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Melon food safety

A best practice guide for rockmelons and specialty melons

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A best practice guide for rockmelons and specialty melons

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Melon food safety: a best practice guide for rockmelons and specialty melons

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Contents

Introduction

Food safety is a continuing challenge for fresh horticultural produce industries including the melon industry. Foodborne illness outbreaks linked to horticultural produce cause huge economic and reputational damage to the industry and loss of consumer confidence. Product recalls, decreased sales, suspension and possible termination of suppliers' contracts as well as legal costs are the main contributors to the economic losses. In addition to the losses to growers, the suffering of the consumers and their families cannot be estimated in monetary terms. Consuming contaminated produce can lead to sickness among consumers and even deaths. Children, the elderly and pregnant women are vulnerable to severe effects due to their compromised immune systems. The melon industry has a responsibility to strengthen food safety systems through evidence-based risk assessment and cultural change to prevent food safety incidences.

Microbial contamination is the greatest challenge for the melon industry (especially rockmelons) worldwide, including Australia. The proximity of rockmelons to soil during production and netted rough skin are key factors predisposing the fruit to contamination. Bacteria such as *Salmonella* species and *Listeria monocytogenes* are the most common foodborne pathogens implicated in human illnesses arising from consuming contaminated rockmelons. There are multiple sources and routes of melon contamination in the field and after harvest. These need to be recognised and understood by all growers, packers and supply chain operators, especially as the produce can be contaminated at any stage along the supply chain.

Supplying safe produce for human consumption is the responsibility of everyone involved in the supply chain and is fundamental to any food business.

Growing produce in open fields creates a number of complex risk factors, therefore, knowledge of food safety risks and the procedures to minimise those risks can help achieve the safe supply of produce. Preventing contamination is the most effective and economical approach to minimising contamination risks and the basis of prevention is an understanding of potential sources and routes of contamination.

Consumer confidence and trust built with marketing and promotion campaigns are negated by food safety incidents. The supply of contaminated produce from just one farm can lead to collateral damage to other melon growers, packers, exporters, importers and retailers. A proactive and preventative approach to food safety across the supply chain is thus better than a crisis response to food safety incidents. Consequently, this best practice guide aims to:

1. strengthen knowledge and adoption of best practice in food safety for melons across the supply chain by developing evidence-based and practical resources
2. develop food safety capacity across the supply chain
3. reinforce a food safety culture in the industry.

About this guide

The melon industry has great diversity in production and postharvest handling methods. Regardless, the basic principles that underpin food safety programs should be followed by all growers and packers to minimise food safety risks. The industry recognises the importance of implementing food safety programs based on risk assessment techniques and preventing contamination. Once contaminated, the fruit cannot be completely decontaminated or sanitised by removing or killing microorganisms. A preventative approach is thus the most effective strategy to mitigate food safety risks. This guide covers food safety principles and practices pertaining to preharvest and postharvest handling of melons that are generally washed before shipping to markets.

The term 'melons' in this guide refers to rockmelons (*Cucumis melo*), honeydew melons (*Cucumis melo* var. *inodorus*), galia melons (*Cucumis melo* var. *reticulatus*), horned melons (*Cucumis metuliferus*), charentais melons (*Cucumis melo* var. *cantalupensis*), Korean melons

(*Cucumis melo* var. *makuwa*), hami melons (*Cucumis melon* var. *reticulatus*) and piel de sapo (*Cucumis melo* var. *inodorus*). However, this guide does not provide guidance on fresh watermelons and pre-cut melons.

The major focus is on reducing microbial food safety risks by informing all personnel involved of the potential sources and routes of contamination based on the best available science that has been proven to effectively reduce, control or eliminate microbial contamination in melons. Potential microbial food safety hazards associated with fresh produce including melons is included in the appendix. The aim is to provide the basic knowledge of the microbial hazards and their key control measures to effectively prevent contamination. This guide will cover major microbial risks and their management at each step along the farm-to-fork continuum. The steps involved in a typical supply chain of rockmelon and specialty melons are shown in Figure 1.

The main purpose of this guide is to provide practical food safety resources for everyone involved in the supply chain because they should have knowledge in identification, assessment and management of potential food safety hazards in growing and supplying melons.

This document is not intended to supersede other established food safety programs that are based on good agricultural practices (GAPs) and hazard analysis critical control points (HACCP). This guide is meant to be considered as a supplement to existing food safety resources. However, some sections in this guide (e.g. fruit washing and environmental monitoring) are comprehensively covered with the latest scientific information to assist in addressing food safety risks specific to rockmelons and specialty melons.

The guide is a compilation of available information and is offered with reliability and good faith without any warranty, expression or implication as to its fitness for a particular purpose or any other matter. The industry practices related to rockmelon growing and postharvest handling are highly variable across Australia. Therefore, it is important that melon businesses consider the recommendations in this guide when developing their own business-specific food safety plans in compliance with local, state and federal laws and regulations. If the business is export-focused, they should also consider their compliance with regulatory requirements in the export markets.

Figure 1. Fresh rockmelon and specialty melon supply chain.

