An allergen management plan is in place for the business.
Inputs	Allergens potentially associated with raw material inputs (e.g. waxes, coatings, mulches, fertilisers, agronomic sprays, storage aids) are identified. Procedures are in place to obtain information from suppliers on the potential presence of allergens.
Growing	Species used in crop rotation, cover crops and interplanted crops are included in the assessment for known allergens.
Assessment and management	All new products are assessed for potential allergen content prior to use, while existing products undergo routine checks to monitor allergen presence. If allergens are identified, an allergen control procedure is documented including: • listing raw materials and produce containing or potentially contaminated with allergens • details on how products containing allergens are stored and handled • what cleaning procedures are required to prevent cross-contact • labelling of allergens in accordance with regulations.
Training	Team members should receive training at induction and through refresher sessions. Training should cover: • awareness of allergen risks • how cross-contact may occur • procedures to identify and control allergen risks.

Resources

Australasian Society of Clinical Immunology and Allergy (ASCIA) (2023) *ASCIA 2023 Conference Report*. Sydney: ASCIA.

Allergen Bureau (2024) *VITAL Program*.

Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) (2020) *Code of practice: CXC 80-2020*. Codex Alimentarius Commission. Rome: FAO and WHO.

Australasian Society of Clinical Immunology and Allergy (ASCIA) (2025) *ASCIA action plans and first aid plans for anaphylaxis*.

CHAPTER 17
Identification and Traceability

Overview

Produce is legally required to be identifiable and traceable throughout the supply chain, from grower to retailer and preferably consumer and in reverse. Traceability enables potentially contaminated (unsafe or unsuitable) produce to be efficiently removed and the source of the issue identified.

Traceability systems are based on the process of identifying all inputs (e.g. production site, water, seed/plant material, fertiliser, agrichemicals, labour, equipment, packaging) and being able to confirm the origin and journey of the inputs that were used to produce the final product. This process enables verification of the product's history.

Fruit and vegetables need to be traceable to remove produce from the supply chain that is either unsafe or potentially unsafe. To achieve this, produce needs to be identifiable, with information documented using a lot or batch identification system.

Beyond food safety, effective traceability systems can also serve as a value driver for the business. Clear identification and documentation of inputs and production practices help demonstrate product provenance, reinforce authenticity claims and support market access requirements. This can strengthen brand reputation, build consumer trust and create opportunities to differentiate in premium or export markets.

17.1 Product identification

To conduct an effective trace-back, businesses across the supply chain need to record essential product identification information including:

- growing location, crop type and variety
- inputs such as fertilisers, composts and chemicals
- operational records such as harvest date, picker or picking team, harvesting equipment, packaging and product labelling
- name, address and other contact details of suppliers and a description of products or inputs supplied
- name, address and other contact details of customers and a description of the product supplied to them
- date of transaction or delivery
- lot identification including date, batch number or other markings
- distribution records such as carton/crate labels and purchase/sales orders, ideally discrepancy between lot/batch/line quantity produced and the quantity supplied should be recorded
- produce identification systems may be paper based, electronic or online. Whatever system is used, stored data should be clear and easily retrieved if needed, such as during a recall.

A lot (batch/line) describes produce that has grouped characteristics and will be treated the same way in the event of a food safety issue. For example, a lot/batch may be:

- seeds/seedlings planted on a certain date in a specific location
- produce harvested on a certain date from a growing location that has had the same water, fertiliser and chemicals applied
- produce from a supplier that is treated with the same postharvest materials, exposed to the same packing line conditions and packed on a single date
- a consignment of produce assigned a lot number on arrival at a distribution facility.

Lot identification systems should be scaled to quantities of produce relevant to food safety risks and product characteristics. For example, the decision on the size of the lot is a commercial one because the lot size may depend on the size of the producer. For a smaller producer, an entire day's production could be considered a lot. For a large-scale producer, a lot could be equivalent to one hour's production.

17.1.1 Growing

A system for identification of growing sites should be established. Production data should include location and all crop input records (spray, fertiliser, water, soil tests, labour records) and all output records (picking team members, harvest time, product quality and quantity).

These records of the history of inputs, activities, team members and crop harvested at the site can then be linked to records of the purchase and management of farm inputs.

17.1.2 Harvest

The growing site and harvest date should be recorded for each batch, lot or line of harvested produce. Details of harvest labour should also be linked to the harvested produce. This allows traceability in the event of infectious diseases or other hygiene issues. This information can be recorded in a diary, harvest record or on a delivery docket.

Harvesting containers used to transport bulk quantities of product for packing should be part of the traceability system. This enables receival records of these bulk containers to be linked from the growing site to the packing site traceability system.

It is also considered good practice to record key details of mechanical harvesters used, especially where equipment is shared between different growers or sites. This includes identifying the harvester unit, operator and cleaning or sanitising history.

Recording this information can support investigations into physical or microbiological contamination and strengthen overall traceability.

17.1.3 Packing

The Australia New Zealand Food Standards Code Standard 1.2.1 [refer Appendix 2] requires all food packages to be labelled as a minimum with:

- name of the food
- lot identification including date, batch number or other markings
- name and physical address of the supplier
- advisory statements, warning statements and declarations
- storage conditions and directions for use (where applicable).

All packed produce should be labelled with a lot identification system on each pack (saleable or orderable unit). During distribution, packages may be separated from pallets and traceability lost if identification is only at the pallet level.

Data carriers such as barcoding systems are widely used by major retailers to support traceability. Traditional linear (1D) barcodes are used for fixed-weight items, while two-dimensional (2D) barcodes such as the GS1 DataMatrix are increasingly used for variable-weight or pre-packed fresh produce. The use of these systems improves accuracy and reduces the time required to conduct a recall or withdrawal. In some cases, this allows traceability down to individual units of produce.

Radio Frequency Identification (RFID) is used in some logistics and distribution applications but is not yet in widespread use for individual item identification at the retail level in fresh produce supply chains. For more information, refer to GS1 Australia or New Zealand.

Where a central packhouse consolidates product from multiple growers, each package should be traceable back to the individual grower. If grower-level traceability is not maintained, the aggregated product is treated as a single lot for the purposes of recall or withdrawal. This increases the business risk, as a recall may affect all produce from all contributing growers within that lot or batch. Choosing not to invest in systems that maintain grower-level identification is a risk-based decision. While it may reduce operational complexity, it significantly widens the potential scope and cost of a recall.

Depending on the destination of the packed produce, there may be additional regulatory and customer specific product identification and labelling requirements. If exporting goods, then the importing country requirements should be considered when designing labels.

A documented procedure should be established to verify that all packaging and labelling materials comply with the Australia New Zealand Food Standards Code (Standard 1.2.1) and customer requirements. Packaging, labelling and date coding should be checked for accuracy and legibility at the start and end of each production run, as well as whenever packaging is replenished. Checks should be undertaken when packing resumes after downtime on the product line. Records of packaging and labelling checks should be maintained, including a copy of the actual label being applied. Only the packaging and labelling specific to the product being packed should be made available for use at the time of packing and should be clearly identified. At the end of a production run, the production line should be fully cleared of label and packaging material. Unused packaging should be fully covered when returned to the storage location.

Vision inspection systems, such as cameras, may be installed on packaging lines to verify that labels, barcodes and date codes are correct, legible and aligned with product specifications. These systems are designed to detect incorrect, missing or illegible labels and can trigger a rejection mechanism when required. Verification checks should be routinely monitored and maintained to ensure ongoing accuracy and compliance.

17.1.4 Distribution

Distribution businesses may use a variety of systems to identify and track fresh produce. Produce is usually tracked by applying system-generated lot/item numbers and labels to pallets on first arrival into the business. Produce identification and traceability systems used by distribution businesses should record:

- name, address and other contact details of suppliers and a description of products or inputs supplied by them
- name, address and other contact details of customers and a description of the product supplied to them
- date of transaction or delivery
- lot identification (e.g. item number or other markings)
- volume or quantity of product supplied or received
- other relevant distribution records.

New, increasingly sophisticated, systems are now available. These will allow increased amounts of information to be recorded and tracked for individual products as they continue through distribution. Where systems differ between supply chain partners, GS1 standards support consistent data exchange to maintain traceability integrity.

The use of GS1 global data standards allows for greater integration along the supply chain with the information flowing alongside the product. It also allows for interoperability between system and external traceability.

Produce should be identifiable and traceable through the supply chain from grower to retailer.

17.2 Traceability

Traceability enables product history to be verified from retail back to growing location and from growing location forward to retail. Traceability requires that each business in the supply chain to record sufficient and accurate product identification information (Figure C17:1). At a minimum the Australian New Zealand Food Standards Code requires each business in the supply chain should be able to trace food sold one step forward and one step backward in the supply chain. Good practice is increasingly shifting towards full-chain traceability for example from seed to shelf.

Fast and accurate traceability systems allow the business to determine the size of the issue they are facing and help reduce the number of people affected by an outbreak of foodborne illness or other food safety hazard. This reduces risk to public health and minimises disruption of trade and the commercial impact of a recall.

A system for quickly retrieving product and location identification records, should be developed by each business. These records will also help investigators identify the cause of the food safety incident and the corrective actions needed to prevent it continuing or recurring [refer Appendix 1].

Appendix 2 Food safety regulations and assurance programmes further outlines traceability requirements in the Food Standards Code. Good agricultural practice also includes traceability of potentially hazardous inputs to production for example agrichemicals and soil amendments, to a lot/batch/line of produce.

Traceability systems used by growers, packers and distributors range from paper-based records and receipts through to advanced business control software (e.g. Enterprise Resource Planning (ERP) software). Such systems are increasingly utilised by packers and distributors in the fresh produce industry, making product traceability increasingly fast and accurate.

Speed is essential in the event of a product recall, as consumer safety is at stake [refer Chapter 19]. Major retailers require their suppliers to provide identification of all products affected by a recall within two hours of the supplier becoming aware their product is affected by the recall.

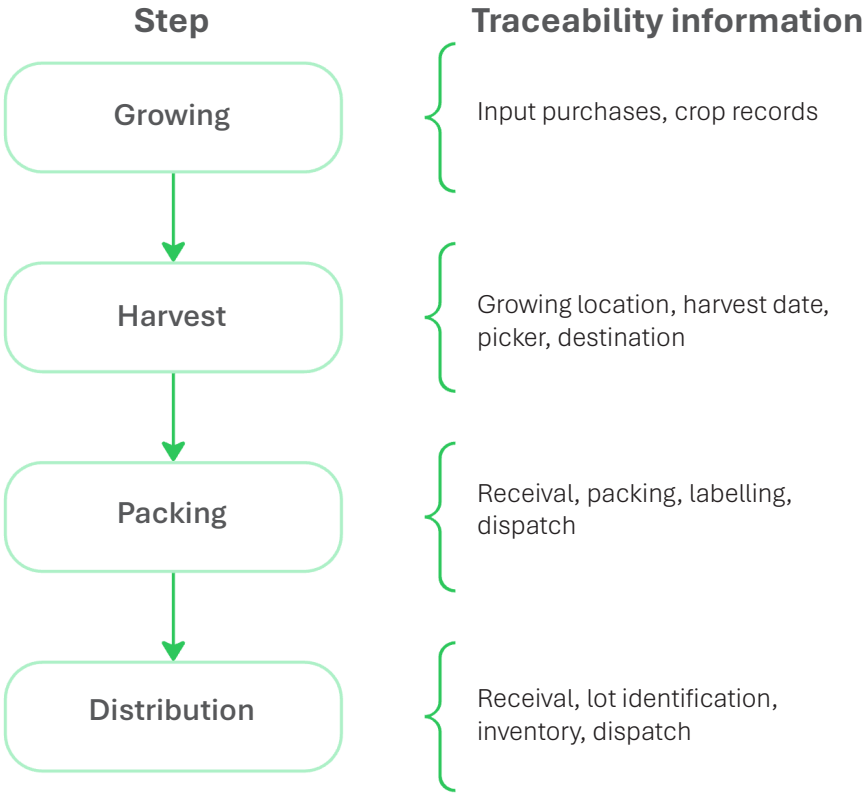

Figure C17:1 | Traceability information needed at different steps in the supply chain.

Other innovations in produce labelling that are assisting with the speed of recall include:

- global trade item number (GTIN) – a unique product identifier assigned to all items traded in the supply chain: it links to master data such as variety, pack size, unit of measure, brand and/or origin and the GTIN forms the foundation for barcode labelling and traceability
- GS1 Databar – a barcode format used on individual loose produce, applied via 'price look up' (PLU) stickers: it encodes the GTIN and enables item-level traceability even when no packaging is present.
- GS1 DataMatrix – a two-dimensional barcode used on pre-packaged produce: it can carry additional information such as lot numbers and use-by dates alongside the GTIN; supporting faster and more precise recalls and the DataMatrix can be printed directly on packaging or on applied labels.

Example:

- a loose apple sold by weight at retail may have a small PLU sticker with a GS1 DataBar encoding the GTIN
- a bag of salad leaves may have a printed GS1 DataMatrix on the label or pack, including the GTIN, lot number, and use-by date.

These formats help identify specific items during a product recall and enable more efficient traceability across the supply chain.

Image C17.1 | Individual loose apples sold by weight or quantity may carry a small PLU sticker containing a GS1 DataBar, enabling identification through the Global Trade Item Number (GTIN) for improved traceability at retail.

Image C17.2 | A bag of salad leaves may have a printed GS1 DataMatrix on the label or pack, including the GTIN, lot number and use-by date.

Image C17.3 | Crate labels often include a GS1-128 barcode that encodes the GTIN, enabling product identification and traceability through the supply chain from packhouse to retail.

Image C17.4 | An RFID chip embedded beneath the label allows wireless tracking of the bin through harvest, transport and packing, enhancing efficiency and traceability across the supply chain.

17.3 Good practice for identification and traceability

Table C17:1 | Summary of good practices for identification and traceability.

Management area	Good practices
Crop production and harvest	The location of growing sites is identified on a property map or equivalent. A record of all harvested produce is kept which includes: • business name • crop/variety • growing site • harvest date • harvest labour • destination. Harvested produce sent to another business for packing or further processing is clearly identified with supplier name and harvest/delivery date.
Post-harvest	All packed produce sent to a customer is marked with: • business name and physical address of supplier/packer • packing date and/or batch identification code • any other legal requirements. A record of all distributed produce is kept which includes: • name, address and other contact details of suppliers and a description of products or inputs supplied • name, address and other contact details of customers and a description of the produce supplied to them • date of transaction or delivery • lot identification (e.g. item number or other markings) • volume or quantity of product supplied or received • other relevant distribution records and legal requirements.

Resources

Food Standards Australia New Zealand (FSANZ) (2024). *Safe Horticulture Australia: A guide to the Primary Production and Processing for Horticulture*, 1st ed. Canberra: FSANZ.

Food Standards Australia New Zealand (FSANZ) (2015). *Australia New Zealand Food Standards Code – Standard 1.2.1: Requirements to have labels or otherwise provide information*.

GS1 (2024). *Fresh Fruit and Vegetable Traceability Guideline*.

CHAPTER 18
Testing

Overview

Testing may be used or required to demonstrate that chemical (including allergen) or microbiological hazards are being controlled. However, testing alone cannot be relied on to confirm whether produce is safe or unsafe. The main use of testing is to check the effectiveness of food safety and quality controls and to assist in identifying potential sources of contamination when they occur.

18.1 Why test?

Routine testing for chemical and microbial contaminants in fresh produce is not a reliable standalone method for ensuring food safety. While testing can support verification activities, it is inherently limited in scope, frequency and responsiveness. Sole reliance on end-product testing contradicts the preventive, systems-based approach central to HACCP principles, which emphasises identifying and controlling hazards throughout the supply chain.

It is important to note that chemical and microbial contamination generally will not be uniformly distributed across crops or postharvest environments. This uneven distribution means the likelihood of detecting food safety risks through sporadic testing is extremely low, unless sampling programmes are continuous and highly intensive, which is an impractical approach for most operations.

Greater assurance comes from conducting thorough hazard analysis and implementing preventive control measures. These proactive steps form the foundation of effective food safety management [refer Appendix 1, Chapters 3 and 4]. While regular testing remains a requirement under most assurance programmes, its primary role is to verify that identified hazards are being controlled. To meet regulatory and customer expectations, businesses should establish, implement and maintain documented testing schedule covering chemical, heavy metal, microbiological and allergen risks.

Types of verification testing that may be required include:

- growing site soil test for persistent chemicals
- growing site soil test for heavy metals
- growing site soil test for microbial contamination
- water test for irrigation water quality
- water test for postharvest water quality
- packed produce test for persistent chemicals, heavy metals and pesticide residues
- packed produce test for microbial contamination
- packed produce test for unintended allergen presence
- environmental testing of the facility and equipment to verify effectiveness of a cleaning and sanitation program.

The following guidelines are provided to assist in understanding and standardising approaches to these tests.

18.2 Sampling

Before conducting any testing, businesses need to consider:

- why they are doing the testing (i.e. routine check, incident related, regulatory or food safety standard requirement?)
- what questions they are trying to answer (i.e. is my product compliant? Do I have an issue, if so, how big could the problem be?)
- where are they going to take samples from and how many do they need to take?

Because hazards are rarely evenly distributed in a field or within a batch of produce, sampling should be conducted randomly and should reflect the characteristics of the produce grown or supplied.

The purpose of testing will influence the sampling approach and producers may need to consult with subject matter experts (i.e. chemical suppliers, microbiologists, accredited laboratories or industry consultants) to ensure appropriate methodology and interpretation. Businesses should also be aware of any minimum testing requirements specified by assurance programmes, customer specifications or regulatory authorities and ensure these are met as part of their food safety and compliance obligations.

Prior to commencing sampling, consult with your laboratory provider to confirm any specific requirements that may affect sample integrity or testing outcomes. This includes verifying whether specialised containers are required and identifying any handling protocols that should be followed during sample collection.

Image C18.1 | Using a telescopic pole allows for safe and controlled collection of water from the centre of the pond, minimising disturbance to sediment and reducing the risk of contamination from the pond perimeter.

Image C18.2 | Disposable boot covers are used to walk through designated sampling zones, to collect soil and debris for microbiological analysis of potential pathogens.

Image C18.3 | Sterile sampling bags should be used to minimise the risk of external contamination and ensures the test results accurately reflect the conditions of the sample.

18.3 Laboratory Selection

While price and convenience for sample delivery are often key factors when selecting a laboratory to test fresh produce, there are several other factors to consider when selecting a laboratory provider and most assurance programmes mandate the use of accredited laboratories.

Table C18:1 | Laboratory selection.

Things to Consider	
1	Do they operate a quality management system that complies with the requirements of international standard ISO/IEC 17025?
2	If so, are they accredited: NATA (National Association of Testing Authorities) in Australia? IANZ (International Accreditation New Zealand) in New Zealand? International Laboratory Accreditation Cooperation (ILAC)? Accredited laboratories are listed on the NATA, IANZ or ILAC websites. Laboratories accredited by NATA or IANZ to ISO/IEC 17025 are preferred when selecting a laboratory to test fresh produce.
3	Does the scope of their accreditation specifically reference the microbiological testing or analysis of residues and contaminants in fresh fruit and vegetables that your business requires? In New Zealand, the Recognised Laboratory Programme (RLP) laboratories are listed on the MPI website.

18.4 Chemical testing

Testing the soil for persistent chemicals or heavy metals should be conducted when the risk at the growing site is high, as determined by a hazard analysis [refer Appendix 1, Chapter 6 and Chapter 8].

Harvested fresh produce may be tested for residues of persistent chemicals, heavy metals or pesticides. Such tests are used to verify that these chemicals do not exceed the chemical Maximum Residue Limits (MRL) or heavy metal Maximum Levels (ML) specified in relevant legislation for harvested produce [refer Appendix 2 and Chapter 8].

Specialised plant nutrient determination and cadmium residues in produce certified laboratories are listed on the Australasian Soil and Plant Analysis Council (ASPAC).

18.4.1 Maximum Residue Limits (MRLs) for agrichemicals

The Maximum Residue Limit (MRL) is the highest concentration of a chemical legally permitted on a type of produce. The concentration is expressed in milligrams (mg) of the chemical residue per kilogram (kg) of the produce type (equivalent to parts per million, 'ppm'). Typically, MRLs are set at levels 100 or even 1000-fold lower than those that would be expected to cause symptoms of illness and consider the susceptibility of people that might be expected to be consumers of those foods.

The Maximum Level (ML) is the maximum level of heavy metal contaminant that is legally permitted to be present in a food. The concentration is also expressed in mg/kg. If the MRL for a persistent chemical or the ML for a heavy metal is exceeded, it indicates that the growing site may not be suitable for growing the produce type or that additional control measures should be implemented.

If an MRL is exceeded for a chemical used in crop protection, it normally indicates the chemical has not been used according to label directions. However, this does not normally indicate an acute public health or food safety concern. Legal prosecution for exceeding an MRL is based on the failure to follow label directions (i.e. misuse of the chemical), not for exceeding the MRL.

In Australia the MRLs for registered crop protection chemicals are established by the Australian Pesticides and Veterinary Medicines Authority (APVMA). MRLs are then adopted into Standard 1.4.2 and Schedule 20 of the Food Standards Code. A residue may meet FSANZ limits but still be non-compliant if the chemical is not authorised by the APVMA for that crop. In New Zealand the MRLs are set by Food Notice, with a default of 0.1mg/kg if no MRL set (set under section 144 (6) of the Food Regulations 2015).

Under the Trans-Tasman Mutual Recognition Arrangement (TTMRA), food imported from Australia may be legally sold in New Zealand, if it complies with Australian requirements. The converse is also true; food imported from New Zealand into Australia is legal if it complies with New Zealand requirements.