Safe melons initiative

'Safe Melons' is an initiative of the New South Wales Department of Primary Industries (NSW DPI) that is aimed at safeguarding the Australian melon industry and consumers against food safety risks. The initiative is based on a whole-of-chain approach to mitigate food safety risks along the melon supply chain. A preventative and proactive strategy is adopted to manage food safety risks to the industry and consumers. During 2014–17, the initiative was co-funded by the NSW DPI and the Australian Centre for International Agricultural Research (ACIAR). From June 2018 onwards, Hort Innovation's investment (VM17002) through the Melon Fund supported the initiative, which intensified the project activities nationally and widened the range of stakeholders to include growers, packers, exporters, food and health regulators and other supply chain participants (Figure 2). As part of this initiative, this guide is targeted to train and educate all supply chain participants about managing microbial food safety risks involved in growing and supplying rockmelons and specialty melons.

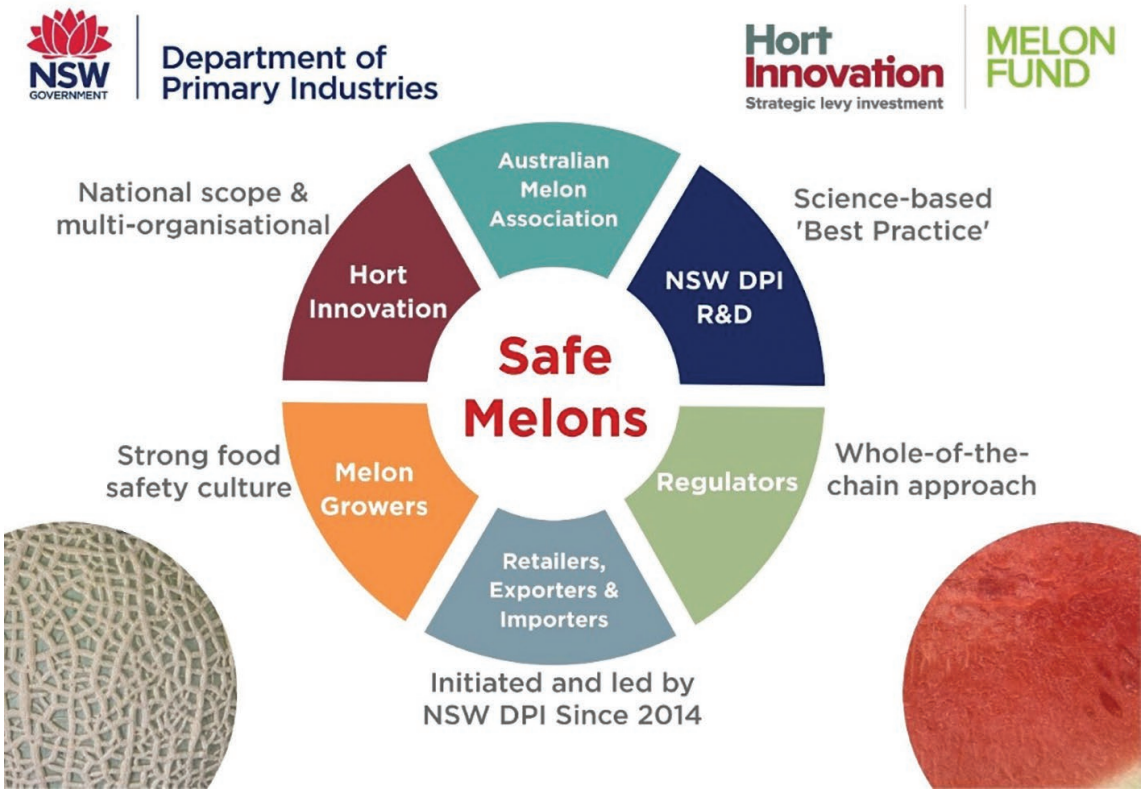


Figure 2. The aim, scope and partners in the safe melons initiative.

Managing preharvest microbial food safety risks in melons

Ground contact

Being in close proximity or having direct contact with soil increases the chances of melons having surface contamination from pathogens such as *Listeria* and *Salmonella* that are found in soil. While in contact with the ground, rockmelons develop ground spots (Figure 3), which are thin and have an undeveloped rind that lacks the mature complex netting, resulting in increased susceptibility to fungal and bacterial growth. These ground spots also have the potential for the internalisation of microbes during postharvest washing (Castillo et al. 2009). Melon ground spots have significantly greater microbial populations than non-ground spot areas of melon rind (Parnell et al. 2005). Using plastic mulch can minimise the risk of pathogen attachment at ground spots.

Figure 3. Ground spots on rockmelons, highlighted in red circles.

Agricultural water

Applying contaminated water in farm operations such as when irrigating and applying pesticides and nutrients can spread pathogens on to fruit and soil. Ensuring microbial water quality is thus critical to mitigating food safety risks in melon production. Among different sources of agriculture water, surface water sources (e.g. rivers, ponds and creeks) are more likely to be variable in their microbial quality compared to groundwater. On-farm and upstream sources of contamination such as compost piles, manure heaps, livestock and wildlife should be carefully monitored and appropriate actions implemented to mitigate the risks.

Water quality is an important risk factor and needs to be managed through regular monitoring and testing, not only for chemical attributes but also for microbiological parameters. Farm-specific risk assessments are required to ensure adequate monitoring of agricultural water quality. Weather such as rainfall and floods can significantly alter the microbiological quality of surface water and need to be considered by growers depending upon the sources of water.

Water sources

There are many sources of agricultural water with each varying in potential pathogen load and contamination risk. Surface water is the most common water source in the melon industry and includes dams, streams and rivers (Figure 4 and Figure 5). The risks associated with these sources increase with proximity to high-density domestic or wild animal populations, human waste and animal product processing facilities. The highest risk occurs when animals are allowed into the water source. Water quality is often unpredictable for rivers, streams and creeks as activity upstream can greatly influence contamination downstream. Another source is groundwater, which is pumped from deep bores underground and considered fairly safe. Direct faecal matter is unlikely to contaminate this source unless the bore from which the water is extracted is close to a major faecal contamination source or geology allows for drainage into groundwater.

Figure 4. An agricultural water channel (unlined).

Water sources vary in quality and are constantly fluctuating due to seasonal and geological changes including rainfall, flooding and drought. Contamination risk for water sources is highest for surface water, less for groundwater and lowest for reticulated/domestic water. When assessing contamination risks to water sources, there are a number of factors to consider, such as:

- the type of water source (as described above)
- rainfall levels
- the possibility of run-off
- the topography of the surrounding area
- the proximity to sewage/septic exposure and other sources of pollution (manure, garbage and livestock)
- animal activity in the area.

Figure 5. A concrete-lined agricultural water channel.

Irrigation methods

There are three irrigation methods currently adopted by the melon industry and the method chosen will affect the contamination risk to the fruit (Uyttendaele et al. 2015). Above surface or sub-surface drip irrigation is the most common method. It involves applying water very slowly to the soil surface or into the root-zone below the surface using drippers, porous tubes or sub-surface pipes. It is best practice to use drip irrigation wherever possible as it minimises the exposure of fruit to the irrigation water and thus reduces the risk of crop contamination from contaminated irrigation water. Furrow irrigation, which is rarely used in melons, involves flooding water across the soil surface between raised trenches of soil. Overhead spraying or sprinkler methods also involve spraying water over the soil surface mimicking natural rainfall. If the water used is contaminated, then it will pass on that contamination to the crops and fruit, which is of particular concern if the water is applied closer to harvest time.

Irrigation water quality standards

It is generally not feasible nor warranted to test irrigation water for the wide range of water-borne microbial pathogens that might affect human health. In practice, water supplies are more commonly tested for thermotolerant coliforms (also known as faecal coliforms), to give a general indication of faecal contamination and thus the possible presence of microbial pathogens. According to the guidelines for irrigation water from the Australian and New Zealand Environment and Conservation Council (ANZECC 2000), the suitability of agricultural water should be based on population trigger values for thermotolerant faecal coliforms for raw human food crops which are:

- in direct contact with irrigation water: < 10 cfu/100 mL
- not in direct contact with irrigation water: < 1,000 cfu/100 mL

These guidelines can be used to determine the suitability of irrigation water for melon production. For example, the level of thermotolerant/faecal coliforms in irrigation water should be less than 10 cfu/100 mL for sprinkler irrigation and less than 1,000 cfu/100 mL for drip irrigation.

Contamination sources of irrigation water

Depending on the water used for irrigation, there are many factors that can affect its quality including:

- rainfall can create polluted run-off by washing contaminants including faecal matter from bank sides into the water flow and by re-suspending sediments containing microbes, making them easier to be picked up by a water source
- some water sources can receive water from streets and grazing lands and some of this run-off can be diverted to irrigation canals
- when using flood field irrigation, remaining water might be returned to canals and used to irrigate other fields; 'run-to-waste' is considered best practice
- bird activity, especially by large numbers of waterfowl, can contribute to bacterial contamination of water with pathogens such as *Campylobacter*
- animal activity near a water source can cause contamination as faecal matter can be washed into the channels by rainwater
- water can be contaminated through biofilms present in irrigation infrastructure
- water from rivers and creeks can be contaminated with microbes especially if it flows close to areas with intensive livestock activity or areas with a high human population
- chemical contamination can occur if the water flows close to industrial or agricultural areas that might release chemicals into the water; it can also be contaminated with toxic algae
- water from dams can be contaminated by run-off and entry of livestock or birds
- underground water is considered safer than surface water but can also be contaminated through seepage of septic systems into aquifers
- tank water can be contaminated by microbes through birds, pest and other animal faeces found on the roof or gutters where water collects.

Recommendations

- document the water source(s) for each field
- identify potential contamination sources of water at the source and take necessary measures to prevent the contamination reaching the water source
- water holding facilities (e.g. dams or tanks) and equipment for distribution should be considered as potential sources of contamination
- follow appropriate water treatment methods and regularly test the microbiological quality of water to ensure it is consistent with food safety certification standards
- analyse and maintain microbiological testing records of agricultural water
- microbial water testing should be conducted in case an animal incursion into the dam or flooding might have changed the water quality
- drinking quality water should be used for applying agricultural chemicals to minimise the microbial and blue-green algal toxin contamination risks.