For other countries, the importing country MRLs should be checked before treatment and export. Ideally, growers should be fully aware of the MRL requirements in all likely destination markets before the growing season commences. Spray programs should be designed to meet those requirements and residue test results checked against the market MRLs. These may differ from Australian and New Zealand MRLs.

18.4.2 Maximum Limits (ML) for heavy metals

The Maximum Level (ML) is the maximum level of heavy metal contaminant that is legally permitted to be present in a food. The concentration is also expressed in mg/kg. If the MRL for a persistent chemical or the ML for a heavy metal is exceeded, it indicates that the growing site may not be suitable for growing the produce type or that additional control measures should be implemented.

MLs are specified in Standard 1.4.1 and Schedule 19 of the Food Standards Code.

18.4.3 What to test for?

Chemical residue tests for pesticides should screen for all chemicals applied during crop growth and postharvest treatment. The commonly requested chemical residue test is a multi-residue screen, meaning that they assess the levels of a range of persistent chemicals, heavy metals and commonly used chemicals for the produce type and production method. Multi-residue screen may not cover the full range of chemicals used so it is important to check the active constituents that are tested for when selecting tests. Utilising multi-residue screen will also detect any residues from chemicals not directly applied that may be present from spray drift from neighbouring sites or from pre-planting applications from nurseries.

Testing can be important on growing sites where there is a high level of risk from persistent chemicals or heavy metals. In general, it is more useful to test the fresh produce type grown on the site rather than the soil, as it is the residue on or in the harvested produce that is most relevant for regulators, customers and consumers. However, soil tests before planting can indicate the degree of contamination and this may affect the choice of crop to be grown.

18.4.4 How often to test?

The requirement for testing should be established by the hazard analysis and the frequency determined by the confidence level required to verify the chemical use program is correct. To meet the requirements of most food assurance programmes, a chemical residue test is generally undertaken once a year, but this may not be enough if different chemicals are used during different growing conditions (e.g. during warm and cool seasons for all year-round crops). Some assurance programmes and customers may require a higher frequency of testing and may prescribe which active ingredients are tested for.

18.4.5 Where to sample?

A sample for testing can be collected at several points in the supply chain:

- prior to harvest, after all withholding periods for crop protection chemicals applied to the crop have elapsed
- after application of postharvest treatments and packing, for produce that may be stored for a short period before dispatch
- before or on delivery to the first customer in the supply chain, for produce that is harvested, packed and immediately dispatched
- prior to storage, for produce that is stored for an extended period before delivery, such as apples
- after storage, where the postharvest application of chemicals for long-term storage is being verified.

18.5 Microbial testing

Microbial testing can support verification of microbial control measure and compliance with customer requirements. However, reliable results require extensive sampling, especially when contamination is low or localised, making this approach costly and often impractical. A preventative strategy, based on good agricultural and hygiene practices, is a more effective way to ensure produce safety.

There are currently no mandatory microbiological limits in the Food Standards Code for irrigation or wash water or for fresh produce not classified as ready-to-eat (RTE). However, Food Standards Australia New Zealand (FSANZ) does stipulate microbial limits for RTE foods under Standard 1.6.1 and Schedule 27. RTE produce includes items intended to be consumed without further washing, peeling, or cooking (i.e. pre-washed leafy vegetables or cut fruit). Whereas whole raw produce requiring consumer preparation is not classified as RTE. Assurance programmes and customer specifications may impose additional microbial requirements. Guidance on critical limits for human pathogens is provided in Table C18:2, with supporting details in Appendix 3 and the Compendium of Microbiological Criteria for Food, available on the FSANZ website.

18.5.1 What to test for?

There are many types of microbes that may pose a concern for food safety [refer Appendix 3]. However, testing for every possible human pathogen is impractical and prohibitively expensive. A more efficient approach is to monitor for 'indicator organisms' [refer Appendix 4], which are non-pathogenic but share similar growth conditions with human enteric pathogens. Their presence suggests potential faecal contamination and the possible presence of pathogens. Common indicators such as *E.coli* or generic *Listeria spp*. are included in testing programs (Table C18:2) to provide a rapid assessment of contamination risk. If indicator organisms are detected at unacceptable levels, further investigation is required to identify the contamination source and determine whether the product is suitable for sale and human consumption. It is important to note that some bacteria may enter a viable but non-culturable (VBNC) state under stress conditions (i.e. exposure to sanitisers or UV light), making them more difficult to detect through standard testing methods.

Testing requirements should be guided by regulatory obligations, food safety standards and customer specifications.

Table C18:2 | Description of microbes that may be part of a testing programme.

Microbe Type	Description
Thermotolerant coliforms	Thermotolerant coliforms are normal bacterial inhabitants of the intestines of warm-blooded animals. They are generally present in high numbers in human and animal faeces and may be used as an indicator of faecal contamination. However, there are also types of thermotolerant coliforms that can grow in the environment in the absence of faecal contamination. Particularly *Klebsiella pneumoniae* in water contaminated with effluents from pulp and paper mills. Based on international and domestic research a limit of thermotolerant coliforms <100 cfu/g is currently set on fresh produce specifications in Australia. However, the specific thermotolerant coliform *E. coli* is the preferred indicator organism for identifying faecal contamination. For the use and limitations of faecal indicators refer Appendix 4.
Escherichia coli (E. coli)	*E. coli* is the most common thermotolerant coliform bacteria present in animal faeces and is therefore the best indicator of recent faecal contamination. It is generally not capable of independent growth on produce unless provided with an environment rich in moisture and nutrients. There are five sub-groups of *E. coli*, however, that can cause human illness (named as EHEC, ETEC, EIEC, EPEC, EAEC). They are called sub-types, and their differentiation is based on the symptoms of the illness they typically cause. Of these five sub-types, the one of most concern to the food industry is enterohaemorrhagic *E. coli* (EHEC) also called Shiga-toxin producing *E. coli* (STEC). Strains of this sub-groups can cause serious illness especially in young children and the elderly. In young children, infection can lead to lifelong kidney damage, usually requiring a transplant for the victim to then have a normal life not requiring frequent dialysis as a therapy. In the elderly, death may result. This subgroup is also the one most commonly involved in foodborne disease outbreaks, including ready to eat salad vegetables. As such, there is much attention given to them in the fresh produce industry, especially their potential presence in ready-to-eat fresh produce offerings.
***Listeria spp.* as an indicator organism**	*Listeria* species are common in the environment, being found in soil, decaying plant material and other sources. Carriers also include many species of animals. The vast majority are not harmful. If *Listeria spp*. are detected, on equipment which comes into contact with produce or the produce itself, this indicates that conditions are favourable for the growth of *L. monocytogenes* also.
Listeria monocytogenes	A number of specific strains of *L. monocytogenes* are human pathogens. While the risk of contracting listeriosis is quite low, unless the levels on or in a food are very high [refer Appendix 3], the disease can be fatal, particularly among the young, elderly, pregnant or immunocompromised. Infection can also result in miscarriages. If *L. monocytogenes* is detected, sources of contamination should be investigated and appropriate control measures implemented.
Salmonella enterica	Species of *Salmonella* bacteria are found in the intestinal tracts of a wide variety of animals and are a significant public health concern. While the incidence of *Salmonella* in fresh produce is low, contamination is possible from the environment and through handling. It may also be found in organic fertilisers and composted biosolids. Most *Salmonella* do not grow at temperatures below 7°C and the optimum temperature for growth is 35-37°C. If *Salmonella* is detected in a 25 g sample of fresh produce, sources of contamination should be investigated and appropriate control measures implemented.
Viruses	While not routine, some customers may request testing for viruses e.g. Norovirus or Hepatitis A, especially for RTE products. These tests are complex and only conducted by specialist laboratories.

18.5.2 Where to test?

Table C18:3 | Example testing locations [refer Chapters 3, 5, 7, 8, 9 and 11].

What	Where	Examples of Why
Environmental surfaces	Examples include product contact equipment, conveyors, scales, floors, produce bins, cool room walls, doors and produce bins.	Testing can be completed to verify controls are effective, meet customer specification requirements or to check for contamination from hazards.
Water **- potable water** **- irrigation water** **- wash water**	Water should be sampled at the point where it contacts produce. When investigating potential contamination, water should also be tested at the water source.	Testing can be completed to verify controls are effective, meet food safety standards, customer specification requirements or to check for contamination from hazards. To determine the risk of contamination, testing should be completed at times when the likelihood of contamination is highest and at a frequency that allows management of the potential risk. Water should be tested more often if it is from variable sources such as dams, rivers or creeks, rather than a stable source such as a deep bore. Bore water is generally considered lower risk than surface water. However, periodic testing is still recommended to verify its safety. Particularly test if the conditions changes, such as after heavy rain or during drought periods or to check whether a water treatment process is effective.
Produce **- pre and post-harvest** **- production lot**	To check the effectiveness of a postharvest practice, sample the produce immediately afterwards. To check for gross contamination, sample the produce at harvest.	Testing can be completed to verify controls are effective, meet customer specification requirements or to check for contamination from hazards. Testing of the inputs such as the water and the produce can also be performed to verify that controls implemented work effectively. For example, if sanitisers in solution on produce reduce the microbial numbers or to determine the frequency that water may need to be changed in rinse tanks. When testing to assess contamination risk, test when the likelihood of contamination is highest. This may mean testing when there is a high risk that a particular practice, inputs or weather conditions may have contaminated produce.

Customers or regulatory agencies may require additional testing for other microbes [refer Appendix 2]. This is particularly likely if produce has no subsequent pathogen reduction step or if it is destined for hospitals or aged care homes, because people in these facilities are considered as vulnerable, often having reduced immunity and are more susceptible to microbiological infections.

Testing for microbial hazards other than bacteria, such as viruses and parasites is difficult and many laboratories are not equipped to perform these tests. However, the presence of *E. coli* can indicate such organisms may be present [refer Appendix 4].

18.6 Allergen testing

While fresh produce is generally free from common food allergens, unintentional cross-contact can occur during post-harvest handling, particularly in packing or processing environments where allergen containing products are also handled. Allergen testing may be required to verify cleaning effectiveness, meet customer or food safety standard requirements or support allergen free claims.

18.6.1 What to test for?

Testing is usually focused on the most common food allergens relevant to regulatory or customer requirements. These may include peanuts, tree nuts, milk, egg, soy, wheat, gluten from wheat, rye or oats, fish, crustacea, mollusc, sesame and lupin. Generally, tests target allergenic proteins, using enzyme-linked immunosorbent assay (ELISA). Some rapid onsite test kits are also available with use the same principle. Testing can be conducted on product, food contact surfaces or rinse water from equipment.

18.6.2 How often to test?

The frequency of allergen testing should be based on the risk of allergen cross-contact identified in the hazard analysis. Testing may be required routinely as part of cleaning verification (e.g. when switching between allergen containing and allergen free products), following environmental swabbing programmes or periodically to verify allergen management programmes. Food safety standards and customer specifications may also have specific requirements for testing frequency and methods.

18.6.3 Where to sample?

Sampling may be conducted on product, food contact surfaces, equipment, water or packaging materials. Areas to consider include shared conveyors, packing lines, storage bins, cutting equipment and packaged produce. It is important to follow laboratory instructions on sample collection, handling and transport to ensure accurate results.

18.7 Facility / Environmental testing

Collecting samples from equipment surfaces, floors, walls and cool rooms at a facility is generally referred to as environmental monitoring. This type of testing may be used to investigate whether a facility is the source of a contaminant identified through produce testing. It can also be used to verify the effectiveness of cleaning and sanitation programs [refer Chapter 9].

A range of commercial testing kits are available for surface sampling and are a valuable tool for measuring cleanliness and sanitation program effectiveness over time but have their limitations.

For example:

- contact plates and dip slides are semi-quantitative i.e. they do not provide an exact number and may be used for general detection but are not recommended for specific pathogen identification
- swab sticks with special nutrients are semi-quantitative and indicate the presence or absence of specific pathogens

- sponges and cloths (large swabs) provide an option for large area sampling and have a high level of sensitivity that can be useful for foodborne illness investigation
- adenosine triphosphate (ATP) based measurement devices are rapid but not specific to microbes, so ineffective if plant waste is present. They may be used to monitor cleaning and sanitation of specific areas over time, single results are of little value unless a baseline has been determined.

These testing approaches do not provide the quantitative and qualitative reliability necessary for conducting foodborne illness investigations. In some cases, the residual presence of sanitisers can interfere with testing results, as a result sampling should not be performed immediately after applying sanitiser.

When collecting sample for onsite testing or for external testing, swabs and slides should be handled carefully to avoid cross-contamination which can impact the test results.

Image C18.4 | Examples of environmental sampling tools used to monitor surfaces for microbial contamination, including swabs, sponge swabs and surface sampling cloths.

18.8 Sending samples to the laboratory

Before sending a sample for testing:

1. check that the laboratory can test for the selected chemicals or microbial test required
2. consider the sample size required and how best to transport the sample. For example, collect a sample by selecting three (3) units at random from a lot/batch. For example, collect three lettuces or apples. For smaller produce (e.g. snow peas) select three (3) x 200g samples
3. consider requesting if the laboratory has specific requirements for sampling and preparing sample for analysis
4. to mitigate potential contamination of the sample, use disposable gloves to collect the sample and change gloves between samples
5. place the sample in a clean/sterile, clearly labelled plastic bag (produce), bottle (water) or other container provided by the testing laboratory
6. clearly label the sample
7. complete all sample submission form details required by the testing laboratory
8. keep the samples cool in a refrigerator, unless instructed otherwise by the testing laboratory until ready to send
9. package the sample securely to prevent damage during transport. Include the completed analysis request form and use ice bricks or freezer sheets to keep the sample chilled until it reaches the laboratory
10. use same-day freight (and otherwise overnight) to ensure the sample gets to the laboratory promptly, ideally within 24h of sampling.

18.9 Interpreting test results

18.9.1 Chemical residue test results

Laboratories may differ in how they report chemical test results. Some provide only the active constituents detected in a multi-residue screen, reported alone or relative to the MRL (mg/kg). Others report all constituents tested, with results compared against each MRL.

When interpreting chemical test results, check all active constituents detected in the report against their MRLs. If the sample value is greater than the MRL, then the MRL has been 'breached'. This is sometimes termed an MRL violation. If an MRL has been breached the cause of the breach should be investigated and appropriate corrective/control measures implemented.

Chemical testing reports may also show a number called the Limit of Detection (LOD) or Limit of Reporting (LOR). The LOD/LOR is the lowest quantity of substance the testing Instrument/method can detect within statistical confidence. This is effectively the lowest detection limit for the substance for the test method selected.

In Australia, if a chemical residue is detected (i.e. greater than the LOD/LOR) and there is no MRL for the substance, then this is a MRL breach (i.e. the substance is not permitted (registered) for use on this type of produce [refer Chapter 8]. In New Zealand, if there is no MRL listed for use of a substance on a particular type of produce then it is considered off-label use and a default limit of 0.1 mg/kg applies. In some instances in New Zealand, the limit is set as the limit of analytical quantification (e.g. 0.01 mg/kg) meaning use of the substance on that produce is not permitted and any residue detection (i.e. greater than the LOD/LOR) is considered a breach.

18.9.2 Microbial test results

It is important to understand how the test has been completed and its purpose when interpreting the results. It is important to note that some tests are not designed to distinguish between pathogenic and non-pathogenic bacteria of the same species or it may be extremely difficult to differentiate between closely related strains without highly specialised techniques. For these reasons, a positive result does not necessarily mean the water is unsafe or the produce will be unsafe to eat. Presumptive positives should be followed up with confirmatory testing to verify if pathogens are viable. Confirmed positives are the basis for corrective action. Conversely, a negative result does not necessarily mean that the water is safe to use or produce safe to consume. In some cases, samples may also be contaminated with material or chemicals, that can interfere with the reliability of the test.

The laboratory performing the testing can provide you the information on how the tests work and any limitations that could impact the results.

Results for microbial tests which are designed to quantify the number of bacteria present are reported as the number of colony forming units (cfu), per unit of volume (e.g. cfu/ml) or weight (e.g. cfu/g). Each colony forming units is assumed to have grown from an individual bacterium.

There are also methods which are designed to simply detect the presence of the bacteria in a certain amount of food tested. These are called qualitative methods and generally report results as Detected / Not Detected or Present / Absent per gram or other quantity of material tested.

The presence or absence of the microbe and the number of microbes present are derived through a variety of laboratory techniques.

The typical terms used in microbial test reports, based on the methods used, along with their advantages and disadvantages are described in Table C18:5.

It is important to note that some tests are not designed to distinguish between pathogenic and non-pathogenic strains of organisms.

Use Table C18:4 to determine when action is required for RTE fresh produce testing.

Note, where *Listeria monocytogenes* is of concern, testing may be conducted using larger sampling sizes (e.g. 125 g) or multiple 25 g subsamples to increase the likelihood of detecting contamination.

Seek guidance from regulators, certification bodies or technical consultants when addressing out-of-specification test results.

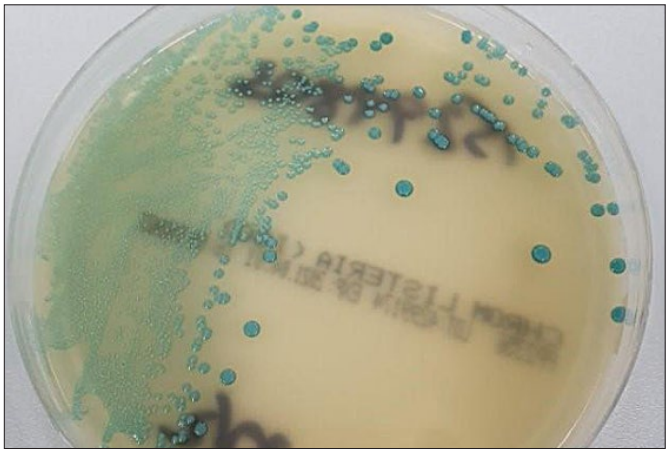

Image C18.5 | The streak plate techniques is used to isolate colonies of *Listeria* on selective agar for further identification and confirmation.

Table C18:4 | Guidance on critical limits on RTE foods (adapted from FSANZ Compendium of Microbiological Criteria for Food).

Hazard		Satisfactory	Marginal	Potentially hazardous
E. coli		<3 cfu/g	3 – 100 cfu/g	>100 cfu/g
Shiga toxin-producing *Escherichia coli* (STEC) (pathogen)		Not detected in 25 g	N/A	Detected in 25 g
Salmonella spp.		Not detected in 25 g	N/A	Detected in 25 g
Listeria monocytogenes	**RTE foods that support growth of *L. monocyto-genes***	Not detected in 25 g	N/A	Detected in 25 g
	RTE foods that do not support growth of *L. monocyto-genes*	Absent in 25 g	<100 cfu/g	>100 cfu/g

Criteria have been agreed internationally for RTE foods that do not support the growth of *Listeria monocytogenes* where the physico-chemical characteristics fall into one of 3 ranges throughout the foods stated shelf-life, these default criteria are: pH<4.4 regardless of water activity; aw <0.92 regardless of pH, and combination of pH>5.0 and water activity <0.94 (FSANZ).

Table C18:5 | Microbiological method terms and considerations when reviewing test reports.

Term	Description	Advantages/disadvantages
Colony Forming Units (cfu)	Obtained by conducting a series of dilutions, plating on selective or non-selective agar plates and incubating for a standard time and temperature. The number of cfu in the original sample is mathematically derived from the dilution series result. Expressed in units of cfu/g or cfu/ml.	This method provides a reliable estimate of the number of viable microorganisms in a sample and is widely accepted. It is relatively inexpensive and standardised. However results typically take 24-48 hours to obtain and may require additional confirmation testing for specific pathogens.
Enumeration	The determination of the number of viable microbes in a sample. The sample is prepared and then a portion tested using agar designed to grow a diverse or specific group of bacteria. Enumeration tests may also be carried out following a presumptive positive identification for the presence of a food safety pathogen, to determine the number of viable pathogen organisms in the sample i.e. a confirmed presumptive positive identification provides the qualitative result whereas enumeration provides the quantitative result.	Should be used when a number is required to meet the food safety limits set by the business. Bacterial growth is dependent on the agar used which contains specific nutrients, and the time and temperature use to grow the bacteria. In some cases, methods looking for the same bacterial group could give different results if different growth conditions have been used.
Most Probable Number (MPN)	MPN is a statistical method used to estimate the concentration of viable microorganisms in a sample by observing the number of positive growth responses in a series of dilutions. The MPN is the most likely concentration of viable pathogens in the sample.	Most Probable Number (MPN) methods are now rarely used for microbial testing due to concerns about accuracy and reliability. Where they are still applied, it is typically for soil and water analysis rather than for fresh produce or other food products. The result from an MPN method cannot be compared to a quantitative result from a plating method (i.e. cfu/g).
Polymerase Chain Reaction (PCR) methods	These methods are highly specific for a bacterial group or even species (i.e. *Salmonella enterica* or *L. monocytogenes*). After the sample has been incubated in a specific nutrient broth to increase the number of cells that might be present, a sample is prepared to detect DNA which is specific to the bacteria.	Highly sensitive and specific for the bacteria being tested. While PCR is highly sensitive and specific, it may detect DNA from non-viable bacteria, resulting in positive findings even when viable pathogens are no longer present. Additionally, presumptive positive results should be confirmed through isolation and culture (Figure C18.5). This is particularly important for STEC testing, where multiple virulence genes may be found across different *E.coli* strains (including non-pathogenic) in the same sample.

Term	Description	Advantages/disadvantages
Whole Genome Sequencing (WGS)	WGS analyses the entire DNA sequence of a microorganism to identify its exact strain, virulence genes, antimicrobial resistance and evolutionary relatedness to other isolates. Commonly used in outbreak investigations and source tracing.	WGS provides the highest level of genetic detail available for a microorganism. This method can link isolates from food and patients to identify contamination sources with high confidence. WGS is more expensive than routine microbiological testing and not typically used for routine monitoring. It may also detect non-viable organisms, similar to PCR, where results often need to be confirmed with culture. Given that WGS can provide such valuable insights it is recommended that, if there are cost or time barriers, the micro-organism is stored (by the testing laboratory) frozen to enable WGS to be carried out at a later date.
Presence/ Absence	Presence or absence tests are designed to detect whether a specific microorganism is present in a given sample (e.g. 25g), without estimating how many bacteria are present. These tests are often used for regulatory compliance, especially for pathogens like *Salmonella*, *Listeria* or *E. coli* O157:H7. Results are typically reported as 'Detected' or 'Not detected'	These tests are generally cost-effective, simple to perform and suitable for routine monitoring. A key limitation is that they do not quantify the level of contamination. If a positive result is obtained, additional testing may be required to confirm organism viability and to determine contamination levels through enumeration.
Presumptive positive	The words 'presumptive positive' on a test report mean the test has potentially found the pathogen present in the sample. However, further confirmation testing is required to determine whether the pathogen is alive or non-viable or if there may have been another similar bacteria present which was wrongly identified by the kit. If the 'presumptive positive' is confirmed a further enumeration test can be carried out to estimate population size.	All methods for pathogen testing will have an initial step, where a presumptive positive is the first alert of a potential problem.

The type and frequency of testing should be based on risk assessments, applicable regulations, assurance programme requirements and specific customer requirements.

Resources

Australasian Soil and Plant Analysis Council (ASPAC) (n.d.) *ASPAC website*.

Australian Pesticides and Veterinary Medicines Authority (APVMA) (n.d.) *APVMA website*.

Food Standards Australia New Zealand (FSANZ) (n.d.) *Safe Horticulture Australia: A guide to the primary production and processing standard for horticulture*.

Food Standards Australia New Zealand (FSANZ) (n.d.) *Australia New Zealand Food Standards Code – Schedule 27: Microbiological limits for food*.

Food Standards Australia New Zealand (FSANZ) (2025) *Compendium of microbiological criteria for food,* July.

Ministry for Primary Industries (MPI) (n.d.) *MPI website*.

CHAPTER 19

Managing Critical Incidents and Recalls

Overview

A critical incident is an event that disrupts normal operations and impacts production and/or the fresh produce supply chain. This may include natural disasters (e.g. floods, dust storms), criminal activities (e.g. sabotage), food fraud, or confirmed risk associated with the consumption of fresh produce (e.g. consumer or trade recall)

Being prepared for incidents means understanding your product and the risks that may occur during the event. It is not just a case of contaminated fresh produce, but also any equipment, facilities, packaging will need to be confirmed as safe and suitable for use.

This will require the review and adjustment of cleaning, sanitisation procedures and monitoring for physical, chemical (including allergen) and microbial contamination. Increased and targeted monitoring is likely to be required. Severe weather events such as flooding, fires and dust storms are becoming increasingly common. Therefore, the potential for food safety incidents caused by these events is increasing.

To manage such incidents effectively, businesses should develop, maintain and regularly test their Incident Management Plan (IMP). The IMP framework should outline procedures for effectively managing food safety incidents, ensuring consumer health and safety. The IMP should integrate with other business systems (e.g. HACCP, risk assessment, traceability, root cause analysis).

The key elements of an IMP include:

1. establish an Incident Management Team with clearly defined roles and responsibilities
2. identification and risk assessment of incidents [refer Chapter 3 and Appendix 1]
3. monitoring and reporting
4. traceability systems including hold and release management [refer Chapter 17]
5. recall and withdrawal management
6. effective stakeholder communication (e.g. regulatory agencies, peak industry bodies, customers, suppliers), certification body, assurance programme (e.g. SQF, GLOBALG.A.P., BRCGS, Freshcare, NZGAP, HARPS) and consumers
7. investigation (e.g. data collection, laboratory analysis and root cause analysis) [refer Chapter 18 and Appendix 1]
8. preparedness and training (e.g. annual system tests, practice implementation via simulation) and use lessons learned to update the IMP.

19.1 Establish an Incident Management Team

Develop an incident response team structure with defined roles. Assign backup people for each role to ensure coverage during absences or extended events. Include responsibilities for activating the plan, coordinating investigations, managing documentation/ communication and overseeing corrective actions. Ensure all team members are trained in their specific roles and they understand escalation protocols. Maintain a contact directory by mobile, email and after-hours contact details for internal and external stakeholders.

Image C19.1 | Develop an incident response team structure with defined roles.

19.2 Identification and risk assessment

Define clear criteria for what constitutes a food safety incident to initiate the IMP, outline potential scenarios. Establish early warning systems such as supplier alerts, customer complaints, audit findings, environmental monitoring and weather events. An incident management plan should be triggered when the incident is likely to impact food safety, compliance, legality or brand reputation.

The incident has clearly defined circumstances. No additional support is required beyond standard internal business procedures.

The incident is emerging and lacks clearly defined circumstances, with little likelihood of a resolution without external coordination (e.g. notify customers, regulatory authorities, peak industry bodies, certification body, assurance programme).

The incident is likely to pose a significant risk of reputational damage and attract media scrutiny. It may affect a single company, an entire industry or span multiple sectors. Additional external support may be required (e.g. media management, legal, broader industry coordination, multi-jurisdictional regulatory authorities, or engagement with the Fresh Produce Safety Centre).

19.3 Monitoring and reporting

Maintain a centralised incident log with times and dates documented, decisions made, actions taken and communications issued. Review investigation outcomes regularly to identify trends or emerging risks.

19.4 Traceability systems including hold and release management

Ensure traceability systems can identify affected produce. Define procedures for placing products on hold (e.g. physical segregation, system flags and signage) to prevent accidental release [refer Chapter 17].

19.5 Recall and withdrawal management

Adhere to documented recall and withdrawal procedures. Maintain records of all actions taken during recall and withdrawals, including quantities recovered and stakeholder responses. Establish criteria for product release following investigation, including verification of corrective actions and regulatory clearance.

Any fresh produce business legally defined as a ‘Food Business’ (e.g. grower, packhouse, wholesaler, has a legal requirement to have a written food recall plan in place and follow this plan in the event of a recall. Most customers also specify time frames around notifications and recalls.

The level of recall will depend on the food safety risk and if the product has been supplied to consumers. An immediate investigation should be conducted to determine the severity of the food safety risk, where and how much product is in the distribution system (i.e. based on your traceability records and the actions to be taken).

A trade recall is required when the produce has not been available for direct purchase by the public, such as produce sold to wholesalers and caterers or produce which has not yet been available for retail sale to the consumer. A consumer level recall is required when the produce has been available for retail sale to the public.

A withdrawal is when there is removal of produce from the supply chain without the requirement for regulatory notification, for example a food quality issue.

A product recall may be required in response to:

- government health authority notification of contamination
- customer complaint or feedback
- internal reviewing of records (e.g. spray records show incorrect rate was applied)
- non-compliant test results (e.g. chemical or microbial levels are exceeded)
- presence of undeclared allergens
- presence of foreign material (e.g. plastic, metal)
- intentional tampering or interference has occurred.

Fresh produce businesses should develop their own recall procedure and practice 'mock' recalls, including mass balance on one product supplied to any customer at least annually. All product should be accounted for within two hours. Mock recalls help businesses test their traceability systems, practice compiling relevant product information and prepare communications for suppliers, customers and food authorities. Such practice helps businesses ensure they are prepared to respond quickly and comprehensively to a recall event.

In the event of a recall, information on the affected product identification and its distribution may be recorded on the FSANZ Recall Report form, GS1 Recall and/or retailer online supplier portal forms.

Consumer level recalls are a collaborative effort between food authorities, retailers and the producer. Any official directions are required to be followed.

The business with primary responsibility for the recall is required to:

- notify the national, state or territory food authority where the head office of the business is located
- notify the Food Standards Australia New Zealand (FSANZ) Recall Coordinator (for Australia) or NZ Food Safety (for New Zealand)
- notify your certification body and your relevant assurance programme (e.g. SQF, GLOBALG.A.P, BRCGS, Freshcare, NZGAP, HARPS)
- obtain and consolidate all necessary information about the affected produce
- determine the level of recall required (i.e. consumer or trade level recall)
- notify all trade customers, including any overseas customers about the recall
- notify the public by point-of-sale notices in stores, website announcements, social media notifications and/or press advertising to ensure as many consumers as possible are informed of the recall
- retrieve unsafe produce from the supply chain including from retail sale
- dispose of the unsafe produce, ensuring it does not re-enter the supply chain
- monitor the effectiveness of the recall
- keep records of all relevant information and actions concerning the recall
- report on outcome of the recall to FSANZ (for Australia) or NZ Food Safety (for New Zealand), including corrective action taken to prevent a recurrence of the hazard.

Fresh produce businesses are required to develop their own recall procedure and practice 'mock' recalls.

The impacted business, regulators and those selling produce to consumers notify the public by point-of-sale notices in stores, website announcements, social media notifications and/or press advertising to ensure as many consumers as possible are informed of the recall.

19.5.1 Regulatory Guidance and Support

Further information and business resources for product recall are available from both Food Standards Australia New Zealand (FSANZ) and New Zealand Food Safety at the Ministry for Primary Industries (MPI).

Australia:

FSANZ provides guidance to food businesses and enforcement agencies on how to conduct a food recall.

This includes:

- the Food Industry Recall Protocol, which outlines legal obligations and steps for conducting a recall
- templates for recall plans, communication notices and recordkeeping
- guidance on roles, responsibilities and best practices during a recall event.

Businesses are encouraged to familiarise themselves with these resources to ensure compliance with relevant Australian food laws and to support timely and effective recall action.

Telephone: (02) 6271 2222
Email: food.recalls@foodstandards.gov.au

New Zealand:

New Zealand Food Safety provides step-by-step guidance and templates to support food businesses in preparing for and managing recalls. This includes:

- a Recall Guidance Document outlining legal obligations under the Food Act 2014
- templates for developing recall plans, internal checklists and communication tools
- advice on preparing recall risk assessments and managing public communication.

New Zealand businesses are encouraged to ensure their plans meet regulatory requirements and are tested regularly through mock recalls.

Telephone: 0800 00 83 33
Email: food.recalls@mpi.govt.nz

19.5.2 Who should be involved in a recall decision?

Senior team management should be involved in the decision, along with team members from operations, marketing, communications, sales and distribution. Effective cross-functional coordination is critical to managing a timely and accurate recall.

19.6 Effective stakeholder communication

Document a communication plan that identifies who needs to be informed, when and by whom, covering internal teams, regulators, customers, suppliers, certification body, assurance programme and consumers. Prepare pre-approved messaging templates for different incident types (e.g. flood contamination, allergen exposure). Maintain a contact directory by mobile, email and after-hours details for internal and external stakeholders. Assign trained spokespersons for media and regulatory engagement. Document all communications issued, including timing, recipients and responses received. Include protocols for managing misinformation, media inquiries and public reassurance.

19.7 Investigation

Outline procedures for initiating investigations (e.g. data collection methods, team member interviews, supplier documentation). Include procedures for sample collection, retention and laboratory analysis. Conduct root cause analysis using structured tools (e.g. fishbone diagrams, 5 Whys) [refer Appendix 1] to identify underlying issues. Document findings, corrective actions and preventive measures. Share investigation outcomes with relevant stakeholders and use them to update risk assessments and training materials.

19.8 Preparedness and training

Schedule mandatory training for all team members on incident identification, response roles and communication protocols. Conduct system tests at least annually, including mock recalls, scenario-based simulations and desktop exercises. Evaluate test outcomes to identify gaps in response, communication or documentation.

Use lessons learned to update the IMP, training content and operational procedures. Maintain training records, including attendance, content covered and assessment results. Encourage a culture of continuous improvement and readiness across all levels of the business.

19.8 Example flooding incident

Flooding is the flowing or overflowing of a field with water outside a grower's control. Pooled water (e.g. after significant rainfall) that is not reasonably likely to cause contamination of the edible portion of fresh produce is not considered flooding.

Image C19.2 Severe weather event, resulting in flooding.

The risk assessment should consider:

- source of flood water (e.g. runoff from adjacent land use, overflow from rivers or canals or pooling from rainfall)
- crop type and if the edible portion of the crop is likely to have contacted flood water (e.g. spinach/lettuce close to ground versus broccoli/cauliflower elevated on stalks)
- stage of growth for example (i.e. young plants with no edible portion versus mature crops close to harvest)
- testing results including water sources and soil
- direct and indirect contact of:
  - » soil and stored soil amendments [refer Chapter 6]
  - » water sources and distribution systems [refer Chapter 7]
  - » protective clothing [refer Chapter 14]
  - » vehicles [refer Chapter 12]
  - » equipment, including harvesting equipment [refer Chapter 10]
  - » buildings, including stores, cold rooms and packing facilities [refer Chapter 9].

The risk management in flood situations may include:

- identifying and clearly marking flood-affected zones (e.g. using flags)
- establishing a minimum 10 metre buffer zone between flood-affected and unaffected crops
- identifying upstream or nearby sources of contamination (e.g. livestock operations, septic systems)
- avoiding movement of people and equipment between flooded and non-flooded areas. Where movement is unavoidable, implementing hygiene controls to prevent cross-contamination

- discarding crops where the edible portion has been in direct contact with flood water or may have been indirectly contaminated
- where the edible portion was not in direct contact with floodwater, seek advice from regulators and food safety experts
- conducting tests for faecal indicators and pathogens if relevant on agricultural water after floodwaters have subsided [refer Appendix 4]
- the cleaning and sanitising of potentially contaminated equipment and facilities
- where risk assessment determines a crop can be harvested, test crop for faecal indicators and pathogens, seek advice from technical experts and regulators [refer Appendix 4]
- delay replanting flood-affected fields until the soil has returned to its normal moisture levels and a minimum of 60 days has elapsed after floodwaters have subsided. This wait period can be shortened through microbiological testing that confirms that the microbial loading has returned to 'normal' [refer Chapter 18].

19.9 Good practice for managing critical incidents and recalls

Table C19:1 | Summary of good practices for managing critical incidents and recalls.

Management area	Good practices
Establish an Incident Management Team with clearly defined roles and responsibilities	Establish an incident team with clear roles and back up person. Train all team members for their roles and responsibilities. Maintain a contact list for internal and external stakeholders.
Identification & Risk Assessment	Define incident criteria and outline potential scenarios. Identify early warning systems e.g. weather events, supplier alerts, customer complaints. An incident management plan should be triggered when the incident is likely to impact food safety, legality or brand reputation.
Monitoring and Reporting	Maintain a centralised log, including decisions, actions and communications. Review outcomes to identify trends and emerging risks.
Traceability systems including hold and release management	Ensure traceability system can isolate affected produce [refer Chapter 17]. Define hold procedures (e.g. signage, stock control).
Recall and withdrawal management	Follow documented recall and withdrawal procedures and record all actions. **Australia:** Telephone: (02) 6271 2222 Email: food.recalls@foodstandards.gov.au **New Zealand:** Telephone: 0800 00 83 33 Email: food.recalls@mpi.govt.nz Practice 'mock' recalls including mass balance on one product supplied to any customer, at least annually.
Effective stakeholder communication	Develop a communication plan. Identify who, when and how to inform stakeholders. Maintain a contact list for external stakeholders. Assign a trained spokesperson for the business with media training, who has been briefed on the facts.

Management area	Good practices
Investigation	Initiate investigations with structured data collection and analysis using (e.g. 5 Why's, fishbone) [refer Appendix 1]. Include sampling and laboratory requirements [refer Chapter 18]. Implement corrective actions.
Preparedness	Conduct training and systems test for mock incident and recall, at least annually. Evaluate and update the IMP based on lessons learned. Maintain training records. Promote a culture of readiness.

Resources

Food Standards Australia New Zealand (FSANZ) (2024). *Safe Horticulture Australia: A guide to the Primary Production and Processing for Horticulture*. 1st ed. Canberra: FSANZ.

Food Standards Australia New Zealand (FSANZ), n.d. *Food Industry Recall Protocol*.

GS1 (2024). *Fresh Fruit and Vegetable Traceability Guideline*.

Horticulture Australia Limited (HAL) (2013). *Horticulture Industry Crisis Management Guidelines*. Version 1. Sydney: HAL.

HortNZ (2023) a. *Grower decision tree for flood-affected produce*.

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Ministry for Primary Industries (MPI) (2023). *Guidance for harvesting flood-affected produce for human consumption*.

Ministry for Primary Industries (MPI), n.d. *Food Recalls and Warnings*.

National Emergency Management Agency (2020). *Coordinated Incident Management System (CIMS), third edition*.

NSW DPI (2023). *Managing floodwater associated food safety risks in melon production and postharvest handling*. Primefact PUB 23/1340.

U.S. Food and Drug Administration (FDA) (2011). *Guidance for industry: Evaluating the safety of flood-affected food crops for human consumption*.

CHAPTER 20
Food Safety Culture

Overview

A mature food safety culture ensures that every team member from leadership to frontline teams prioritise safe practices consistently and not just when someone is observing (e.g. management, auditors). It protects consumer health and fosters accountability and continuous improvement. Food safety becomes second nature, businesses build trust, meet regulatory requirements, meet food safety standards and create a resilient foundation for long-term success.

A mature food safety culture level is attained when everyone within your business:

- understands why food safety is important and
- consistently applies practices that collectively reduce the presence of hazards and likelihood of produce being contaminated.

There are various definitions of food safety culture that assist in describing its relevance to fresh produce businesses.

Food Standards Australia New Zealand (FSANZ) defines food safety culture in a business as '... how everyone (owners, managers, employees) thinks and acts in their daily job to make sure that the food they make or serve is safe for human consumption'.

The Global Food Safety Initiative (GFSI) defines food safety culture as 'shared values, beliefs and norms that affect mindset and behaviour toward food safety in, across and throughout an organisation'.

Another definition that accounts for the effort and time commitment in food safety culture improvement is '*...a long-term construct existing at the organisational level relating to the deeply rooted beliefs, behaviours and assumptions that are learned and shared by all employees which impact the food safety performance of the organisation'. (Sharman et al., 2019).*

All businesses have a food safety culture at a particular level of maturity. A common understanding of what a food safety culture is supports businesses to assess, measure, develop and sustain the continual improvement of its food safety culture. A mature food safety culture is evident when all team members consistently uphold safe practices, regardless of workload, production pressure or supervision.

20.1 How to develop a mature food safety culture

Team members perform their best when they have adequate time and resources to carry out their responsibilities. Table C20:1 outlines the key resource requirements, along with practical examples that support and strengthen improvements in food safety culture.

Image C20:1 | Hold regular toolbox meetings focused on food safety and quality to engage team members in daily practices.

A mature food safety culture is evident when all team members consistently uphold safe practices.

Table C20:1 | Key resources that support food safety culture improvements, along with the responsible team members are outlined with examples illustrating how each contributes to positive cultural change.

Resources	Personnel	Examples
Management leadership and commitment	Board / management	Food safety culture and food safety updates are an agenda item for all board and management meetings, sending the message that food safety is a top priority.
Time	Operations, technical	Required skills are identified and planned for. Sufficient time to perform critical tasks such as cleaning and sanitising encourages team members to follow procedures.
Financial	Management, operations, technical	When financial pressures place food safety controls at risk, open communication of the need to balance priorities can lead to teamwork and innovative solutions.
Infrastructure/ Equipment	Management, operations	Maintaining buildings and equipment in good condition provides a safer working environment, makes team members feel valued and conveys the importance of preventing contamination.
Research	Management, technical	Engagement with research increases knowledge and risk awareness.
People	Management	Knowledge, skills and compliance all depend on employing the right number and type of people for the business. Identifying team members as food safety champions or ambassadors helps keep food safety front of mind.
Communication	Management, operations, technical	Communicating root causes of incidents and failures to help improve attitudes. Regular discussion about food safety builds confidence in raising concerns. Pass information on potential increased risk through the supply chain to build awareness, trust and enable better risk management in specific circumstances.
Team members feedback and engagement	Management, operations, technical, team members	Utilise suitable communication channels to receive and act on team members' food safety feedback. Engage team members in decision making and problem solving.

Resources	Personnel	Examples
Training	Management, operations, technical	Keep training positive and fun to encourage enthusiasm to do the right thing. Use stories to make food safety relevant to team members' lives as consumers. Short, regular sessions with one key message enhances knowledge retention. A 'buddy' system for new or returning team members helps consistency in food safety behaviours and builds confidence and trust.
Information access	Management, operations, technical	Share Fundamental Guidelines for Fresh Produce Food Safety with team members. Share Quick Guides for Fresh Produce Food Safety with team members. Use posters, photographs and cards as reminders of the right food safety behaviours at workstations and other key areas. Provide learnings from outbreaks, incidents, and near misses which increases knowledge about risks and their management.
Regulatory support	Management, operations, technical	Use of materials available from FSANZ, state departments and local government provides clarity of expectations.
Alignment of government and customer requirements	Management, technical	Encourages a supply chain approach to food safety culture improvement and enhances understanding.
Technology	Management, operations, technical	Technology improvement motivates team members. Helps make tasks easier which increases compliance.
Clarity in company guidelines	Management, technical	Promotes understanding of why food safety is important. Encourages compliance and taking responsibility.

20.2 Measuring food safety culture

A business's food safety culture maturity can be measured through various methods, with key focus areas typically including:

- team members' understanding of hazards and risks
- level of communication across teams and individuals
- operational conditions, including resource adequacy, timeliness and flexibility
- observable behaviours that reflect compliance with company procedures, regulations and food safety standards
- positive attitudes toward feedback, inclusion in decision-making and accountability
- emphasis on food safety priorities such as people, training and health & safety
- adoption of technology, tools and resources to drive continuous improvement.

Image C20:2 | Acknowledging team members as food safety champions or ambassadors helps keep food safety front of mind.