Soil amendments

Soil amendments are physical, chemical and biological materials added to the soil to improve its health, nutrition and crop productivity. These include inorganic fertilisers, manure, compost, raw mulch, biochar, biosolids, fish/animal by-products, seaweed extract, rock phosphate, lime, gypsum or sawdust. Using manures and composts as soil amendments is common in horticultural production systems. The microbial content of manure or compost will vary depending on its origin, composition and treatment. The biggest risk comes from manures or other materials of animal origin that have not been treated to reduce pathogen load. Untreated, inadequately treated, or recontaminated manure might contain pathogens with significant health risk that can contaminate produce. This risk increases for melons where the fruit is grown in contact with soil and

is eaten raw or uncooked. Using plastic mulch reduces the risk of soil-borne microbial contamination (Figure 6). Fruit grown without a plastic mulch bring a large quantity of soil and dirt into the packhouse (Figure 7).

Figure 6. Using plastic mulch reduces the risk of soil-borne microbial contamination.

Figure 7. Rockmelons grown without plastic mulch bring a lot of soil and dirt into the packhouse.

Although many microorganisms found in soil do not pose a threat to humans, soil does provide a home for human pathogens. Many human pathogens found in agricultural soils originate from faecal contamination by animals and humans. Livestock can easily contaminate agricultural soils with pathogenic microorganisms. Wildlife, rodents, birds and pets can also introduce faeces to growing sites. While it is not possible to completely exclude all animal life from production areas, effective measures should be taken to prevent animals from entering the fields and maintain buffer zones. Some important pathogens and parasites that can be found in soil due to natural and livestock contamination include *Escherichia coli*, *Salmonella* spp., *Listeria monocytogenes*, *Campylobacter* spp., *Clostridium perfringens*, *Clostridium difficile*, *Cryptosporidium* spp., *Giardia* spp., *Toxoplasma gondii*, *Yersinia enterocolitica* and *Y. pseudotuberculosis*.

The persistence and survival of pathogens in soils is influenced by a range of factors such as exposure time, soil temperature, pH, moisture, relative humidity, tillage, sunlight, predators, microbial competition present in the soil, soil characteristics, climate, type of soil amendment and how the amendment is used.

Microbial contamination risks are reduced when soil amendments containing manure undergo treatment where they are exposed to extended periods of high temperatures, killing pathogenic microbes. If purchasing treated fertiliser and soil amendments, evidence of appropriate treatment must be obtained from the supplier including treatment method and microbial test results (in accordance with Australian Standard AS 4454-2012). Growers who have their own compost-making facilities should ensure the effectiveness of their processes through regular monitoring, data recording and microbiological testing of the compost before applying it in the field.

Recommendations

- soil amendments containing untreated or raw animal manures MUST NOT be used in melon production fields
- avoid using treated composts containing animal manures or poultry litter
- if compost is applied, document the source of the compost and its microbial quality test report
- improving soil health through crop-based manures and crop rotation are safer alternatives.

Environmental factors

Contamination can occur at any time throughout the supply chain from the initial crop planting through to delivery to the consumer. There are a number of environmental factors that might influence contamination during preharvest including the location of production fields, irrigation source, potential wildlife habitats, livestock, residential areas, roads, fences, adjacent land use and slope of the land. The influence of weather on contamination routes should also be considered.

Site location

Growing sites should be assessed for possible microbial, chemical or physical contaminants. If hazards are found they should either be removed or managed through crop choice, management and timing. Knowledge of the site's history and other factors that might be present in the surroundings are important to minimise contamination risks and are beneficial in uncovering previously undetected/unexplained risks (such as groundwater contamination). This information, along with the previous exposure of the site to significant environmental events such as flooding or dust storms can help assess the suitability of the site.

Before selecting the production field site, potential sources of microbial contamination from land use as well as neighbouring properties should be examined. Land previously

used for cattle feedlots, dairy and poultry waste disposal and council waste are some of the more notable sources of foodborne pathogens. Contaminants on adjacent properties can be distributed into the production site via surface run-off, wind, traffic, animals and human movement. Neighbours' livestock or poultry operations and their water run-off carrying animal faecal matter could potentially spread contaminants to the field site depending on the slope, direction of flowing water and drainage system design.

Wildlife (e.g. deer, rodents, reptiles and birds) also harbour a number of foodborne pathogens (e.g. *Salmonella*) in their gastrointestinal systems and might spread contaminants by defecating in the field or irrigation water source. Although it is difficult to control wildlife movement in and around the production fields, it is an important food safety measure. Access to wildlife and potential risks should be considered while selecting the field site. The food safety hazards associated with wildlife should be managed appropriately as permitted by local, state and federal government laws and regulations. Baits and poisons can also be used however, some animals such as rodents can carry poison baits into fields and packhouses, which can potentially expose produce to chemical risks. Baits and poisons should be pinpointed and maintained in order to prevent accidental spread.