The FSANZ website offers food safety culture assessment examples and by monitoring food safety culture through tools like questionnaires, interviews and compliance data (Table C20.2), businesses can establish benchmarks, prioritise improvements and enhance food safety culture through targeted training and communication.

Table C20:2 | Aspects of food safety management system that can inform assessments of food safety culture maturity.

Aspects of FSMS and management requirements	Examples of outputs that can demonstrate food safety culture improvement
Records	The trends of physical, chemical (including allergen) and microbiological results being reviewed demonstrate compliance with and effectiveness of food safety controls (e.g. cleaning and sanitising, pesticide use and wash water control). Good record keeping and team members understanding the reason behind keeping accurate records, demonstrates commitment and responsibility. Effective traceability systems demonstrate transparency and commitment to regulatory compliance.
Training	Discussion, workshopping and test outcomes show: • level of risk awareness • understanding of food safety requirements for specific tasks • commitment to teamwork.
Verification	Monitoring and documenting trends in hygienic practices such as handwashing can demonstrate risk awareness, team member responsibility and willingness to comply.

Aspects of FSMS and management requirements	Examples of outputs that can demonstrate food safety culture improvement
Communication	An increase in the number of team members prepared to: • speak up about food safety • report incidents • provide ideas for improvement. Visual reminders of good practices at workstations supports supervision and compliance. A daily/weekly key food safety message that is monitored and reported promotes common purpose. A policy to inform customers of incidents requiring adjustments in controls indicates understanding, commitment, responsibility and food safety priorities.
Internal audits	Reduction in the number of corrective actions demonstrates commitment to following SOPs. Timeliness in closing audits and correcting non-conformances illustrates priority is given to improving food safety. Inclusion of visual assessment of practices provides opportunity for instant feedback and correction. Compliance assessments for approved suppliers directly affecting food safety increases risk awareness and encourages supply chain communication.
Customer complaints, withdrawals and recalls	Reduction in complaints illustrates improved compliance with food safety controls and practices. Absence of or reduction in withdrawals and recalls indicates effective corrective actions and compliance improvement.
Root cause analysis	Documenting trends in results and implementing solutions provides encouragement and instils team member responsibility. Determining behaviours that need to improve and implementing triggers to enhance demonstrates priorities and commitment.
Team member turn over	Improvement in team member retention indicates a workplace with common purpose, teamwork, reward for effort and clarity of expectations.
Quality targets in production	Improvements in product quality metrics demonstrate commitment to compliance with quality control points.

20.3 Food safety objectives

Food safety objectives set realistic performance targets that drive team motivation, clarify cross-departmental roles and promote continuous improvement by strengthening awareness, understanding and compliance within available resources.

Examples of Food Safety Objectives that indicate food safety culture improvement include:

- X% reduction in customer complaints within six months
- X% reduction in team member resignations within twelve months
- X% reduction in corrective actions at each internal audit
- Zero chemical residue breaches detected in product within twelve months.

Image C20:3 | The FSANZ Food Safety Questionnaire is designed to support businesses in assessing and strengthening food safety culture.

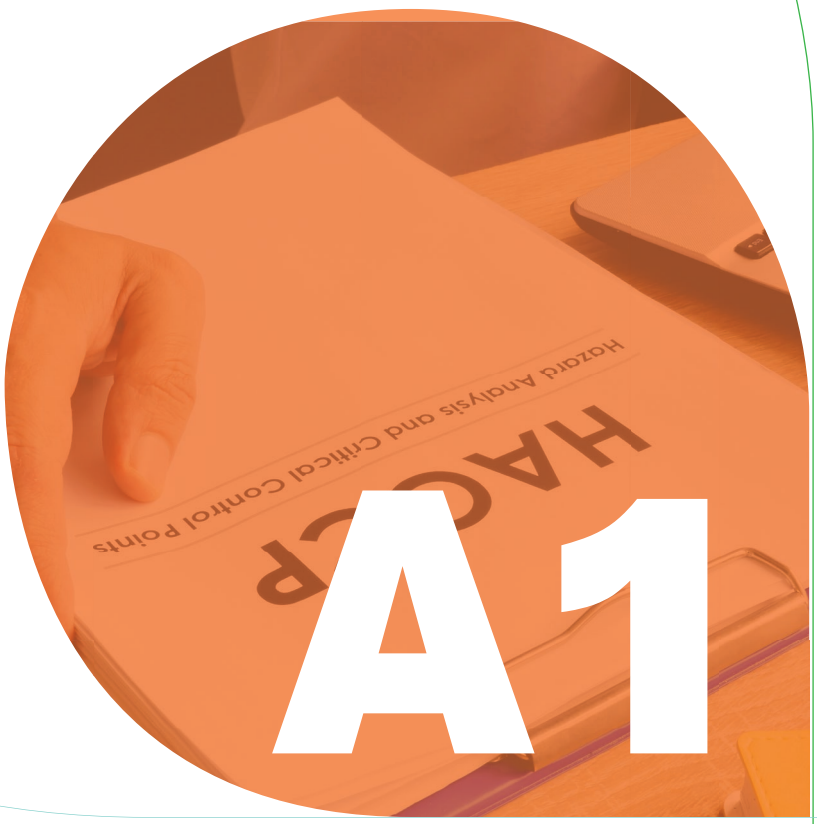
20.4 Good practice for food safety culture

Table C20:3 | Summary of good practices for food safety culture.

Management area	Good practices
Motivate team members	Identify food safety champions and empower teams in decision making. Design the working environment and equipment to encourage the right food safety behaviours. Develop a reward and recognition program. Develop team member retention initiatives to reduce turnover rate and increase employee engagement. Provide an environment of support from colleagues and management.
Food safety objectives	Establish food safety objectives and targets. Analyse data trends to identify strengths and weaknesses in the food safety management system. Align investment with food safety objectives. Encourage cross-functional collaboration.
Provide a clear statement of responsibilities	Ensure food safety culture responsibilities and accountabilities are outline for each role within the business. Include the reason the responsibility for each role is required. Provide opportunity for team members to plan their activities for the day.
Leadership presence	Visual leadership presence through role modelling, active engagement and consistent reinforcement of food safety values (e.g. GEMBA walks). Consider frontline team members' engagement and impact when implementing food safety changes.
Near misses	Record and analyse food safety near misses. Include human psychosocial factors (e.g. workload, role clarity, motivation, job control, team dynamics) and external social factors within RCA's investigations.

APPENDIX 1

Food Safety Management Systems



Overview

A food safety management system (FSMS) is a structured documented framework designed to identify, control and mitigate food safety hazards within a business's operations. The primary objective is to prevent contamination, reduce its impact when it occurs and prevent any increase in contaminants during the growing and production process. Food safety risks can occur through multiple pathways, as outlined in Figure A1.1. An effective FSMS implements controls to manage potential food safety risks in fresh produce, ensuring the integrity of the product and safety of consumers.

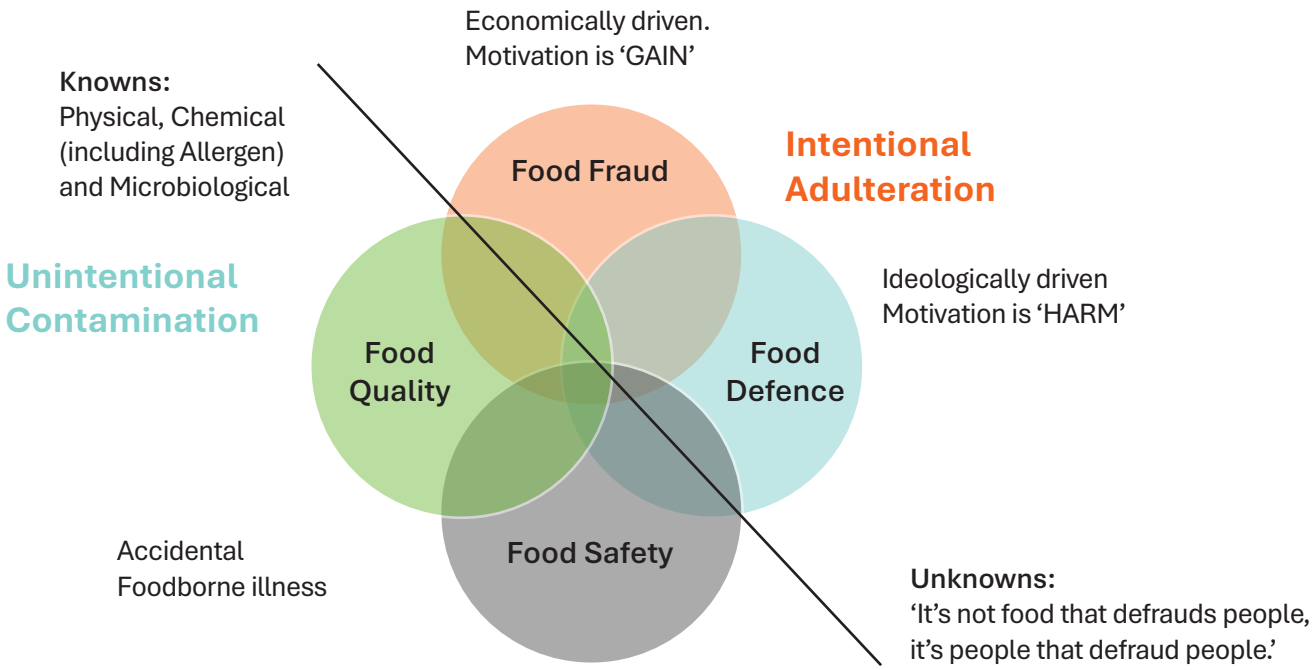


Figure A1:1 | Summary of food risk types and causes adapted from GFSI Position Paper on Food Fraud (2014).

A1.1 Hazard analysis and critical control point (HACCP) system

HACCP shifts control from reliance on end-point produce testing (i.e. prevent, eliminate or reduce hazards to an acceptable level). While some end-point verification testing remains necessary, the primary focus is on proactive management (i.e. the effective control of day-to-day potential hazards within a HACCP system is supported by prerequisite practices). These practices establish the fundamental environmental and operational conditions required for the production of safe produce, examples include:

- Good Agricultural Practices (GAP) for cultivation
- Good Hygienic Practices (GHP) for preharvest and postharvest handling

The cross functional HACCP team members should have sufficient working knowledge of the process, the product and the likely hazards to be able to contribute to the development and maintenance of the HACCP plan. Prior to commencing the hazard analysis, it is necessary to describe the product, identifying intended use or users and process (i.e. state the start and end points and define the hazards to be considered) [refer Chapter 3]:

- physical (e.g. wood, stones)
- chemical including Allergen (e.g. natural toxins, heavy metals, peanuts, soy)
- biological (e.g. microbiological - *Salmonella, Listeria)*

A food safety management system (FSMS) is a structured framework designed to control food safety hazards within a business's operations.

The process flow diagram should cover all relevant steps of the operation. Each step in the process should be numbered and clearly identify any inputs (e.g. ice, packaging), rework and outputs (e.g. waste). The HACCP team is responsible for verifying that the flow diagram accurately represents the process, which is typically achieved by walking through the operation from start to finish.

The seven principles of HACCP:

1. conduct a hazard analysis and identify control measures
2. determine the critical control points (CCPs)
3. establish validated critical limits
4. establish a system to monitor control of CCPs
5. establish corrective actions to be taken when monitoring indicates a deviation from a critical limit at a CCP has occurred
6. validate the HACCP plan and then establish procedures for verification to confirm that the HACCP system is working as intended
7. establish documentation concerning all procedures and records appropriate to these principles and their application.

Hazard analysis consists of identifying potential hazards and evaluating these hazards, which involves evaluating the potential severity, likelihood and overall significance of risk for each identified hazard within the business's operational processes. The scoring system is one approach to determine the significance of a hazard, assigning scores for severity and likelihood and multiplying together. Figure A1:2 provides an examples of a five point scoring systems. This calculation establishes whether a risk is classified as significant (i.e. requiring controls) or not significant. The severity of many food safety hazards are known. It is the likelihood of hazard occurrence that many fresh produce businesses need to determine.

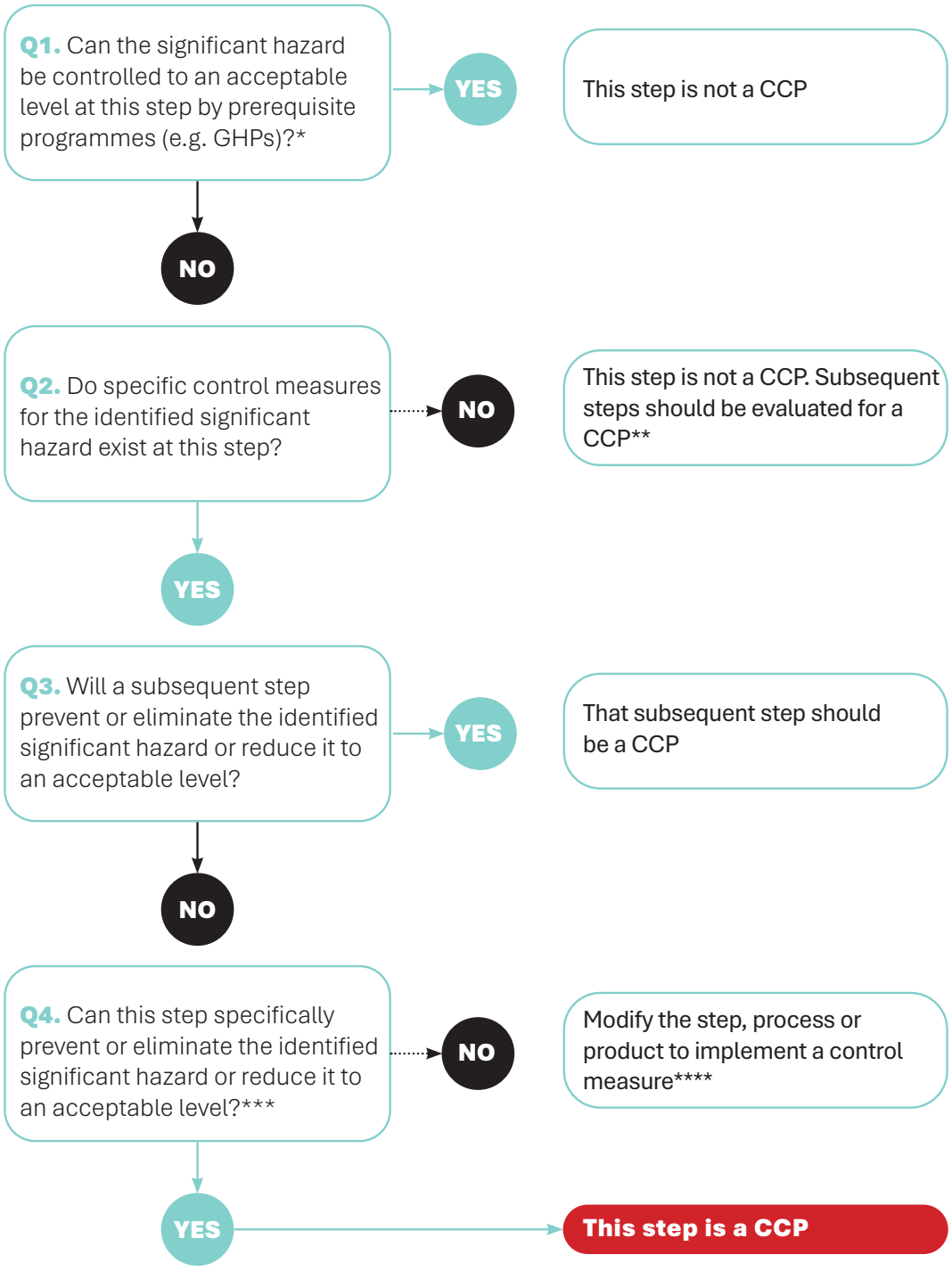
Likelihood	
1	Improbable event (once every 5 years)
2	Remote possibility (once per year)
3	Occasional event (once per month)
4	Probable event (once per week)
5	Frequent event (once per day)

Severity	
1	Not significant
2	Customer complaint
3	Product recall
4	Serious illness
5	Fatality

5x5	Likelihood				
Severity	**1**	**2**	**3**	**4**	**5**
5	5	10	18	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Figure A1:2 | Example food safety 5x5 risk matrix.

The next action for the HACCP team is to consider what control measures can be applied to each significant hazard. Control measures are those actions that are required to prevent, eliminate or reduce the occurrence of the hazard to acceptable levels. The identification of a CCP for a control of a hazard requires a logical approach, this maybe aided by a decision tree (Figure A1:3).



* Consider the significance of the hazard (i.e. the likelihood of occurrence in the absence of control and the severity of impact of the hazard) and whether it could be sufficiently controlled by prerequisite programmes such as GHPs. GHPs could be routine GHPs that require greater attention to control the hazard (e.g. monitoring and recording).

** If a CCP is not identified at questions 2–4, the process or product should be modified to implement a control measure and a new hazard analysis should be conducted.

*** Consider whether the control measure at this step works in combination with a control measure at another step to control the same hazard, in which case both steps should be considered at CCPs.

**** Return to the beginning of the decision tree after a new hazard analysis.

Figure A1:3 | CCP decision tree (FAO and WHO, 2023).

Critical limits establish whether a CCP is in control and in doing so separates acceptable products from unacceptable products. Critical limits should be measurable (e.g. contact time and chemical concentration) and scientifically validated to provide evidence that are capable of controlling hazards to an acceptable level, if properly implemented.

Monitoring is a planned sequence of measurements or observations at a CCP relative to the defined critical limits. The monitoring system and frequency should be capable of timely detection of any failure to remain within critical limits, to allow timely isolation and evaluation of affected produce.

Specific written corrective actions should be developed for each CCP in the HACCP system. Corrective actions taken in response to a deviation should ensure the CCP is brought back under control and that any potentially unsafe produce is appropriately managed to prevent produce from reaching consumers. Any CCP deviation should be investigated and timely remedial action taken.

Process step	CCP no.	Significant hazards and cause/ source	Control measures	Critical limit	Monitoring (what, how, when & who)	Corrective action	Verification activities	Records

Figure A1:4 | Example of a HACCP worksheet adapted from the FAO and WHO, 2023.

The HACCP plan should be validated prior to implementation. The main objective of validation is to ensure that the hazards identified in the study are complete and correct and that selected controls and frequency of monitoring of these hazards are suitable. Validation could include review of scientific literature, using mathematical models, conducting trials and/or using guidance developed by authoritative sources.

After the HACCP system has been implemented, procedures should be established to confirm the HACCP system is working effectively. Verification activities included observation, internal and external auditing, calibration of equipment, analysis of customer complaint trends, targeted sampling/testing and systematic record review. Verification should be carried out by someone other than the person who is responsible for preforming and monitoring and completing corrective actions.

HACCP team members should be trained, at least annually in HACCP principles to ensure they understand food safety hazards and their role in developing, implementing and maintaining a food safety management system.

Accurate record keeping is essential to the successful application of HACCP. Examples of HACCP documentation include:

- HACCP team composition
- pre-requisites programmes
- HACCP plan
- CCP monitoring
- CCP deviations and corrective actions
- root cause analysis reports
- verification procedures performed
- HACCP team member training.

A1.2 Root cause analysis

When a food safety control failure occurs, the root cause should be identified so that further failures can be prevented. Always start by creating a clear, concise problem statement. Records, data trends, customer complaints or a food safety incident may alert the business to loss of control in the FSMS. For example, equipment failures, out- of-specification produce or training deficiencies all have a root cause that will need to be addressed. There are various methods to undertake root cause analysis such as the Ishikawa (Fishbone) technique that assesses the effects of people, equipment, materials, methods, environment, and measurement on a problem (Figure A1.5) and the "5 Whys" technique (Figure A1.6). Each method provides root cause analysis, informs preventative controls and contributes to continuous improvement.

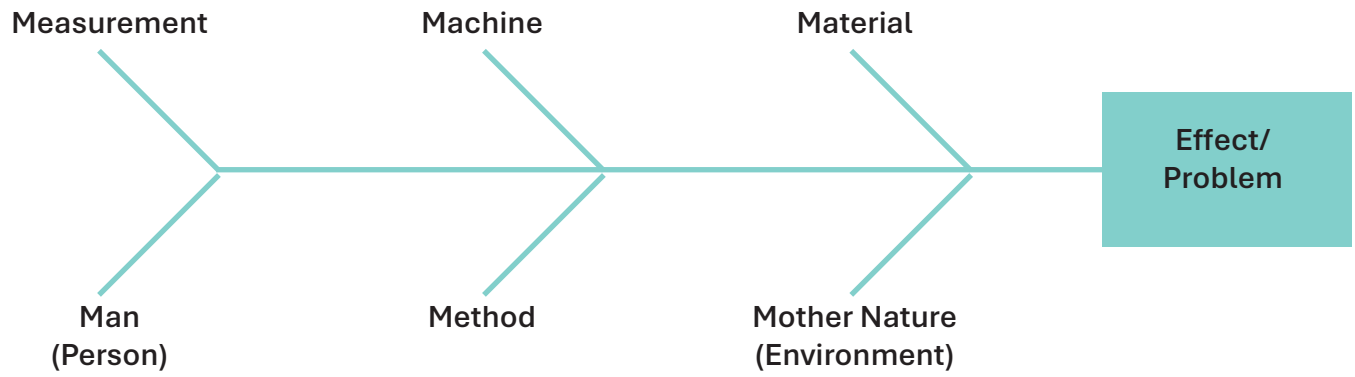


Figure A1:5 | Ishikawa (Fishbone) leading to root cause of a problem.