Airborne pathogens also pose a serious contamination risk and their dispersal is determined by prevailing and seasonal wind directions. Providing vegetative buffers to serve as windbreaks can minimise the possibility of contamination by airborne pathogens from neighbouring livestock, poultry and composting activities. Buffer zones and vegetative barriers are not only effective against surface water run-off, but also against spray drift. Buffer zones reduce the extent of spray drift by allowing spray droplets to settle before reaching sensitive areas. Vegetative barriers also help by filtering out spray droplets in the air passing through their foliage.

Plant growth regulators, insecticides, fungicides and herbicides are applied to effectively manage production, plant protection and improve product quality. The potential chemical drift from neighbours and from the weed control programs of roads, railways and councils should be considered in chemical risk assessments.

Dust storms

Dust storms are common in some melon production regions (Figure 8). Dry and dusty conditions can cause problems with pathogen-contaminated soil and they increase melon crop exposure to wind-blown soil and sandblasting. Melons have very low tolerance to wind-blown soil, therefore managing the effects of dust storms and high-speed winds is critical to improve crop productivity and reduce dust load on harvested fruit. Since pathogens such as *Listeria* and *Salmonella* can be present in the soil, dust storms can cause contamination and increase microbial load on the fruit surface, thus reducing the efficacy of postharvest washing and sanitising processes.

Windbreaks are barriers used to reduce wind speed and provide a buffer between wind and crops. There are a number of options for windbreak selection, each with their own advantages and disadvantages depending on specific production systems and offering varying levels of protection.

Annual herbaceous plants such as wheat, barley and triticale (a hybrid of wheat and rye) are relatively easy to establish and maintain. Triticale and wheat are popular windbreaks in some melon production regions. These are planted in between every bed or every couple of rows and protect the crop from wind that can desiccate or physically injure the plants and reduces sandblasting in sandy soils.

Figure 8. A melon production field in a dust storm-prone region.

Perennial plants such as trees are often used as windbreaks surrounding paddocks (Figure 9). These can be used on their own or in addition to annual windbreaks used between crop beds. Perennial windbreaks can take around 10 years to reach mature height, but due to their life spans, once established they can serve as windbreaks for many years. Suitable perennial species include *Casuarina* and *Allocasuarina* species, evergreens, alders, melaleucas (can suffer from spring frost), hakeas (can become too dense), hybrid willows, sudax, barna grass (*Pennisetum purpureum*) and bamboo (potential weed problem).

Artificial alternatives do not compete with crops and can be installed yearly or be a permanent fixture (Figure 10). They can be used on the edges of annual crop fields or as strips running through the planting, similar to annual grain windbreaks. Artificial alternatives include plastic row covers or tunnels, plastic or wooden slat fences.

General disadvantages of windbreaks include their capacity to interfere with irrigation, the need for irrigation of annual herbaceous plants (before the crop), and grain windbreaks (e.g. oats) attract birds and can serve as a reservoir for pest and diseases.

Using windbreaks is recommended to minimise the food safety risks associated with dust storms.

Figure 9. An established perennial windbreak.

Figure 10. An artificial strip windbreak running through a planting.

Each farm is different and will have different requirements for windbreaks. An ideal windbreak should be positioned perpendicular to problematic winds (Figure 11). It is important to note that a windbreak provides two zones of protection: one to the leeward (downwind) side and a smaller one to the windward (the side from which the wind is blowing) side. The leeward distance of wind protection is directly proportional to the height of the windbreak (H), which can extend up to 10 H (Figure 12). Maximum reduction occurs within the zone from 3 to 6 H with 4 H as the mid-point of maximum wind reduction.