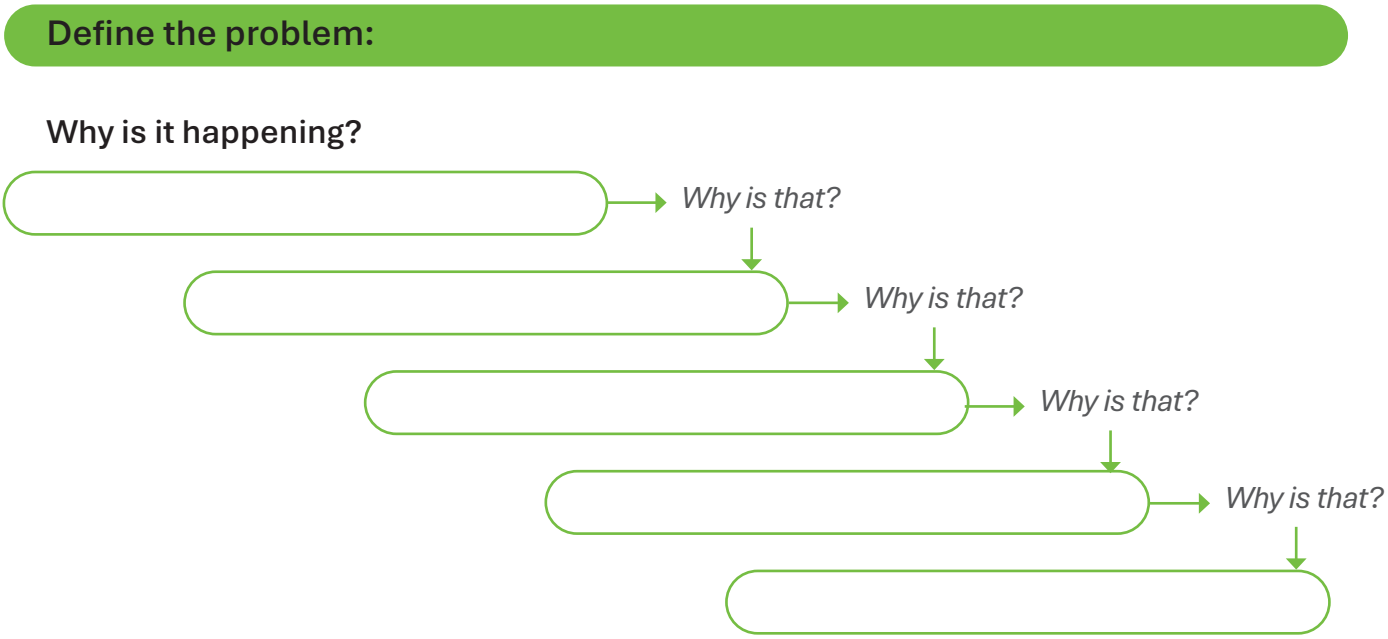


Figure A1:6 | The 5-Whys leading to root cause of a problem.

A1.3 Food defence

While GAP and HACCP are concerned with food safety hazards that can be unintentionally introduced, there are other risks related to intentional threats/attacks aimed at causing harm to consumers, businesses or disrupting the supply chain. Procedures and activities to control such threats are food defence measures.

As defined by the Global Food Safety initiative (GFSI), food defence is: 'the process to ensure the security of food, food ingredients, feed or food packaging from all forms of intentional malicious attack including ideologically motivated attack leading to contamination or unsafe product'.

Attacks can vary in their impact, potentially affecting public health, consumer confidence and business. Attacks come in different forms, for example, malicious contamination, extortion and cybercrime. One example is the intentional introduction of needles into strawberries sold in Australia and New Zealand in 2018.

Attackers can be an organised criminal, a disgruntled individual including disgruntled employee or ex- employee, an extremist, extortionist or a cybercriminal. For instance, a disgruntled team member might attempt to introduce harmful substances onto fresh produce or an external attacker might seek to disrupt a company's operations by tampering with packaging or raw materials.

Controls to mitigate such threats include:

- restricting access to sensitive areas
- securing the site using fences
- installing lights and surveillance and alarm systems
- implementing tamper-evident seals on packaging
- using suitable information system and network controls.

Food defence threat assessment can be conducted using appropriate methods, such as a simple risk matrix to prioritise measures aimed at reducing the risk of intentional attacks or at least detecting them before a food safety incident occurs.

Creating awareness across the business, especially among key team members on-site ensures that everyone understands the importance of these measures. Awareness training and clear communication about reporting suspicious activities, recognising potential threats and responding effectively can significantly strengthen a company's ability to prevent or at least detect food defence attacks. By fostering a culture of vigilance and continuous improvement, businesses in the fresh produce industry can reduce threats and ensure a more secure supply chain [refer Chapter 20].

A1.4 Food fraud prevention

Food Fraud is another aspect that HACCP and GAP is not designed to control.

According GFSI, food fraud is 'A collective term encompassing the deliberate and intentional substitution, addition, tampering or misrepresentation of food, food ingredients, feed, food packaging or labelling, product information or false or misleading statements made about a product for economic gain that could impact consumer health'.

It involves deliberate deception for economic gain. Fraudulent activities, such as substitution, mislabelling, counterfeiting or dilution, can undermine consumer trust and safety.

Food fraud incidents vary widely. Examples include:

- mislabelling lower grade produce as premium
- bulking a commodity with a similar commodity of lesser value
- using false certifications to sell non-compliant goods
- selling diluted or counterfeit pesticides.

Such actions can lead to reduced consumer confidence, economic losses and in some cases, direct harm to public health. Food fraud can also introduce allergens to a product (e.g. the addition of ground peanut and almond shells to ground cumin).

Those committing food fraud may include dishonest suppliers, organised crime groups or individuals within the supply chain. For example, a supplier might knowingly provide substandard packaging or fertilisers and misrepresent them as compliant or a dishonest trader may falsify documentation to sell goods that do not meet regulatory or safety standards.

Preventive measures against food fraud include:

- establishing supplier approval and monitoring processes
- conducting regular audits and authenticity testing
- verifying supplier certifications
- maintaining full traceability of products and materials
- product authentication systems
- traceability solutions
- data analysis techniques to identify and deter fraudulent activities.

Raising awareness among team members about the risks of food fraud and how to detect signs of it is equally important. Ongoing training, clear reporting channels and transparent communication encourage team members to speak up if they encounter questionable practices [refer Chapter 20]. Collaborating and exchanging information among growers about suppliers, fraud incidents and effective preventive measures fosters a collective protection against food fraud across the entire industry. By integrating these prevention efforts into their operations, businesses in the fresh produce industry can protect their brands, maintain consumer trust and help ensure a fair and secure market.

Resources

British Standards Institution (BSI), (2017). PAS 96: *Guide to protecting and defending food and drink from deliberate attack*. London: BSI.

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APPENDIX 2

Food Safety Regulations and Assurance Programmes

Overview

The food safety framework in Australia and New Zealand comprises a combination of mandatory and voluntary standards designed to mitigate risk, demonstrate compliance and enable adoption of industry good practice. Figure A2:1 illustrates the hierarchy of mandatory and voluntary food safety standards in Australia and New Zealand. The base represents the regulatory framework, including national legislation, Food Acts, and biosecurity laws (includes food safety requirements in Australia), which establish the legal food safety requirements. Above this, the Food Standards Australia New Zealand (FSANZ) Food Standards Code, including Primary Production and Processing Standards for Australia defines specific compliance obligations. The second level comprises voluntary food safety assurance programmes, often driven by customer or market access, exceeding regulatory requirements. Industry guidance and good practice resources support compliance and continuous improvement. Together, this framework demonstrates the interaction of government regulations, food safety standards and assurance programmes ensuring fresh produce safety.

A2.1 Interdependent roles in fresh produce food safety

The fresh produce food safety system in Australia and New Zealand relies on a coordinated network of stakeholders collaborating on food safety, regulatory compliance and market access, including:

- producers
- regulatory agencies
- industry bodies
- assurance programmes
- retailers and wholesalers
- researchers.

Food safety laws, standards and guidelines are enforced by regulatory authorities, including the Ministry for Primary Industries (MPI) in New Zealand, state and territory food authorities, and local councils to protect public health. FSANZ sets standards that these authorities then implement and enforce. Regulators collaborate with industry bodies and assurance programmes to align voluntary food safety standards with regulations promoting a harmonised approach and also manage food recalls and outbreak investigations.

Peak Industry Bodies (PIBs) and Produce Groups serve as intermediaries between government agencies and business, advocating for industry interests and members, through the development of good practice frameworks, coordinated research and practical guidance. They often collaborate with research institutions to strengthen scientific understanding of emerging food safety risks.

Producers and post-harvest operators, including growers, packhouses, processing facilities and cold storage providers, are responsible for implementing food safety management systems on farm and post-harvest stages. Compliance with good agricultural practices (GAP), Good Manufacturing Practices (GMP) and risk-based hazard control is essential for maintaining food safety. Participation in voluntary assurance programmes supports compliance and aligns with market and regulatory expectations.

Retailers and wholesalers require fresh produce suppliers to meet stringent food safety standards, often exceeding regulatory requirements. Many implement assurance programmes aligned with internationally recognised certification framework such as the Global Food Safety Initiative (GFSI), to ensure consistent food safety standards across the supply chain.

This appendix supports the fresh produce industry in understanding food safety regulatory obligations.

Research institutions and academic organisations with industry, play a vital role in developing evidence-based food safety policies and risk management strategies. Their scientific research informs regulatory decision and supports industry response to emerging food safety risks.

Independent certification bodies and accredited laboratories help ensure fresh produce businesses meet regulatory and voluntary food safety standards. Auditors verify compliance across the supply chain, while labs test for microbiological and chemical (including allergen) risks to validate control measures.

Australia and New Zealand's fresh produce safety framework, driven by collaboration across regulators, industry, researchers and supply chain partners aims to minimise food safety risks, builds consumer trust, and support market access through continuous improvement.

A2.2 Overview of Australian and New Zealand food safety legislation

A range of agreements and laws set out how the joint food regulation system works. The food standards are given legal effect by the food law in New Zealand and the state and territory food laws in Australia. Key legislative documents for food safety are outlined on the Food Regulation website and include the model food provisions, which serve as the basis for state and territory Food Acts. These Acts give legal effect to the Food Standards Code, noting there is some variation between jurisdictions in how standards are incorporated into law.

A2.2.1 Food Standards Australia New Zealand (FSANZ)

The governance of FSANZ is outlined in its Governance framework 2023, which specifies the policy, legal, and operational structures that enable effective agency oversight. FSANZ operates under an intergovernmental agreement between the Australian Government, New Zealand Government, and Australian States and Territories. This agreement fosters a cohesive food regulatory system across both countries. Regular reviews and updates to the Governance Framework ensure that FSANZ's operations remain effective in addressing food safety risk. Some regulatory standards require Hazard analysis critical control point (HACCP) based food safety systems, as recommended by the Codex Alimentarius Commission.

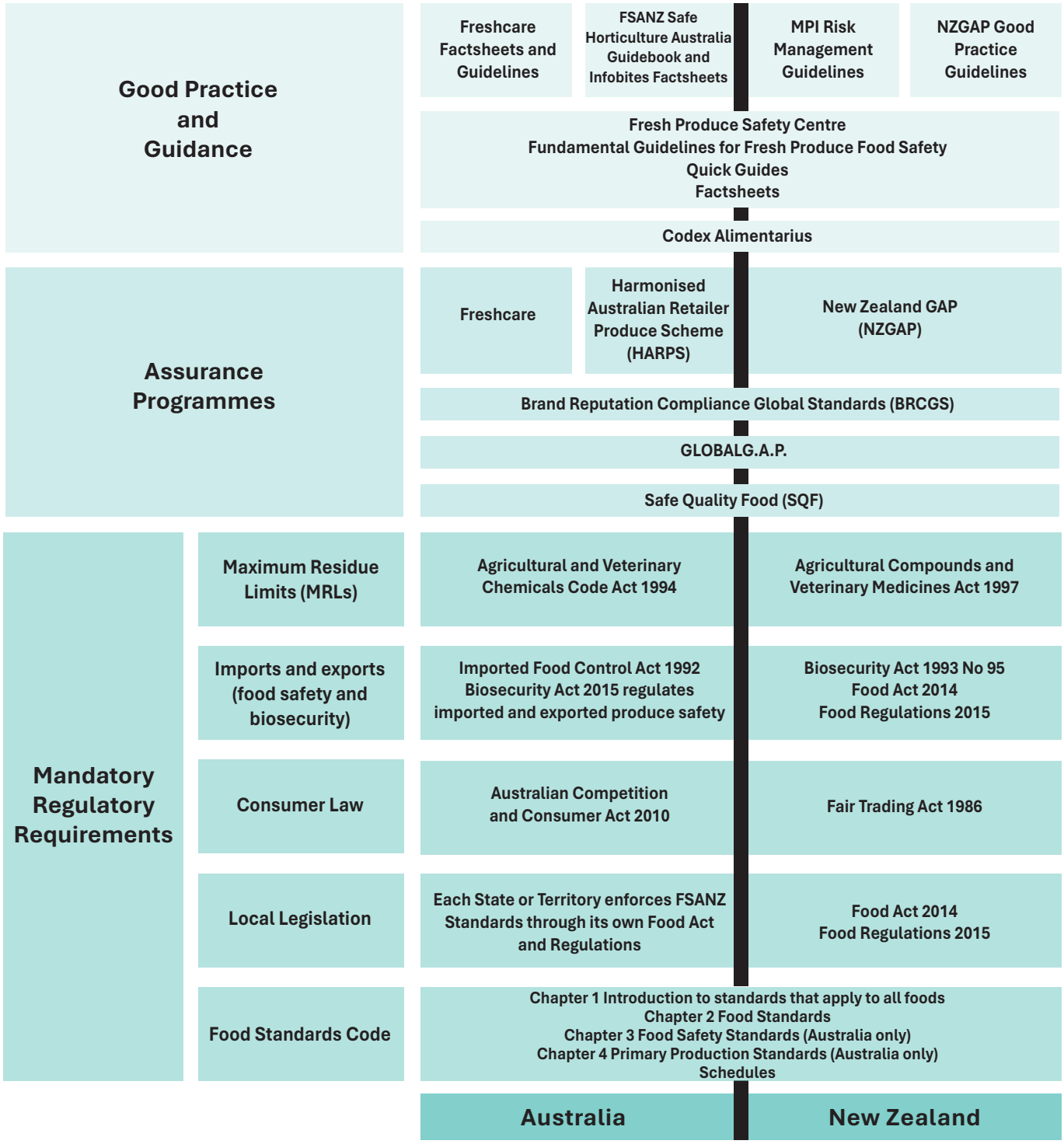

Figure A2:1 | Framework of food safety requirements in Australia and New Zealand.

FSANZ, established under the Food Standards Australia New Zealand Act 1991, develops and updates the Food Standards Code (FSC), based on scientific advice and stakeholder input. Proposed changes may come from FSANZ or external parties with each undergoing risk assessment and public consultation to ensure standards remain practical, enforceable and aligned with public health goals. New Zealand adopts the FSC under the Food Act 2014. However, it retains the ability to implement equivalent or supplementary national requirements. Australia recognises Codex standards as international benchmarks and considers them when developing or amending national food regulations.

The FSC outlines the regulatory requirements for food safety, providing mandatory standards for food production, processing and sale, ensuring public health and safety and consumer confidence. This section summarises key chapters of the FSC relevant to fresh produce, including regulatory changes, effective February 2025 in Australia for the primary production and processing of berries, leafy vegetables and melons.

A2.2.2 Key Chapters of the FSANZ Food Standards Code for fresh produce

Chapter 1: General food standards

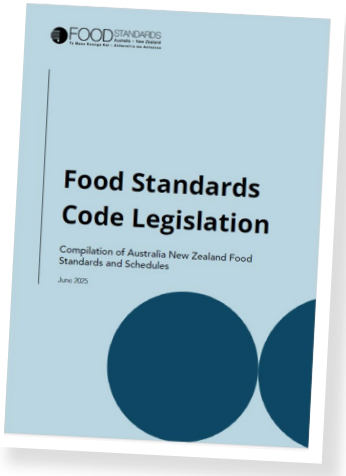

Image A2:1 | FSANZ Food Standards Code outlines the regulatory requirements for food safety.

- Standard 1.2.1 outlines requirements to have labels or otherwise provide information. The standard requires that fresh produce sold in retail is labelled or displays accurate information as defined in 1.2.1-8 (there are some exemptions for whole or cut fresh fruit and vegetables). Labelling includes, but is not limited to, the name of food, lot identification, name and address of supplier, advisory statements and ingredients (where applicable), date marking, storage conditions, information relating to nutrition, health and related claims, information relating to foods produced using gene technology and information relating to irradiated foods.
- Standard 1.4.2 Agvet Chemicals within the Code includes provisions for Maximum Residue Limits (MRLs). MRLs specify the highest permissible levels of agricultural chemical residues from pesticides, fungicides, herbicides in food, including fresh produce. These limits are established to ensure consumer safety and facilitate international trade. FSANZ determines MRLs in consultation with the Australian Pesticides and Veterinary Medicines Authority (APVMA) based on good agricultural practices and toxicological assessments to ensure residue levels in food remain safe for consumption. Imported produce is also subject to MRL compliance under Australia's Imported Food Control Act 1992. Under the Trans-Tasman mutual recognition agreement, food imported into Australia from New Zealand that complies with New Zealand Regulations is exempt from Schedule 20 Maximum Residue Limits of the Code. New Zealand has its own standards for chemical residues in food, namely Food Notice: Maximum Residue Levels in Agricultural Compounds, which is enforced by the Ministry for Primary Industries (MPI). Imported foods into New Zealand (unless from Australia) are required to comply either with New Zealand MRLs in the MRL Notice or the International Food Standards Pesticide Index.
- Standard 1.6.1 Microbiological limits in food establishes limits for pathogens in foods, including ready-to-eat fresh cut and packaged horticulture products. Testing requirements additionally aim to minimise risks associated with *Listeria monocytogenes* contamination.
- Standards for amendments, processing aids and allergens apply to pre-packaged or minimally processed fresh produce (e.g. ready-to-eat salad mixes or fresh-cut fruit).

Chapter 2: Food product standards

This Chapter establishes specific compositional, labelling and processing standards for different food categories, ensuring consistency, safety and transparency across the food supply chain. While much of Chapter 2 focuses on processed and packaged foods, Standard 2.3.1 defines fruit and vegetables.

Chapter 3: Food safety standards (Australia only)

This Chapter sets out food safety requirements for food businesses operating in Australia. These standards ensure food safety through hazard identification, risk management and regulatory compliance. These standards do not apply in New Zealand where food safety is regulated under the Food Act 2014 and Food Regulations 2015.

- Standard 3.2.1 is based on Hazard analysis critical control point (HACCP) system, as recommended by the Codex Alimentarius Commission. The Standard enables States and Territories to require food businesses to implement a food safety program, which is required to be reviewed by the food business and subject to periodic audit by a suitably qualified food safety auditor. The food safety program is required to identify, monitor and control food safety hazards.
- Standard 3.2.2 outlines mandatory food safety practices and general requirements for all businesses and includes standards for food handling, health and hygiene, temperature, cleaning and maintenance and prevention of contamination during handling, storage and transportation.

Chapter 4: Primary production and processing standards (Australia only)

The Primary Production and Processing (PPP) Standards in Chapter 4 of the Code establish food safety requirements for specific fresh produce categories, namely seed sprouts, berries, leafy vegetables and melons, with focus on activities and inputs ensuring produce is acceptable for human consumption.

- Standard 4.1.1 outlines preliminary provisions defining when food is unacceptable, general food safety management requirements and food safety management statements.
- Standard 4.2.6 applies to the primary production and processing of seed sprouts, covering activities such as soaking, germination, harvest, washing, drying, packing and decontamination. Businesses are required to manage the safety with traceability systems in place.
- Standards 4.2.7-4.2.9 establish food safety requirements for the primary production and processing of berries, leafy vegetables and melons, which are generally consumed uncooked. Producers are required to take reasonable measures to ensure that all activities and inputs (including soil, fertiliser and water) do not make produce unacceptable. Premises and equipment are required to be kept clean and properly maintained, and team members and visitors are required to follow personal health and hygiene practices. Businesses are required to have traceability systems in place. These standards do not regulate retail sales or manufacturing of harvested berries, leafy vegetables and melons.

A2.3 Food Act and regulations for food safety

In Australia and New Zealand, Food Acts mandate that businesses ensure food is safe and suitable for human consumption.

There are numerous important documents that form integral parts of the food regulatory system such as the Joint Food Standards Treaty between Australia and New Zealand, the Food Regulation Agreement (FRA) (Australia) and the Food Standards Australia New Zealand Act 1991. The FRA contains a model Food Act with two Annexes. State and Territory authorities implement the Food Act food safety requirements via localised regulations (refer Table A2:1). Food Regulations in each State and Territory provide more detailed provisions, guiding food businesses on how to comply with the overarching laws. These regulations are developed through consultation with industry stakeholders, health departments and food safety experts.

In Australia and New Zealand, Food Acts mandate that businesses ensure food is safe and suitable for human consumption.

Table A2:1 | Examples of State and Territory regulations for food safety in Australia.