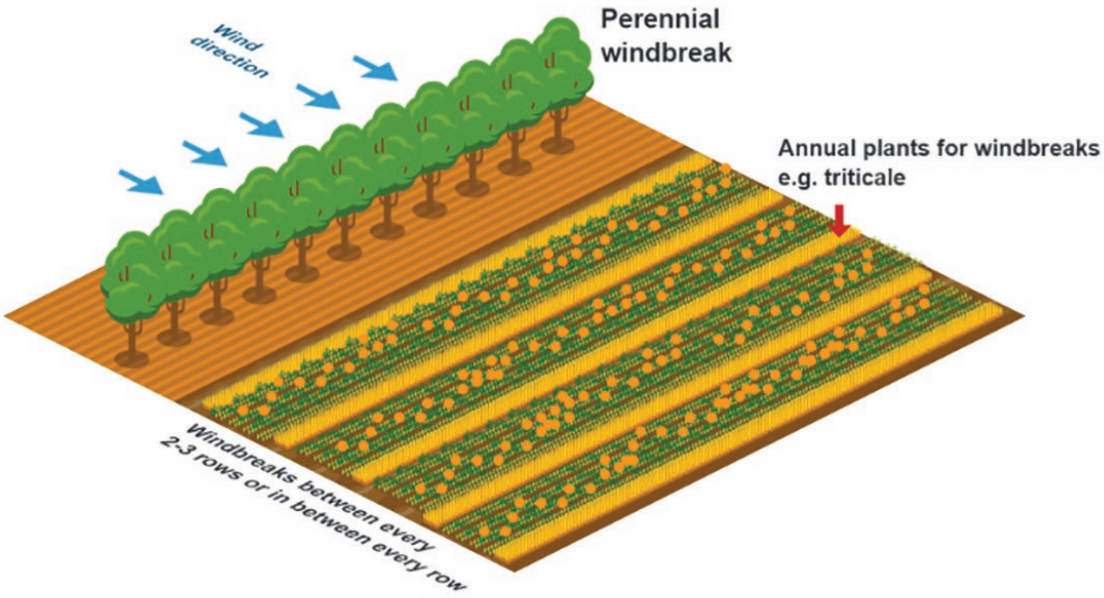


Figure 11. An ideal windbreak should be positioned perpendicular to problematic winds.

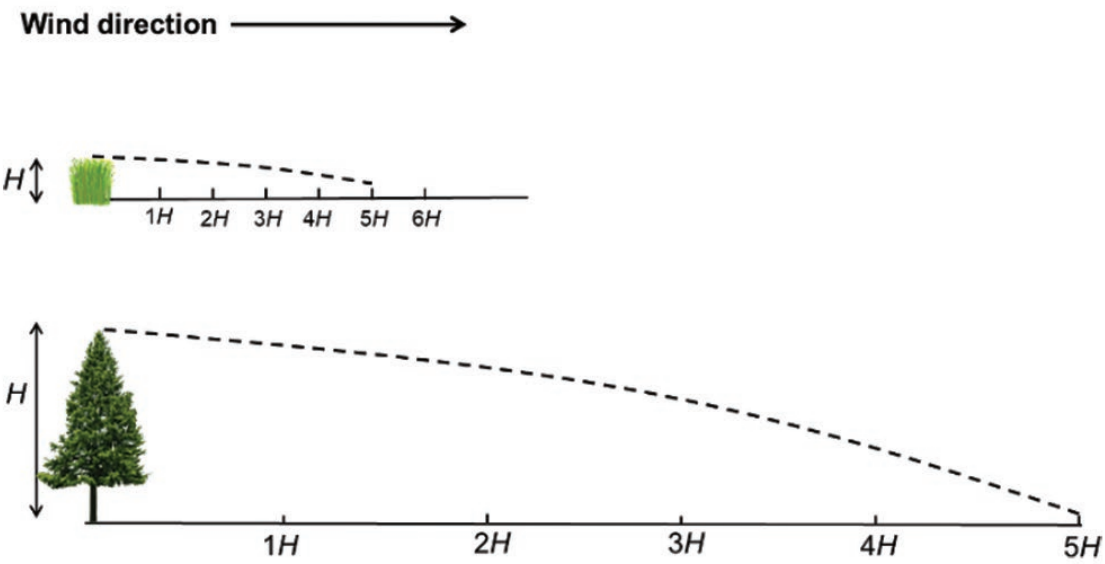


Figure 12. The leeward distance of wind protection is directly proportional to the height of the windbreak (H), which can extend up to 10 H.

Staff

Staff pose a significant risk for food safety and several food contamination incidents have been traced back to staff and their handling practices. Staff, contractors and visitors can become sources of contamination whether it is microbial, chemical or physical through personal hygiene practices, illness and cross-contamination.

Personal hygiene

Staff and visitors should be considered as contamination hazards as they can transfer human pathogens to produce via their hands, body and clothes. Some behaviour is also considered hazardous such as spitting, coughing and sneezing. Maintaining high personal hygiene standards, minimising or covering jewellery and wearing appropriate and safe clothing are all important in minimising contamination risk.

The most effective food safety practice is hand washing. Considered a basic procedure that all adults follow, it must not be overlooked as each person has a different background and might either have a different concept of hand washing or fail to exercise this knowledge. Thus it is important that all staff are trained in proper hand washing techniques with clear signage provided. It is critical that hands are washed before the start of work and after each visit to the toilet, blowing their nose, sneezing or coughing, touching their face, eating or smoking, touching animals, handling waste, performing maintenance on equipment, handling cleaning materials, handling chemicals and any break from work.

A good rule of thumb is, when an employee uses their hands for something other than the task they are assigned, they should wash their hands.

All employees and visitors should be given access to clean water, soap and single-use paper towels. It must be emphasised that cuts, wounds and sores must be covered securely with dressings and bandages and covered with a glove.

Gloves are a very common method of managing personal hygiene but they do not substitute for correct hand washing and other hygiene practices. When used correctly, gloves are an effective means of protecting employees and preventing contamination. However, dirty gloves can be a source of microbial contamination. Hands should be washed thoroughly before wearing gloves. Disposable gloves are preferable and should be changed frequently. This will help assure cleanliness and reduce potential pathogen growth on wet or dirty gloves.

Hair and beards raise the risk of physical contamination and should be secured in hair nets during fruit packing.

Clothing can also be a vehicle for microbes and chemical contamination. Outer garments should be clean with no loose buttons, hanging material or attachments.

Shoe covers might need to be worn, or shoes cleaned or changed.

Jewellery can also be a source of physical and microbial contamination and should not be worn during packing as it can get caught in or fall in packed produce.

Personal electronic devices such as phones and tablets can also be a source of microbial and physical (e.g. broken glass) contamination and should not be allowed to be used by staff in packhouses.

Illnesses

Staff, contractors and visitors who are unwell pose a risk of direct and indirect contamination of produce. Any person suffering from a gastrointestinal illness and having symptoms such as diarrhoea, vomiting, fever or jaundice must not have contact with produce during harvesting, packing and storage activities. People can remain infectious for some time after symptoms have passed and therefore should not return to work until they have fully recovered. Staff should be trained to inform and notify supervisors of any illness that could affect food safety.

Recovering staff should be assigned other duties on the farm so that they can still work but not contaminate produce, equipment or other personnel. This should encourage people to report illness when appropriate. Establish clear policies for reporting illness and reassigning staff. Staff recovering from a cold should take extra precautions preventing contamination through coughing, sneezing and nose blowing. Hand washing frequency should be increased and staff should remain vigilant in managing their personal hygiene.

Staff facilities

Staff should be provided with facilities such as meal rooms, change rooms and toilets at harvesting sites and in packing facilities. These facilities should have adequate hand washing stations with drinking quality water, soap, single-use paper towel and appropriate signage (Figure 13). Staff facilities should be clean and conveniently located for staff to use and enable compliance with personal hygiene requirements. Before staff enter facilities such as lunchrooms, change rooms and bathrooms, they should be trained to remove any protective clothing they are wearing and to wash their hands.

Hand wash stations should use clean potable water and include hot water if possible. Appropriate soaps and nail brushes should be supplied, along with single-use hand towels for drying and closed bins for waste. Towels, rags and cloths must not be used for drying as they can easily become contaminated and spread microbes. If used appropriately, air dryers can be used (hands must be left underneath long enough to thoroughly dry).

Clean toilet facilities must be made available to staff and visitors in the field and packhouses. Providing these facilities, in particular in harvesting fields (Figure 14), follows proper field sanitation practices, which helps reduce possible contamination risk of produce and protects both staff and consumers from foodborne diseases. Having a toilet close by reduces the chances of staff using inappropriate areas, such as the produce fields and surrounding areas. For every 20 people, there must be at least one toilet facility and one hand-washing facility. Staff should also be given the opportunity to use these facilities when they need to and not just during scheduled breaks.

Figure 13. Hand wash station with appropriate soap, single-use hand towels and signage.

Figure 14. Clean toilet and hand washing facilities must be made available in the field.

Training

Training is a critical part of managing the food safety risks linked to staff in both the field and processing facilities (Figure 15). Managers need to ensure staff are trained in the procedures and protocols for their duties as well as ensuring they understand the effects of contamination. It is important to teach staff about food safety and their role in preventing contamination. Staff should feel a sense of responsibility in their role in minimising risks and in turn follow correct protocols. Staff training should include:

- hand washing techniques and their significance
- what good hygiene is and why it is important
- procedures for using staff facilities e.g. bathrooms
- awareness of the possible foodborne pathogens and how they could cause cross-contamination in the workplace
- procedures and protocols for cleaning and sanitising.

The training should be provided to all staff in a format and language that is easily understood. Refresher courses should be run so that all staff can stay up-to-date with the procedures and protocols. There should also be occasional audits to determine if staff are following the correct procedures in both the field and packhouses. Effective signage is also recommended as visual aids and demonstrations are often more effective than simple explanations.

Figure 15. Training is a critical part of managing food safety risks.

Sabotage

A deliberate act of sabotage through contamination is a continuing food safety risk for horticultural industries. Growers must have a security plan for controlled access to the property with special attention and locking procedures in important areas such as fertigation or water tanks, pump houses, spray tanks, chemical storage rooms, packhouse and cold stores. Staff, ex-staff, visitors and contractors should be considered as risk factors when developing a sabotage prevention plan.

Managing microbial food safety risks when harvesting melons

Melon harvesting operations should be supervised to implement best practice (Figure 16).

Figure 16. Machinery, staff and portable toilets in a melon harvesting operation.

The following precautions should be taken during melon harvesting:

Do not pack melons in the field, they need to be washed and sanitised before they can be marketed for human consumption

- label the harvest bins and containers for robust traceability of the fruit to the block and paddock (Figure 17)
- move harvested melons immediately to the packhouse for pre-cooling and subsequent washing, sanitising and packing
- train employees to identify food safety risks (e.g. animal incursion, any faecal material) in the field and encourage them to report this to the supervisor
- train employees to avoid mechanical damage to the fruit during harvesting, e.g. no rough handling such as throwing
- physical damage such as cracks, bruises and punctures provide entry points for plant and human pathogens; minimising this damage will reduce the likelihood of microbial contamination
- depending upon the variety, appropriate harvesting methods (slipping versus clipping) should be used to minimise physical damage at the stem-end
- diseased, overripe and damaged fruit should be culled to prevent spoiled fruit from contaminating other fruit

Figure 17. Labelled harvest bins in a melon harvesting operation.