State or Territory	Food Safety Regulation
Australian Capital Territory (ACT)	Food Act 2001 and Food Regulations 2002 requires that food sold in the ACT is safe and suitable for human consumption and meets all standards set out in the Code. Food Safety in ACT is governed by the ACT Health Protection Service.
New South Wales (NSW)	Food safety requirements are underpinned by the Food Act 2003 (NSW) and the Food Regulation 2025 (NSW). This legislation requires that food sold in NSW is safe and suitable for human consumption and meets all standards set out in the Code. Food Safety in New South Wales is governed by the NSW Food Authority which comes under the NSW Department of Primary Industries and Regional Development.
Northern Territory (NT)	Food safety in the NT is governed by the Food Act 2004 (NT). This Act requires that all food sold in the NT is safe and suitable for human consumption and meets all standards set out in the Code. This legislation is enforced by the NT Department of Health.
Queensland (QLD)	Food safety requirements are set by the Food Act 2006 (QLD) and Food Regulation 2006, Food Production (Safety) Act 2000 and Food Production (Safety) Regulation 2014. This Act requires that food sold in Queensland is safe and suitable for human consumption and meets all standards set out in the Code. Regulating Food Safety in Queensland is a joint responsibility of Safe Food Queensland and local government.
South Australia (SA)	Food safety in South Australia is governed by the Food Safety Act 2001 and Food Regulations 2002. The Act requires that all food sold in South Australia is safe and suitable for human consumption and meets all standards set out in the Code. This legislation is enforced by SA Health. Primary Industries and Regions South Australia (PIRSA) is the primary food production regulator in SA.
Tasmania (TAS)	Food safety in Tasmania is governed by the Food Act 2003 (TAS) and Food Regulations 2012. This Act requires that all food sold in Tasmania is safe and suitable for human consumption and meets all standards set out in the Code. This legislation is enforced by the Tasmanian Government Department of Health. The Department of Natural Resources and Environment Tasmania (NRE Tasmania) is the primary food production regulator in TAS.
Victoria (VIC)	The sale and production of food in Victoria is controlled by the Food Act 1984. This Act requires that all food sold and produced in Victoria is safe for human consumption and meets all standards set out in the Code. This legislation is enforced by the Victorian Government Department of Health. Agriculture Victoria (Vic DPI) is the regulator of primary food production and primary processing of horticulture commodities is regulated under the Food Standards Code.
Western Australia (WA)	Food safety in Western Australia is governed by the Food Act 2008 (WA) and Food Regulations 2009. This Act requires that all food sold in Western Australia is safe and suitable for human consumption and meets all standards set out in the Food Standards Code. This legislation is enforced by WA Health

As implementation of the new Primary Production and Processing (PPP) standards may vary across states and territories, businesses should check with their most local food safety authority for the most current requirements.

In New Zealand, food safety legislation applicable to fresh produce is governed by the Food Act 2014, which provides a risk-based framework to ensure food sold in New Zealand is safe and suitable for consumption. Fresh produce businesses in New Zealand typically operate under a national programme or custom food control plan, depending on their level of risk or food safety standard which MPI recognises as an approved Template Food Control Plan (TFCP) for the purposes of meeting the objectives of the Act. The Food Regulations 2015 and the Code set out specific requirements for food handling, processing and safety practices. The Biosecurity Act 1993 plays a critical role in protecting fresh produce from biosecurity threats and the Agricultural Compounds and Veterinary Medicines Act 1997 regulates the use of chemicals to ensure food safety. MPI oversees enforcement and provides risk management guidance for food businesses, including growers.

In Australia and New Zealand, food safety legislation is developed through stakeholder input, including government agencies, food producers, industry groups and consumers, that is coordinated via the Food Ministers' Meeting to ensure regulatory alignment. Acts and regulations are regularly reviewed and updated in response to emerging risks, scientific developments and technological advances, maintaining an effective food safety framework across both countries.

In some instances, Australia and New Zealand have established equivalency pathways and systems to recognise voluntary food safety standards and assurance programmes (such as those with Global Food Safety Initiative (GFSI) recognition) as meeting regulatory food safety requirements.

A2.4 Import and export of fresh produce

Australia and New Zealand have strict import and export food safety requirements to ensure fresh produce meets regulatory and market standards. These requirements include compliance with biosecurity laws, food safety standards and certification processes to protect public health, support international trade and prevent the introduction of pests and diseases. While the emphasis is on food safety, some biosecurity requirements (e.g. foreign objects) are also applicable for food safety, and in Australia food safety is regulated under biosecurity laws for imports and exports.

In Australia, fresh produce imports are regulated by the Department of Agriculture, Fisheries and Forestry (DAFF) under the Imported Food Control Act 1992 and Biosecurity Act 2015. Imported fresh produce is required to meet food safety and biosecurity requirements, including pest risk assessments, inspection protocols, and chemical residue limits. The FSC applies to all imported food, ensuring it meets the same safety requirements as domestic products. Businesses importing fresh produce for commercial purposes are required to also comply with import permits, phytosanitary certification and traceability requirements to verify the produce is free from contamination and pests.

The Export Control Act 2020 establishes the legal framework for regulating the export of fresh produce and other goods from Australia. For exports, Australia requires fresh produce to comply with export certification programs, including phytosanitary certificates issued under the International Plant Protection Convention (IPPC) through an electronic documentation system (EXDOC). Exporters must meet destination country requirements, which may include Good Agricultural Practice (GAP) certification, chemical residue compliance and product traceability. The Manual of Importing Country Requirements (MICoR), is a database maintained by DAFF, provides detailed guidance for exporters on specific commercial market access conditions for agricultural products.

Australia and New Zealand have strict import and export food safety requirements...

In New Zealand, imported fresh produce is regulated under the Biosecurity Act 1993 No 95 and the Food Act 2014. MPI oversees food safety requirements, ensuring that all imported produce complies with New Zealand's Food Standards Code. Importers must check the Import Health Standards (IHS), which outline country-specific requirements for fresh produce, including pest control treatments, food safety testing and documentation such as phytosanitary certificates.

For fresh produce exports, New Zealand enforces strict food safety and biosecurity standards to meet international commercial market access requirements. Similar to DAFF, MPI as the National Plant Protection Organisation (NPPO) provides export certification to verify compliance with importing country requirements (ICPRs) through an electronic documentation system (ePhyto) and businesses are required to meet the food safety, New Zealand maximum residue limit standard and phytosanitary regulations of their destination markets.

A2.5 Consumer protection laws

The Australian Competition and Consumer Commission (ACCC) is an independent Commonwealth statutory authority responsible for the enforcement of the Competition and Consumer Act 2010 and other legislation, including the Food and Grocery Code of Conduct, promoting competition and fair trading. Under the Australian Consumer Law, businesses are prohibited from making false or misleading claims about food products, including requirements of Country of Origin Food Labelling Standard 2016.

The Fair Trading Act 1986 is the key consumer protection law in New Zealand that applies to all businesses, including the fresh produce industry. The Act is designed to encourage competition and protect consumers from misleading or deceptive conduct and unfair trade practices. For fresh produce businesses, this includes accurate labelling and representation, country of origin, weights and measures. In addition, the Horticulture Code of Conduct is a mandatory industry code prescribed under the Competition and Consumer Act 2010. The Code of Conduct aims to improve clarity and transparency of trade between growers and traders of horticulture produce (unprocessed) with some exceptions for nursery products and trading relationships and covers a range of aspects including contract negotiations and dispute resolution to help improve the efficiency and sustainability of New Zealand's horticulture industry.

Australia and New Zealand have legislation governing trade weights and measures to ensure fair trade and consumer protection in the marketplace. In Australia, the National Measurement Act 1960 regulate trade measurement activities. These laws establish the framework for ensuring that goods sold by weight, volume or length are accurately measured and that consumers are not misled. In New Zealand, the Weights and Measures Act 1987 governs the accurate measurement of goods in trade and is administered by the Ministry of Business, Innovation and Employment.

A2.6 Voluntary assurance programmes

Assurance programmes provide trust for the safe production and supply of fresh produce. They offer fresh produce businesses an internationally accepted framework for managing food safety risks and meeting consumer and regulatory expectations. They also enhance the reputation of businesses by enabling them to demonstrate their commitment to food safety and quality. The main assurance programmes operating in Australia and New Zealand's fresh produce industries are Freshcare (Australia), NZGAP (New Zealand), GLOBALG.A.P., Safe Quality Food (SQF), and Brand Reputation Compliance Global Standards (BRCGS).

In addition, the Harmonised Australian Retailer Produce Scheme (HARPS) is a food safety standard in Australia designed to streamline food safety practices across the fresh produce industry, particularly for retailers ALDI, Coles, Costco, Metcash (IGA) and Woolworths. HARPS certification is achieved after demonstration compliance via audit, in conjunction with a Global Food Safety Initiative (GFSI) benchmarked standard (e.g. Freshcare), thus reducing the need for multiple retailer-specific audits.

HARPS supports the alignment of audit processes and reduction of the audit burden on businesses.

Assurance programmes are widely implemented in the fresh produce industry with each providing a structured approach to managing food safety and quality within the food supply chain. They develop and administer food safety standards which are adopted and implemented by fresh produce businesses including growers, packhouses and wholesalers.

They operate in a robust assurance framework where businesses are subject to independent audits by approved certification bodies. Assurance programmes are also subject to robust assessments and recognition via the accreditation system, regulators and international benchmarking requirements which ensure that the standards, systems, and processes are in place to provide the required level of assurance. When a business demonstrates that they meet the programme requirements and food safety standards via audit, they can attain certification which in turn enables market access. Where the assurance programme is recognised by regulators, businesses can also demonstrate that they meet regulatory food safety requirements.

A2.6.1 Global Food Safety Initiative (GFSI) standards for fresh produce

GFSI is an international organisation administered by the Consumer Goods Forum that sets globally harmonised food safety requirements. It also recognises assurance programmes as meeting those requirements through its benchmarking framework. The framework was established by members of the global food safety community, who collaborated to develop a benchmarking model based on international standards such as Codex Alimentarius. GFSI benchmarks a range of food safety assurance programmes, ensuring they meet international harmonised standards for food safety. Several assurance programmes are recognised by GFSI including Freshcare, GLOBALG.A.P., BRCGS, and SQF. The currently recognised assurance programmes, version and status can be found on the GFSI website: https://mygfsi.com/how-to-implement/recognition/certification-programme-owners

A2.6.2 Regulatory recognition pathways

Australia and New Zealand maintain effective food safety frameworks aligned with international standards to protect public health and support trade across the fresh produce supply chain. In horticulture, recognition pathways enable businesses to use certifications like BRCGS, Freshcare, GLOBALG.A.P., SQF and NZGAP to meet national regulatory requirements. Where accepted by authorities, these pathways streamline certification, reduce audit burden, reduce non-compliance risk and enhance operational efficiency. Recognition is beneficial for exporters by ensuring alignment with both domestic regulations and global benchmarks such as Codex Alimentarius and GFSI, ultimately reducing barriers to international market access.

A2.7 Good practice and guidance for fresh produce Australia and New Zealand

The FPSC *Fundamental Guidelines for Fresh Produce Food Safety, Quick Guides* and factsheets provide science-based recommendations on managing physical, chemical (including allergen) and microbiological hazards.

Freshcare factsheets and guidelines support certified businesses with guidance ensuring alignment with regulatory requirements and food safety standards. FSANZ's *Safe Horticulture Australia* guidebook and *InfoBites* assist horticultural businesses navigate the Code, offering best practice and risk management strategies.

Commodity-specific guidance documents address food safety risks for different produce types.

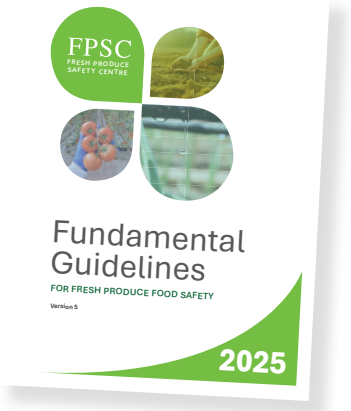

Image A2:2 | The FPSC Fundamental Guidelines for Fresh Produce Food Safety provide science-based recommendations on managing hazards.

For example, in Australia, the ***Safe Melon Toolkit*** focuses on reducing contamination in melon production, while Berries Australia's ***Best Practice Guide*** provides hygiene and post-harvest handling recommendations for berry growers.

In New Zealand, the Ministry for Primary Industries (MPI) ***Risk Management Guidelines*** outline food safety hazards and preventive measures. NZGAP ***implementation guidelines*** help certified growers implement food safety controls in line with regulations and market standards.

Zespri GAP as a commodity-specific example ensures kiwifruit growers meet food safety and traceability requirements for domestic and export markets, supported by Zespri ***Food Safety Guidance***.

These resources provide good practice guidance to assist the fresh produce industry manage food safety risks effectively and drive continuous improvement across the supply chain.

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APPENDIX 3

Microorganisms Associated with Fresh Produce

Overview

A wide variety of microorganisms are capable of causing foodborne illness. While bacteria, viruses and parasitic protozoans are the most common, microscopic worms can also lead to severe disease symptoms. Alegbeleye *et al*. (2018) compiled a comprehensive list of produce-borne pathogens based on six authoritative, published, international reviews. A slightly augmented list of their findings is presented in Table A3:1.

Table A3:1 | Microorganisms that have been implicated in foodborne illness involving fresh produce as a vector Fraud (2014).

Bacteria	Fungi	Parasites	Viruses
Aeromonas spp. *Bacillus cereus* *Brucella spp.* *Campylobacter spp.* *Cronobacter (*formerly *Enterobacter) spp.* *Escherichia coli (*STEC*)* *Listeria monocytogenes* *Pseudomonas spp.* *Salmonella enterica* *Shigella spp.* *Staphylococcus aureus* *Vibrio spp.* *Yersinia spp.*	*Alternaria spp.* *Aspergillus spp.* *Candida spp.* *Fusarium spp.* *Penicillium spp.*	*Ascaris spp.* *Cryptosporidium spp.* *Cyclospora cayetanesis* *Giardia spp.* *Toxoplasma gondii* *Trichinella spp.* *Trichuris trichiuria*	Hepatitis A Hepatitis E Norovirus (formerly Norwalk virus) Rotavirus Sapovirus

Based on Alegbeleye *et al*. (2018) slightly augmented with data in FSANZ (2010) the columns are in alphabetical order, not in order of relative importance.

Foodborne pathogenic bacteria that have been associated with fresh produce include *Bacillus cereus, Campylobacter spp*., pathogenic *Escherichia coli* (STEC), *Listeria monocytogenes*, various *Salmonella enterica* subspecies, *Shigella spp*., *Clostridium botulinum*, *Clostridium perfringens*, *Staphylococcus aureus*, *Cronobacter* (formerly *Enterobacter*) *sakazakii* and *Yersinia enterocolitica*. All may be found in soil or water. Growth of various fungal species on produce may result in generation of mycotoxins that are harmful to human consumers. Foodborne viruses include hepatitis A, hepatitis E and noroviruses, while parasitic protozoa such as *Giardia spp*., *Cryptosporidium spp*. and *Toxoplasma gondii* and small multicellular roundworms (like *Ascaris*) can also cause human foodborne illness. Of the above list of pathogens, or their products, potentially able to contaminate fresh produce many, but not all, are typically associated with faecal contamination of soil, water or from team member hands. Others, however, are natural in the agricultural environment (e.g. *L. monocytogenes*, *B. cereus*) and may require different risk management strategies.

As outlined in Table A3.1, a diverse range of microorganisms have been associated with outbreaks linked to fresh produce. The most common causes of foodborne disease linked to the consumption of fresh produce are pathogenic *Escherichia coli* of which those termed STEC (an acronym for shiga-toxin producing *E. coli*) are of most concern in foodborne outbreaks because of the potential for very serious disease. Similarly *Listeria monocytogenes* while a relatively rare source of human disease, is known to be able to cause very serious disease. *Salmonella spp*. are very common in the environment and are one the commonest causes of foodborne and water-borne disease in many nations, including developed nations. Some of these microbes are particularly problematic due to the relatively low "infectious dose" required to cause illness or their ability to survive in the soil and under refrigerated conditions.

Some of the microorganisms listed in Table A3.1 are rarely, if ever, reported from fresh produce foods in Australia or New Zealand, possibly because we have learned from the experience of other regions and nations and have instigated reliable hazard management control systems. Also, Australia's climate, geography and relatively low population densities in most growing regions probably provide some extra protection. We are fortunate that some pathogens are not endemic to our countries. Australia and New Zealand cannot forget, however, that our countries also import fresh produce from other regions where some food-borne pathogens are more prevalent and hazard management systems may not be as reliable. Also, with increased international travel, we should remain vigilant about potential accidental incursions. The Australian Department of Agriculture, Fisheries and Forestry (DAFF) manages biosecurity risks to Australia. As a regulator, DAFF enforce laws relating to agricultural and food products imported into Australia. This includes pest and disease risks including food safety of goods, people and vessels arriving in Australia. In New Zealand the Ministry for Primary Industries (MPI) manages New Zealand's biosecurity system which has similar objectives and functions.

Surveys and studies completed in Australia offer much shorter lists of microbiological hazards that have, or might, contaminate fresh produce. Based on FSANZ (2010) which contains a summary of thousands of FreshTest microbiological assessments, a list of the pathogens most assessed in fresh produce in Australia includes:

- *Listeria monocytogenes*
- *Escherichia coli (generic)*, but also STEC strains and *E. coli* O157:H7 specifically
- Coagulase positive *Staphylococcus aureus*
- *Salmonella enterica* subspecies

Available results from Australian surveys and routine testing are inherently biased, as they typically focus on historically common pathogens. Organisms that are more expensive, technically challenging or slower to detect (i.e viruses) are often excluded from testing.

The analysis of Rothwell *et al*. (2024) is probably more representative because it is based on actual outbreak investigations, not designed surveys. Outbreak investigations could be expected to be more complete in their search for the causative organisms. Notably, viruses were responsible for many Australian fresh-produce associated outbreaks (almost always coming from sewage contamination in the field or from infected food handlers) but are not included in the routine testing by Freshcare, nor the FSANZ (2010) prospective survey.

Rothwell *et al*. (2024) identified that most outbreaks in Australia from fresh produce were due to Salmonella enterica (including its various sub-species and serovars), followed by norovirus and Hepatitis A. For ~10 – 25% of outbreaks. However, the causative agent was not identified but, based on international experience (Grieg *et al*., 2007), many could be expected to be human viral pathogens. Rothwell et al.'s review also suggested that many outbreaks originated in catering/food service, though this would be expected to be where such outbreaks were most easily detected. They also noted that a high proportion of outbreaks involving fresh produce involved multi-component foods/dishes that included fresh produce. Some of the outbreaks studied were most likely due to imported ready-to-eat foods (e.g. sun-dried tomatoes, frozen berry fruits). *Salmonella spp*. were the main cause of outbreaks.

Reducing the risk of microbial contamination and growth begins at the growing site and continues through every stage of the supply chain.

A brief overview is provided below on some of these organisms. In depth information on foodborne pathogens can be accessed from the US Food and Drug Administration's "Bad Bug Book', which is a 'handbook of foodborne pathogenic organisms'.

The use of faecal indicator bacteria as a proxy for potential contamination of food or water with a range of enteric pathogens [refer Chapter 7 and Appendix 4].

A3.1 The idea of an 'infectious dose'

The term 'infectious dose' for pathogenic microorganisms is a misnomer. In principle, even one organism/cell/viral particle of a pathogen can cause an infection. If that single cell/virus particle can survive passage through the upper gastrointestinal tract and then establish itself within the gut and start replicating it can cause all the symptoms of infection that we associate with gastrointestinal illness and any long-term complications beyond the gastrointestinal tract. Rather, the chance of getting an infection increases relatively directly in proportion to the number of viable (infectious) pathogens that a person ingests. In other words, the probability of getting sick is essentially a continuum that depends on, and increases with, the dose ingested.

However, some types of pathogens are much better adapted than others to survive the upper gastrointestinal tract, for example:

- surviving the acidity of the stomach
- being able to survive the effects of bile salts
- having specific ability to attach to cells in parts of the gastrointestinal tract and invade them as well as survive the host's immune defence
- to produce toxins that change the behaviour of the gastrointestinal tract to aid the dissemination of the pathogen.

Instead, a more useful description of the invasiveness or infectivity, of a pathogen is represented by its ID50, which is shorthand for the numbers of cells/virus particles that would be required to be ingested to cause an infection in a person of average health or to cause infection in 50% of the people in a population. However, we know that some people are much more susceptible to infectious diseases, particularly the very young, the very old, people who are receiving treatments or have illnesses that reduce their immunity. Pregnant women too are at higher risk because of the challenge to their immune system of having something growing inside them that doesn't fully match their own genetic make-up. Where possible, information has been provided in the following sections on the ID_{50} of each pathogen, including for populations known to be at higher risk.

A3.2 Bacteria

A3.2.1 *Escherichia coli* (*E. coli*)

Among bacteria that normally live in the intestines of humans and other animals are a number of different strains of *E. coli*. Although the vast majority of *E. coli* strains are harmless, a few described as pathotypes, such as STECs, can cause severe disease and even death. Strains of *E. coli* can grow in a broad pH range (~4 – 9.5), survive freezing temperatures and can remain alive for long periods in water, soil and manure. Total culturable *E. coli* a specific group within the thermotolerant coliforms are often used as a more specific indicator of faecal contamination, partly because of the availability of fast and affordable detection methods. The most dangerous types are Shiga toxin-producing *E. coli* (STECs). The toxins can cause bloody diarrhoea and can cause permanent kidney damage predominantly in young children. *E. coli* O157:H7 is a specific and often-studied example of an STEC.

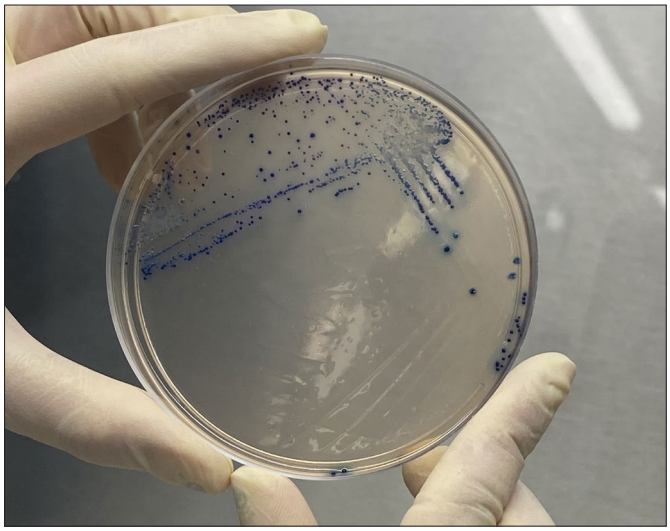

Image A3:1 | Growth of Shiga-toxin producing *E.coli* (STEC) on selective agar used in fresh produce testing.

Symptoms usually occur around 1–5 days after consuming an infective dose. For a healthy adult the ID_{50} for STECs is in the range 1000 – 10,000 cells.

A3.2.2 *Salmonella enterica*

While some specific subspecies of *Salmonella enterica* bacteria are most commonly associated with livestock and chickens, the species have also been responsible for food safety outbreaks associated with fresh produce. When using organic soil amendments, particular attention should be paid to the age and process of composting fresh animal faeces are often contaminated with enteric pathogens and large numbers can be shed in the faeces of infected humans and other animals both before and after symptoms of disease.

In most cases gastroenteritis symptoms are relatively mild, including cramps, nausea and diarrhoea, although severe disease and even septicaemia can occur in susceptible individuals. For a healthy adult an ID_{50} is in the range 1000 – 10,000 cells. For perspective, in a person with an active diarrhoeal infection, a gram of faeces could contain between millions and 100's of millions of enteric pathogens.

Image A3:2 | Typical colonies of *Salmonella* bacteria that produce hydrogen sulphide growth on selective agar.

A3.2.3 *Listeria monocytogenes*

Listeriosis is the term given to the illness caused by the bacterium *Listeria monocytogenes*. There are two main forms of listeriosis. Non-invasive listeriosis is a mild form, causing symptoms typical of gastroenteritis around a day or two after infection. Invasive listeriosis, occurs when the bacteria enter the blood and begin to be disseminated around the body. The incubation period of invasive listeriosis can be three days to three months. Invasive listeriosis is a relatively uncommon illness, with about 150 cases per year detected in Australia. The rate of listeriosis notifications in Australia per capita is similar to most developed nations.

Image A3:3 | Environmental monitoring is conducted using surface swabbing to detect the presence of microbial contaminants, such as *Listeria monocytogenes*.

Due to a strong education campaign aimed at pregnant women in Australia since the 1990s, the incidence of invasive listeriosis among pregnant women is lower than in many other nations.

The invasive form causes miscarriage/stillbirth (20%) or neo-natal infection (63%) among pregnant women who contract listeriosis and is fatal in up to 20-30% of cases in people with known pre-disposing conditions that compromise their immune response. *L. monocytogenes* is found throughout the environment, including within soil, water and vegetation including in waste mounds and in silage on-farm and from wet areas of food production facilities. It is a 'saprophyte', meaning that it needs pre-digested foods for nutrients.

For this reason, it is commonly found associated with decomposing plant materials, or in 'nooks and crannies' in food-processing plants where food scraps and water collect. The bacterium can grow in a temperature range from roughly 0°C to 45°C but is killed at 50°C and higher.

The rate of killing increases rapidly with increasing temperature, such as used in cooking. Major outbreaks have been associated with cabbage fertilised with manure and rockmelon (cantaloupe) contaminated during packing/processing, both in Australia and overseas.

The ID50 for healthy adults is in the range of 10s to 100s of billions of cells. For pregnant women the ID_{50} is in the range of tens to 100s of millions of cells. For people who are very immunocompromised (e.g. life-threatening cancers, organ transplant recipients) the ID_{50} is in the range 10s to 100s of thousands of cells.

A3.2.4 *Yersinia spp*.

Infections from the bacteria *Yersinia enterocolitica* and *Y. pseudotuberculosis* have been increasing in recent decades, particularly in New Zealand. Both bacteria cause fever and right-side abdominal pain, which can resemble appendicitis and have sometimes resulted in inappropriate appendectomies. In the case of *Y. enterocolitica*, infection also causes watery or bloody diarrhoea. The bacteria can be carried by many different animals and birds, which may or may not show evidence of illness as a result. While poorly cooked meat, contaminated water and milk are the more usual sources of infection, salad vegetables were considered to be a potential source of a major outbreak in NZ in 2014. *Yersinia* can grow at low temperatures and are difficult to detect and grow in culture. Research in NZ is currently focused on new ways to isolate this bacterium. Outbreaks involving Y. *enterocolitica* are typically associated with high levels of contamination in the range 1 million to 10 million cells per gram of the food.

A3.2.5 Coagulase positive *Staphylococcus aureus*

Staphylococcal food poisoning is an intoxication that is caused by the ingestion of food containing pre-formed staphylococcal enterotoxin produced by the bacterium *Staphylococcus aureus*. Staphylococcal enterotoxins are produced during the exponential phase of *S. aureus* growth in foods before consumption. About half the human population carries *S. aureus* on their body at one time or another, it lives on their skin or in their nose. Inadequate food hygiene practices by food handlers carrying enterotoxin-producing *S. aureus* can lead to the pathogen being transmitted to food. Depending on the environmental conditions, *S. aureus* may be capable of growth if temperature control is inadequate.

While some fresh produce has physical barriers to bacterial growth, therefore preventing access to water and nutrients for microorganisms to thrive, if produce has been damaged in the field or processed in ways that release those nutrients and water (e.g. cutting, slicing) pathogens can begin to grow.

S. aureus prefers warmer temperatures (above ~10°C for growth) and even then, grows relatively slowly. It is less tolerant of low pH than many other foodborne pathogens but can survive for extended periods on various food processing surfaces or on human skin, due to its tolerance to desiccation (i.e. drying out).

If conditions of temperature and salt levels (i.e. *S. aureus)* is relatively salt tolerance compared to other bacteria and pH allow and if nutrients are available, 'coagulase positive' *S. aureus* can produce and release into the food a toxin that is not eliminated by washing or cooking. When ingested, the toxin induces vomiting, often severe, but may also lead to other typical gastrointestinal illness symptoms.

Image A3:4 | Maintaining effective hand hygiene prevents the spread of harmful microbes, including *Staphylococcus aureus*.

Whilst unpleasant, most consumers recover from the vomiting within 12 hours and are fully recovered within a few days. The dose level required to produce enough toxin on the food to cause overt illness is estimated at above 105 cells per gram of food. A typical serving size might be 20 to 100 g, so the "dose" leading to illness is probably above 10,000,000 cells.

The main risk management approach is appropriate food team members personal hygiene, both hand hygiene and the wearing of face masks.

A3.2.6 *Cyanobacteria*

Cyanobacteria are photosynthetic bacteria and occur naturally in water. They have a bluish-green colour and were formerly known as blue-green algae, but they are bacteria, not algae. They sometimes bloom in still water. They produce toxins, collectively called cyanotoxins including microcystins and saxitoxins, that are environmentally stable. Consumption of water in which cyanobacteria have bloomed, can be toxic to animals and humans. There is strong evidence of harm on ingestion of water contaminated with cyanotoxins, including increased risk of liver disease.

Microcystins can also be toxic to plants and can accumulate in soils. Microcystins in soil can also be taken up by plants and while there is no conclusive evidence currently that microcystins in produce have caused human illness and to date, would have been difficult to demonstrate conclusively (WHO, 2020a), it is probably prudent not to use water contaminated with high levels of cyanobacterial blooms (e.g. > 50,000 – to 100,000 cfu/ml) to irrigate food crops [refer Chapter 7].

A3.3 Viruses

Enteric viruses are major contributors to foodborne disease and the viruses of most concern are norovirus, hepatitis A and sapovirus. From a foodborne transmission perspective, norovirus is the most important. Hepatitis A is associated with more serious and long-term illness.

Hepatitis A is endemic in many developing countries. Hepatitis A is less common in sewage than other human enteric viruses, but its presence is an indication of the prevalence of active viral infections in the community. Infection can result in no clinical symptoms, mild illness or in a small proportion of cases, can cause liver damage and death. A range of symptoms can occur including fever, nausea, muscular pain and general malaise, followed in the later stages by jaundice. Infected team members can contaminate fresh produce with Hepatitis A during handling.

Caliciviruses include two genera, Norovirus and Sapovirus, associated with disease in humans. Norovirus and Sapovirus are the most common cause of gastrointestinal tract illness in humans and due to their high infectivity (ID_{50} ~ 10-100 viral particles) are the most common cause of foodborne illness from sewage and human hygiene contamination. This means they are easily spread in contaminated water or on the hands and from vomit of infected team members. These caliciviruses cause viral gastroenteritis, resulting in frequent vomiting and diarrhoea.

While human viruses cannot replicate outside the body of their host (humans), they can remain infective for long periods in untreated sewage/biosolid-contaminated soil and water, as well as on the surface of fresh produce and hands of team members.

A3.4 Parasitic protozoa and helminths

Some microscopic parasites can also cause foodborne illness. These unicellular microorganisms include Toxoplasma gondii, which causes the disease toxoplasmosis, *Cyclospora cayetanensis*, *Cryptosporidium parvum*, *C. hominus* and *Giardia* spp. The group also includes microscopic multicellular intestinal worms (e.g. helminths such as *Ascaris*, *Taenia spp.)*.

These organisms are more common in less developed countries, where they may infect a large percentage of the population. For example, it has been estimated that one third of the world's population has been exposed to *Toxoplasma*, which is common in warm-blooded animals.

Parasites are commonly transmitted in undercooked meat or in faeces. However, contaminated water can be a source of infection in some situations.

Parasitic protozoa are excreted as cysts or oocysts that, like excreted *helminth ova* (eggs), are highly resistant to environmental stressors and many disinfection systems. Most transmission of these parasites is person-to-person, but they are commonly present in human sewage or animal manures and like bacterial pathogens, should always be assumed to be present in produce contaminated by soil/environmental waters (Robertson & Gjerde, 2000), but assay methods are complex and costly to undertake (Rousseau et al., 2014).

A3.5 Mycotoxigenic Fungi

Mycotoxins are naturally produced by certain types of moulds (a form of fungus). Such moulds can contaminate numerous foods such as cereals/grains, dried fruits, nuts and spices. Mould growth can occur either before or after harvest, during storage, on/in the food itself and particularly if the food/grain/nuts experience warm, damp/humid conditions. Most mycotoxins are chemically stable and survive food processing and cooking. They can also be passed up through the food chain from the produce itself to domesticated food animals and can even be found in human mother's milk. Nut wastes can be used as soil amendments and if contaminated with mycotoxins may lead to contamination of fresh produce [refer Chapter 3].

Of more direct relevance to fresh produce, however, is the mycotoxin patulin, which is of concern in apples and apple-products, including recent events. Patulin is produced by some *Penicillium* species, and is heat stable, meaning it survives pasteurisation. It is thought that it may be genotoxic (i.e. able to induce genetic mutations).

At the sorts of levels normally encountered in at-risk produce in the modern world, the health consequences from mycotoxins arise from long term exposure to those mycotoxins in grains and nuts, including the induction of cancers and immune deficiency. Nonetheless, there have been incidences of highly contaminated grain being sold and eaten in developing countries, leading to acute symptoms and deaths. As such, industries with crops that are likely to be affected undergo regulation and testing to ensure that mycotoxins levels are acceptable. Acceptable doses are calculated using a systematic process established and conducted by an international expert panel (JECFA, the Joint FAO/WHO Expert Committee on Food Additives).

Resources

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APPENDIX 4

The Use and Significance of Faecal Indicator Bacteria

Overview

Many foodborne hazards are microbial, called pathogens and can be transmitted by fresh produce [refer Chapter 3 and Appendix 3]. While these microbial hazards potentially include bacteria, viruses and parasitic protozoa, faecal bacteria that are relatively easy, cost effective and rapid to detect are used to indicate the likely presence of any pathogen. Hence the term indicator bacteria. While a few pathogens that can be transmitted by fresh produce can cause severe symptoms beyond the gastrointestinal tract, (e.g. blood, heart or brain infections) most foodborne pathogens affect the human gastrointestinal tract. The illness caused typically includes some or all, of the following symptoms: nausea, stomach cramps, vomiting and diarrhoea. These pathogens include pathogenic strains of *Escherichia coli* (a relatively small sub-set of all *Escherichia coli* strains), *Salmonella*, *Shigella*, *Campylobacter* and others that are commonly referred to as faecal-oral (or more correctly enteric) pathogens because when they cause gastrointestinal illness they are passed out (often in very high numbers) in the faeces of those infected (Figure A4:1).

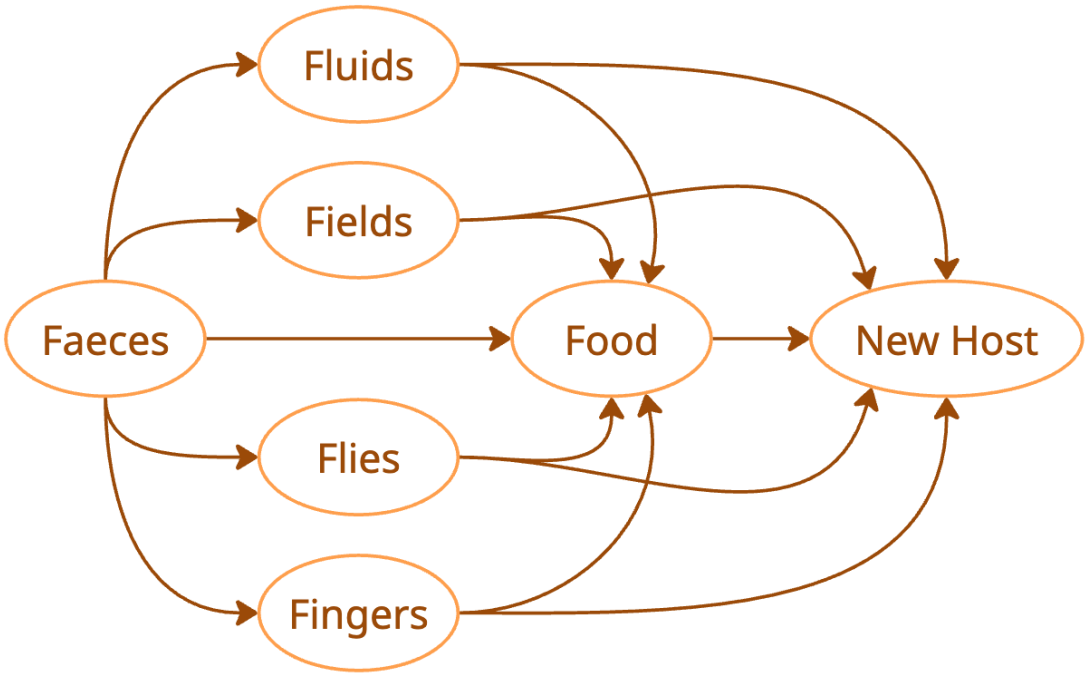

Figure A4:1 | The faecal-oral route. Source: Wagner and Lanois (1958).

Even in the absence of overt illness, some people periodically shed faecal-oral pathogens in their faeces as well. The same is true of many animals and birds. Breaking the cycle of transmission of enteric pathogens involving fresh produce as a food vector requires exclusion of animals from growing areas (e.g. by strong and complete fencing) whether from nearby natural habitats or domestic animals from nearby human populations. The aim is to exclude their faeces. Likewise, it is essential to prevent any potential sewage or septic contamination originating from nearby human populations.

Effective personal hygiene of food handlers, clean food handling equipment, awareness of other potential sources of contamination (e.g. proximity of intensive animal rearing operations) are also critical as is being alert to the possible implications of unusual weather events (e.g. dust storms and floods) that could bring bacterial contaminants from sources beyond the specific farm/growing facility. Use of organic amendments requires that they are certified to be fully composted or that withholding times for harvest after application of manures are strictly adhered to [refer Chapter 6 Section 6.2].

The best way to protect raw fresh produce is by preventing contamination.

Once fresh produce becomes contaminated, it is extremely difficult to remove or eliminate pathogens without compromising product freshness. While chemical sanitisers are useful to keep water and surfaces clean, they are relatively ineffective to decontaminate fresh produce.

For produce intended to be consumed raw, the most effective approach is to minimise contamination through consistent and thorough application of preventive measures. While it has sometimes been suggested that increased levels of sanitisers and contact time in wash tank systems could compensate for potentially increased microbial loads after known events, this could only be undertaken with input and advice from some-one with appropriate expertise to develop a validated process. Validated processes should be subject to ongoing monitoring to confirm that control measures are consistently implemented and remain effective. Monitoring would include testing for *E. coli* levels in the wash tanks as verification of the process.

Contamination can also sometimes occur from irrigation or processing water or contact with infected team members or contaminated surfaces. Testing for individual enteric pathogens can take several days and is impractical due to cost and product holding time. Instead, detection of faecal indicator bacteria, typically *E.coli* is recommended, most pathogens of concern are transmitted via the faecal–oral route. *E. coli* is common in the faeces of mammals and birds and serves as a sensitive marker of likely recent faecal contamination.

The methods for testing for the presence and enumeration of *E. coli* have also been refined over the last few decades so that a test result can be obtained in 12 – 16 hours and completed relatively inexpensively. These tests will detect all *E. coli*, not just pathogenic strains and the detection of these generic *E. coli* does not demonstrate that pathogens are present, but merely that they may be. Conversely, not detecting *E. coli* because of the sensitivity of the test methods provides confidence that faecal contamination has not occurred and that the probability of any faecal-oral pathogens being present is very low.

Other groups of bacteria sometimes used as faecal indicators include coliforms, thermotolerant coliforms (formerly known as faecal coliforms) and *enterococci*. *E. coli* is a sub-group of thermotolerant coliforms, which in turn are a sub-group of coliforms. While thermotolerant coliforms are mostly specific to the gut of warm-blooded animals and some reptiles and amphibians, coliforms include a range of natural contaminants of soil and there are some thermotolerant coliforms that can exist and proliferate in environments other than the mammalian gut. As such, their detection and enumeration can be misleading in some circumstances.

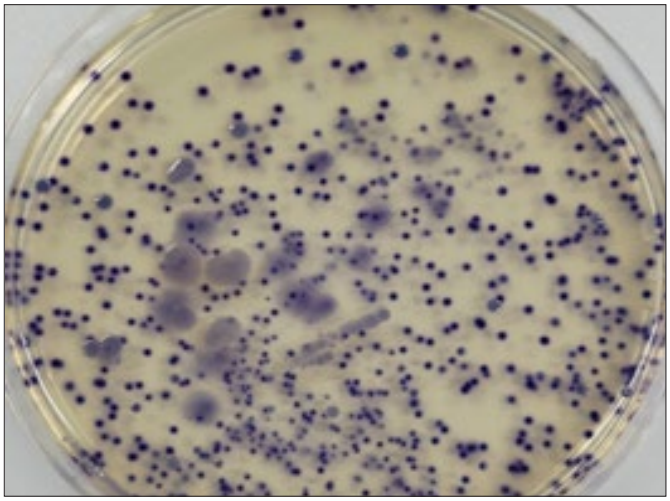

Image A4:1 | Rapid *E.coli* 2 agar is a selective medium used for the identification and enumeration of generic *E.coli* in fresh produce and water testing.

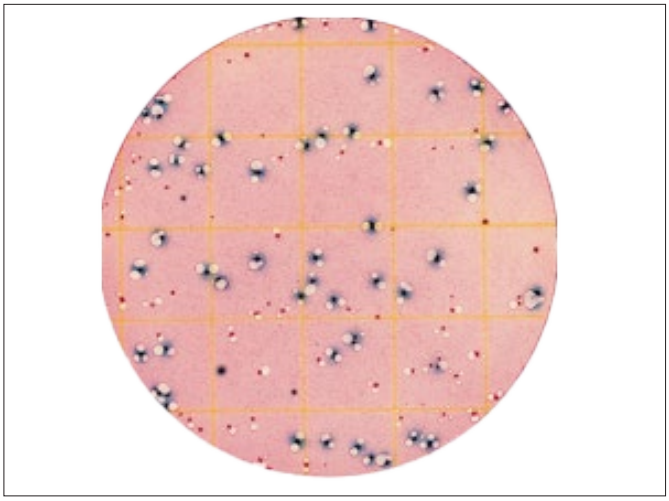

Image A4:2 | Petrifilm, often used for cost-effective in-house testing, provides a rapid culture method for the enumeration of generic *E.coli* and coliform bacteria as hygiene indicators.

Enterococci are also a common inhabitant of the mammalian gut but are also less specific than *E. coli*. *Enterococci* are sometimes favoured as faecal indicators because they survive longer in the environment and may be able to detect potential faecal contamination from more distant sources both spatially and temporally. However, this is generally more relevant for testing water contamination in environmental settings than for contamination of food crops. *E. coli* test methods are now relatively rapid and highly sensitive, cost-effective and specific for detecting mammalian and avian faecal contamination and remain the most widely used indicator for faecal contamination in agriculture settings.

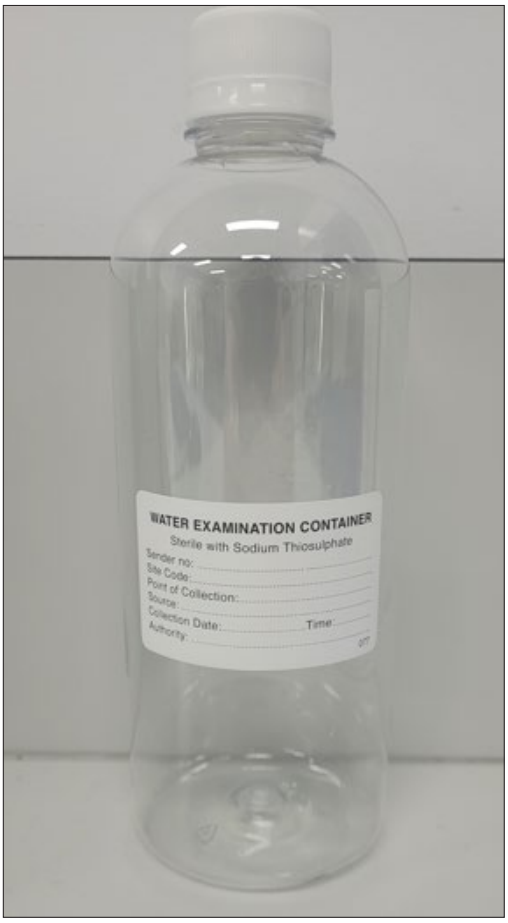

Image A4:3 | Sterile water sampling container with sodium thiosulphate to neutralise residual chlorine during microbiological testing.

Resource

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APPENDIX 5

Glossary of Key Terms

Term	Definition
Accreditation	Independent assessment and approval of an organisation (e.g. certification body, laboratory), management system, product, or person against agreed standards (e.g. ISO) to carry out their conformance activity (e.g. audit, testing).
Agrichemicals	A broad term encompassing all chemicals used in agriculture, including pesticides (insecticides, fungicides, herbicides), growth regulators and fertilisers. Agrichemicals can be applied pre-harvest or post-harvest to protect crops, enhance production or preserve product quality.
Allergen	A food allergen is an ingredient or product that causes an allergic reaction in a susceptible person. A person can be allergic to substances that are not on the list of food allergens that are required to be declared under the mandatory labelling requirements of the Australia and New Zealand Food Standards Code. Allergens can cause symptoms such as skin rashes, swelling, breathing difficulties or, in severe cases, potentially fatal anaphylaxis. The most common allergens are peanuts, tree nuts, milk, eggs, sesame seeds, fish, shellfish, soy, lupin, wheat and sulphites (>10 mg/kg).
Approved supplier	A supplier who has been checked, approved and documented by the business to provide a product or service that meets defined specifications. Is an individual or business that supplies materials (e.g. pallets) or services (e.g. technical advisor, agronomist).
AS4454:2012 Composts, soil conditioners and mulches	An Australian Standard that specifies requirements for organic products and mixtures of organic products that are to be used to amend the physical and chemical properties of natural or artificial soils and growing media.
Aseptic sampling technique	A method of collecting a sample to ensure that microbiological contamination does not occur during sampling. This means that the sample should not come into contact with anything that is not sterile. Team members required to collect samples aseptically should receive appropriate, documented training.
Assurance programme	A structured conformity system that provides independent assessment and certification of a product, process, or service against agreed food safety standards
ATP testing	Adenosine triphosphate (ATP) is an energy-rich compound present in all plants, animals and microorganisms. Rapid hygiene monitoring tests can determine the effectiveness of cleaning by measuring the amount of ATP present in any remaining food residues and microorganisms.
Audit	Comprehensive evaluation to assess whether a food business complies with procedures designed to meet food safety standards and regulations.
Australian Pesticides and Veterinary Medicines Authority (APVMA)	Australian government authority responsible for the assessment and registration of agricultural and veterinary chemical products.

Term	Definition
Best-before-date	Date printed on food container or package, advising the date to eat an appropriately stored food by before its sensory quality (favour, texture) starts to deteriorate. Foods with a best-before date can usually be consumed for a while after the best-before date.
Biofilm	A community of microorganisms and associated extracellular products (polysaccharides, eDNA, proteins, lipids) growing on a surface. The extracellular matrix (slime layer) enhances the survival of the microbes in hostile environments and increases their resistance to sanitisers and other stressors (UV, heat, drying).
Biosolid	Solid or semisolid by-product obtained from treated human sewage or wastewater.
Calibrate	To check, adjust, make corrections or determine accuracy by comparison with a standard.
Certification	Formal process of verifying that a person, product, system, or organisation meets specific standards or requirements, typically via independent assessment.
CFU	Colony forming unit. A count of colony forming units estimates the number of viable cells in a sample. It assumes that each colony of cells growing on a standard sized petri dish plate is separate and has arisen from a single cell. To ensure that individual colonies can be counted, the sample is diluted in a suitable diluent and a range of dilutions is added to agar plates. After the cells have had time to replicate and form visible colonies, the number of colonies are counted and the result expressed as CFU per g or ml of the original sample.
Chemical	Chemical compounds are substances composed of two or more types of atoms bonded together. In the context of food safety, the term chemicals refer broadly to both naturally occurring and manufactured substances that may come into contact with food or food production environments. These include: • agricultural and pest control products such as insecticides, acaricides, herbicides, fungicides, growth regulators, pheromones, and other organic treatments used to control pests, diseases, weeds and plant growth. These may be applied on or around the property, within production areas or directly on harvested produce • post-harvest chemicals such as fruit waxes, sanitisers and fungicides applied to maintain product quality and safety after harvest • cleaning and maintenance chemicals including cleaning agents, sanitisers, greases, oils and lubricants used in equipment maintenance or facility hygiene • other substances of concern such as heavy metals, naturally occurring toxins and allergens.
Cleaning agents	Chemicals used to remove contaminating material (soil) from equipment, processing and storage facilities.

Term	Definition
CODEX	The Codex Alimentarius Commission (Codex) is the international food standards setting body established by the United Nation's World Health Organization and Food and Agriculture Organization. Codex develops international food standards, guidelines and codes of practice that contribute to the safety, quality and fairness of food trade.
Competent	Demonstration of knowledge and skills to complete tasks to specified performance criteria.
Contamination	The introduction or occurrence of a direct or indirect food safety hazard to produce. Types of contamination include physical, chemical (including allergen) and microbiological. Contamination may be introduced via growing sites, water sources, packing facilities, team members, pests or other sources.
Control measure	Any action and/or activity that can be used to prevent, eliminate or minimise food safety hazards to an acceptable level.
Corrective actions	Any actions to be taken when the results of monitoring at the CCP, indicates a loss of control or trend towards loss of control. These should include actions that prevent a possible recurrence of the same failure.
Critical Control Point (CCP)	A process step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.
Critical limit	A value that separates safe product from potentially unsafe product. Critical limits are usually measurable values which need to be achieved such as temperature, water activity, time or pH values.
Extraneous Residue Limit (ERL)	The maximum permitted limit of a pesticide residue, arising from environmental sources other than the use of a pesticide directly or indirectly on the food that are no longer registered.
Exclusion period	The time between the use of an input (e.g. pre-harvest water, fertilisers, soil amendments) and the intended harvest date of the crop.
Facility	A structure or building in which produce is grown, packed or stored.
Fertilisers and soil amendments	Products that are to improve plant growth or enhance soil structure. Examples include inorganic (chemical) fertilisers such as lime and gypsum; organic amendments such as animal manure, sawdust, compost, compost tea, seaweed, fish-based products, other biological compounds and those derived from food waste.
Flood event	The submersion of a growing site or edible portion of a crop by water from a source which may contain microbial or chemical food safety hazards. Pooled water (i.e. after rainfall that is not reasonable) likely to cause contamination of the edible portion of fresh produce is not considered to be a flood event.
Food defence	The protection of food products and raw materials from intentional contamination or adulteration. Food defence deals with the prevention, protection, minimisation, response and action to be taken if a food defence vulnerability or threat is identified.

Term	Definition
Food fraud	The deception of consumers for economic gain by providing food, ingredients or packaging which is different to that specified. It can include presentation of substandard products as well as adulteration of food with undeclared or low-quality ingredients.
Foreign object	Any material that is not intended to be present in or with the product. Examples include, but are not limited to glass, hard plastic, wood, metal, paper, string, tape, maintenance debris, pens, paperclips, staples, packaging, personal effects (i.e. mobile phones).
FSANZ	Food Safety Australia and New Zealand. A Government agency responsible for developing and administering the 'Australia New Zealand Food Standards Code'.
FSMS	Food Safety Management System. A systematic, organised plan that a food business uses to guarantee the safety and appropriateness of the food they produce, preventing foodborne illnesses and protecting public health. It involves identifying hazards, implementing control measures (often based on HACCP principles), monitoring these controls, and keeping records to ensure the food is safe at every stage of the supply chain.
GAP	Good Agricultural Practices. Practices used to prevent or minimise the risk of hazards occurring during growing, harvesting, packing, storage and transport of produce.
GHPs	Good Hygienic Practices. A set of guidelines for preventing contamination and ensuring food safety, encompassing personnel hygiene (i.e. handwashing) and the wearing of appropriate PPE, cleaning and sanitising equipment and surfaces, appropriate food handling (i.e. preventing cross-contamination, cooking thoroughly), maintaining temperature control, effective pest control and ensuring a clean and well-designed facility. Adhering to GHPs is fundamental for reducing foodborne illnesses.
GFSI	Global Food Safety Initiative. An independent forum made up of major retailers, food service companies and manufacturers with the aim of improving food safety. It benchmarks International Standards, leading to international recognition of audit results.
GMPs	Good Manufacturing Practices. A set of regulations and guidelines that ensure food is consistently produced and controlled to meet food safety and quality standards and protect public health. GMP minimises risks such as contamination and errors by establishing comprehensive systems for premises, equipment, team member training, raw materials, process validation and detailed documentation of every step in the manufacturing process.
Growing site	Areas or structures where produce is grown which differs from another based on-site history or characteristics; inputs to the growing system (i.e. different irrigation water supply, types of produce are grown) or where produce is treated differently (i.e. different chemical treatments).
GS1	GS1 is a global, not-for-profit organisation that develops and maintains standards for supply chains across industries, for example traceability.

Term	Definition
GS1 Databar	GS1 Databar is a barcode format used on individual loose produce, applied via 'price look up' (PLU) stickers: it encodes the GTIN and enables item-level traceability even when no packaging is present.
GS1 DataMatrix	GS1 DataMatrix is a two-dimensional barcode used on pre-packaged produce: it can carry additional information such as lot numbers and use-by dates alongside the GTIN; supporting faster and more precise recalls and the DataMatrix can be printed directly on packaging or on applied labels.
GTIN	Global trade item number. This is a unique product identifier assigned to all items traded in the supply chain. It links to master data such as variety, pack size, unit of measure, brand and/or origin and forms the foundation for barcode labelling and traceability.
Hazard Analysis Critical Control Point (HACCP)	A systematic, science-based food safety management system that identifies, evaluates and controls hazards (e.g. physical, chemical including allergen and microbiological), throughout the entire food production chain. It's a preventative approach designed to ensure food safety from farm to table by establishing and monitoring the effectiveness critical control points to reduce hazards to acceptable levels.
Hazard	A physical, chemical (including allergen) or microbiological agent in fresh produce that can potentially cause injury or illness to a consumer if not controlled. A quality hazard is any factor that prevents produce from meeting customer, quarantine or legal requirements.
Hazard Analysis	The method of identifying potential hazards, assessing the significance of the risk posed by each hazard and determining the practices that prevent or satisfactorily minimise the risk of the hazard being present at an unacceptable level.
Heavy metal	Usually defined as metals with a specific gravity of four or more, meaning they are at least four times heavier than water for a given volume. Some (not all) heavy metals are toxic, particularly cadmium, lead and mercury.
Herbicides	Chemicals used to control unwanted plants or weeds.
Illness	A disease, condition or period of sickness affecting the body. Illnesses that can contaminate and be passed on through food include (e.g. norovirus, Hepatitis A virus (HAV) *Giardia*, *Salmonella*, *E. coli* (STEC), *Listeria monocytogenes* and *Campylobacter*).
Internal audit	An audit conducted by the business to review its own processes and system management.
ISO 17025	An internationally recognised standard that specifies the general requirements for organisations to be deemed competent to carry out tests and/or calibrations, including sampling. It covers testing and calibration performed using standard methods, non-standard methods and laboratory-developed methods. It is applicable to all organisations performing tests and/or calibrations (i.e. laboratories).

Term	Definition
Laboratory	External testing should be completed by a laboratory that operate a quality management system that complies with the requirements of international standard ISO/IEC 17025. If so, they should be accredited to: • National Association of Testing Australia (NATA) • International Accreditation New Zealand (IANZ). The scope of the accreditation will reference the relevant microbiological and/or chemical analysis methods available.
LOD/LOR	Limit of detection/limit of reporting. The lowest quantity of a chemical substance that can be detected by the laboratory within statistical confidence limits.
Lot (or batch)	The Food Standards Code defines a lot as: An amount of a food that the manufacturer or producer identifies as having been prepared or from which foods have been packaged or otherwise separated for sale, under essentially the same conditions, for example: (a) from a particular preparation or packing unit; and (b) during a particular period of time ordinarily not exceeding 24 hours.
Manure	Organic matter, primarily animal waste such as faeces and urine, which can include bedding material (straw), that is used as a natural fertiliser to enrich soil and improve crop yields. Manure can contain a wide range of pathogenic bacteria, viruses and protozoa. Applying manure too close to harvest can pose food safety risks. Prior to use manure should be aged or composted to reduce pathogens levels.
Mass balance	The quantitative reconciliation of process inputs to process outputs minus yield adjustments, rework and waste. Also known as 'Quantity check'.
ML	The maximum level of a specified contaminant, or specified natural toxicant, which is permitted to be present in a nominated food expressed, unless otherwise specified, in milligrams of the contaminant or the natural toxicant per kilogram of the food (mg/kg).
MOAH	Mineral Oil Aromatic Hydrocarbons. Considered to be a significant concern because some of them are linked to genotoxicity and carcinogenicity (cancer-causing effects) in humans.
MOH	Mineral oil hydrocarbons. Complex chemical mixtures derived from crude oil, coal, natural gas or biomass, consisting of mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH). These substances can enter food through various pathways, including environmental contamination machinery lubricants and food contact materials (e.g. packaging, inks).
MOSH	Mineral oil saturated hydrocarbons. While their concentrations in food are monitored, it is generally accepted that they do not pose a risk to public health at the current levels of exposure.

Term	Definition
MPI	Ministry for Primary Industries (New Zealand). They provide policy and regulatory advice, market access and trade services, and manage major regulatory systems of biosecurity, food safety, forestry, fisheries management, and animal welfare.
MPN	Most probable number (of microbes in a sample). It involves serial dilutions of a sample into multiple tubes of liquid growth medium, followed by incubation and observation for growth (indicated by a colour change or turbidity). The pattern of positive and negative tubes is then matched to a standard MPN table to provide an estimate of the original microbial count per unit volume, often with a 95% confidence interval.
MRL	Maximum Residue Level. This is the legal limit for a specific residue (agricultural chemical or veterinary medicine) in food. MRLs are set at levels that are unlikely to be exceeded if chemicals are used according to label instructions.
NZFS	New Zealand Food Safety is a business unit of the Ministry for Primary Industries (MPI). They regulate the safety and suitability of New Zealand food.
Pathogen	Microorganism that causes illness or disease in human hosts (e.g. bacteria, virus, protozoa).
Pathogen reduction step	A process which results in at least a 2-log reduction in the number of viable pathogens on a product or in water. This is equivalent to 99% mortality. Pathogen reduction steps often involve application of a sanitiser (e.g. 100 ppm chlorine) but can also use a process such as curing or irradiation to achieve the same result.
PCBs	Polychlorinated biphenyls.
Pesticides	A subset of agrichemicals used to prevent, destroy, repel or control pests, including: • insecticides (targeting insects) • fungicides (controlling fungal diseases).
Pest control chemicals	Chemicals used to control pests such as rodents during production, processing and storage.
PFAS	Per- and polyfluoroalkyl substances. A large and diverse group of man-made chemicals. They are known for their ability to repel grease, water and stains. PFAS are known as 'forever chemicals' and persist in the environment, accumulating in soil, water and the human body. Exposure to certain PFAS has been linked to various health concerns, including potential effects on the liver, immune system and reproductive health. PFAS can contaminate produce through various pathways, including contaminated soils, water, food packaging or processing equipment.
Planting material	Seeds, seedlings, young plants, roots, corms, bulbs, bits and suckers used for planting to establish crops.
Post-harvest	Any activity that is undertaken to produce that has been harvested.

Term	Definition
Potable water	Water suitable for drinking. Potable water is required to meet several standards relating to mineral contaminants, pH and turbidity. The number of *E. coli* in potable water to be less than 1 cfu/100 ml, meaning *E. coli* cannot be detected in a 100 ml sample.
PPP	The Primary Production and Processing Standards (Australia only). In Chapter 4 of the FSANZ Food Standards Code. These standards establish food safety requirements for specific fresh produce categories, namely seed sprouts, berries, leafy vegetables and melons, with focus on activities and inputs ensuring produce is acceptable for human consumption.
Precautionary Allergen Labelling (PAL) statements	Used by food manufacturers to warn consumers of the risk that an allergen may be present in a food through cross contact (also known as cross contamination) during manufacturing or elsewhere in the supply chain. Examples of PAL statements include 'may contain x' or 'may be present: x'.
Pre-harvest	Any activity that is undertaken on-farm prior to the harvest of a crop.
Pre-requisite programmes	Essential over-arching food safety practices and conditions, which are required to ensure the production of safe food and are documented within a business's food safety programme.
Process hygiene criteria	Microbiological criteria used to verify hygiene measures or control of process at a specified point in the process.
Property map	Any combination of aerial photographs and topographical, cadastral or self-drawn maps or map overlays that document the relevant boundaries, infrastructure and features on or adjacent to, the property.
QACs	Quaternary Ammonium Compounds. A group of chemicals used for a variety of purposes including preservatives, surfactants and as active ingredients in sanitisers.
Qualitative tests	Tests that establish the presence or absence of an organisms in a quantity of a sample (produce, ingredient, water, soil), (e.g. the presence or absence of *Listeria monocytogenes* in a 25 g sample).
Quantitative tests	Tests that determine the number of organisms in a sample such as produce, ingredient, water, soil (e.g. 10 *E. coli* / 100 ml of water).
RCA	Root cause analysis. An Investigation to identify the cause of a failure of a process to meet set limits or criteria. The use of the fishbone and/or the 5-Why's process.
Repellents	Chemicals used to repel pests.
Representative sample	A sample drawn from a lot/batch which reflects as accurately as possible the properties of the entire batch from which it is taken. This may be comprised of composite samples taken at intervals over the production period or from a number of finished products.
Risk	The probability of an adverse health effect occurring due to a hazard in food, combined with the severity of that effect.

Term	Definition
Risk assessment	An assessment of both the likelihood and the severity of the consequences should a hazard be present. This gives a guide as to the overall significance of the risk.
Sanitisers (disinfectants)	Chemicals used to reduce microbial numbers on processing equipment, processing and storage facilities or produce.
Sample integrity	The microbiological integrity of the sample is crucial to obtaining meaningful results. The goal is to prevent both contamination of the sample and the growth of any pathogens which may be associated with the sample. This includes taking the sample aseptically and placing it into a sterile container. Securely transporting the sample to the testing laboratory, as quickly as possible under temperature-controlled conditions (where appropriate).
Sampling plans	Testing of food usually involves either 2-class or 3-class sampling plans: **2-class sampling plans** are performed when a microorganism of concern is not permitted in the food and are described using the terms n, c and m. Used for testing the presence or absence of an organism such as (e.g. *Salmonella spp*). For example: n=5, c=0, m= not detected n = number of samples units to be drawn randomly from a lot/batch c = maximum number of sample units yielding a positive result. For pathogens this is usually set at zero m = microbiological limit (separates a good result from an unacceptable result) **3-class sampling plans** are adopted if an acceptable level of microorganisms is permitted in a unit volume and involves quantitative testing. The plans separate good results, from marginally acceptable results and unacceptable results using the m and M. For example: n=5, c=1, m=1, M=10 m = microbiological limit which separates good results from marginal results c = the maximum number of samples which may exceed the limit given for m M = microbiological limit above which results are unacceptable or defective. The term m reflects the upper limit under good manufacturing practice (GMP), while M marls the limit beyond which the level of contamination is considered hazardous, unacceptable or indicative of an ineffective control.
Shelf life	The period of time when a food product remains safe and suitable for consumption when stored at recommended conditions.
Smart sensors	Devices that provide precise and accurate measurements of various parameters such as temperature, humidity, pH level, and microbial activity. This ensures real time detection of deviations from optimal conditions, allowing for prompt corrective action.

Term	Definition
Spore	Dormant forms of bacteria and fungi. Spores survive unfavourable environmental conditions, allowing the organism to persist and potentially germinate when conditions improve.
Supply chain	The integrated sequence of activities through which food progresses from primary production (farm) to the consumer's table.
Team members	All people working in the business, including family members, staff and contractors working on the property or in the business.
Thermo- tolerant coliforms	A group of bacteria, including *E. coli*, that grow at 44.5°C and are used as an indicator of recent faecal contamination in water and food. Thermotolerant coliforms are common in the environment and include bacteria whose natural habitat is the human intestine. Most do not cause illness, however a positive test for thermotolerant coliforms can indicate that other, pathogenic, bacterial species may also be present.
Traceability	The ability to follow the movement of a food product and its ingredients through all steps in the supply chain, both backward and forward.
Treated product	Fertiliser or soil amendment containing animal faeces (manure) that has been subjected to a process that minimises food safety risks. This is usually defined as certification to the Australian or New Zealand standards AS4454-2012 or NZS 4454-2005 or equivalent. These require five exposures of organic materials to ≥55°C for three consecutive days, with the pile turned (aerated) between each heating event. The total treatment time is therefore over fifteen days.
Turbidity	The haziness or milkiness of a liquid, caused by fine particles scattering light.
Use-by-date	The date on or before a product should be consumed. Foods should not be eaten after the use-by date as they may pose a health risk. Food cannot be legally sold after this date.
Validation	Obtaining evidence that a control measure or combination of control measures, if properly implemented, is capable of controlling a hazard to a specified outcome.
Verification	The application of methods, procedures, tests and other evaluations, in addition to monitoring to determine whether a control measure is or has been operating as intended.
WGS	Whole Genome Sequencing. A method that identifies the complete DNA sequence of an organism's genome (genetic material). Increasingly used to facilitate the detection, investigation and control of outbreaks of foodborne illness and food regulatory action.
WHP	Withholding period. The required time period that is required to elapse between a crop treatment and harvest.