- harvesting equipment should be regularly cleaned and sanitised following appropriate processes that are scheduled to occur after every shift or at the end of the day (Figure 18). All equipment such as harvest bins, clippers, conveyors, tractors and trailers used should be included
- equipment such as bins and conveyor belts should not be trodden on to ensure shoes do not contribute to cross-contamination
- equipment used for harvesting should not be used for transporting garbage, animals or their products e.g. manure
- only material that can be properly cleaned and sanitised should be used for padding on the harvest equipment
- do not allow employees to work if injured, sick or under the influence of drugs or alcohol
- ensure that employees are provided with clean water and breaks to prevent them from getting ill and becoming a possible source of contamination
- provide and maintain clean toilets and field sanitary stations including wash stations
- supply soap, clean water and single-use towels for hand washing and make sure these are used.

Figure 18. Harvest equipment including conveyor belts should be cleaned and sanitised at the end of each shift or at the end of the day.

Managing postharvest microbial food safety risks in melons

Pre-cooling

Pre-cooling is the rapid removal of field heat from the fruit to extend its shelf-life, inhibit microorganism growth and prevent pathogens from entering the fruit during its contact with water. When harvested, fruit are often warm (25–40 °C) and cooling them to 5 °C as quickly as possible is a critical postharvest operation. It is recommended that:

- pre-cooling be carried out immediately after harvest and before washing and sanitising melons to minimise the microbial food safety risks
- pre-cooling melons before washing and sanitising minimises the risk of internalisation of pathogens through the wash water. The greater the temperature difference between the fruit and wash water, the more likely the fruit is to absorb water from the surroundings
- forced air cooling should be used as it can rapidly bring down the temperature of the fruit pulp to 5–8 °C. Standard cool rooms that do not use forced air cooling systems are often used, but they take longer to cool the fruit
- stacking the bins in front of the pre-coolers should be carefully designed and executed for efficient and uniform heat removal and ease of air flow circulation (Figure 19)
- fruit must be cooled uniformly, rather than only the outer or top fruit in the bin being cooled, while the inner fruit remains warm
- separate cool rooms should be used for pre- and post-processing fruit. There should be a clear definition between areas handling harvested/unprocessed fruit and washed/sanitised/processed fruit

Figure 19. A pre-cooling facility in a melon packhouse.

- condensation units or drip pans should drain directly into a drainage system and this water should be drained and disposed of away from the product and product contact surfaces
- condensation units should be cleaned and sanitised at regular intervals. Equipment should be inspected on a regular basis according to a Standard Operating Procedure (SOP) to ensure the potential for cross-contamination is minimised
- all equipment must be kept in good operating condition.

Dry dumping versus wet dumping

Dry dumping is where the fruit is placed onto conveyor belts (Figure 20) and is then moved along to be rinsed, washed and sprayed with sanitisers whereas, in wet dumping, the fruit is dumped directly into large capacity tanks containing sanitised water, then is moved on to be washed and further sanitised (Figure 21). Wet dumping has the advantage of minimising physical damage to the fruit but is a potential hotspot for cross-contamination; using dump tanks should be avoided if possible. The major challenge is to maintain the dump tank water quality to be consistent with drinking water quality at all times. Water replacement, which includes emptying and refilling the tanks with water containing a sanitiser, can be considered a time-consuming and costly operation and a busy packhouse operation might ignore the frequent need for water replacement. Dump tanks (5,000–10,000 litre capacity) require large doses of sanitisers to maintain the effective concentration, which increases processing costs. However, if the dump tank is not managed with appropriate sanitiser levels and frequent water replacement, it can increase the microbial load on the fruit surface leading to reduced effectiveness of subsequent washing and sanitising treatments. A summary of the critical factors involved in dump tank management is presented in Figure 22.

Figure 20. Dry dumping: the fruit is placed onto conveyor belts where it moves on to be rinsed, washed and sprayed with sanitisers.

Figure 21. Wet dumping: the fruit is placed directly into large capacity tanks containing sanitised water.

Considering the food safety risks associated with this postharvest operation, it is recommended that:

- dry dumping is preferred over wet dumping
- the water used in dump tanks should be drinking quality
- pre-cooling fruit to 5–8 °C should be mandatory to minimise the risk of pathogen infiltration into the edible pulp
- dump tank water should be 5 °C warmer than the fruit pulp temperature to avoid infiltration of water into the fruit
- the fruit holding time in the dump tank should be kept to a minimum to minimise the infiltration of water into the fruit
- an automated system should be installed to inject and monitor sanitiser concentration in the dump tank
- sanitiser concentration and fruit and water temperatures should be measured at set intervals (e.g. half-hourly) using digital tools and equipment
- an alarm system (Figure 23) could be used in the dump tank to alert the QA/packhouse manager if sanitiser concentration falls below the critical limit or if the organic load in the tank exceeds the set limit
- water replacement frequency is determined based on objective measurements such as turbidity values; subjective judgement to determine water replacement in dump tanks is not acceptable
- dump tank management must allow for changes in organic load on incoming fruit, which can be caused by weather such as dust storms, rainfall, flooding and changes to wash water quality or chemical attributes.

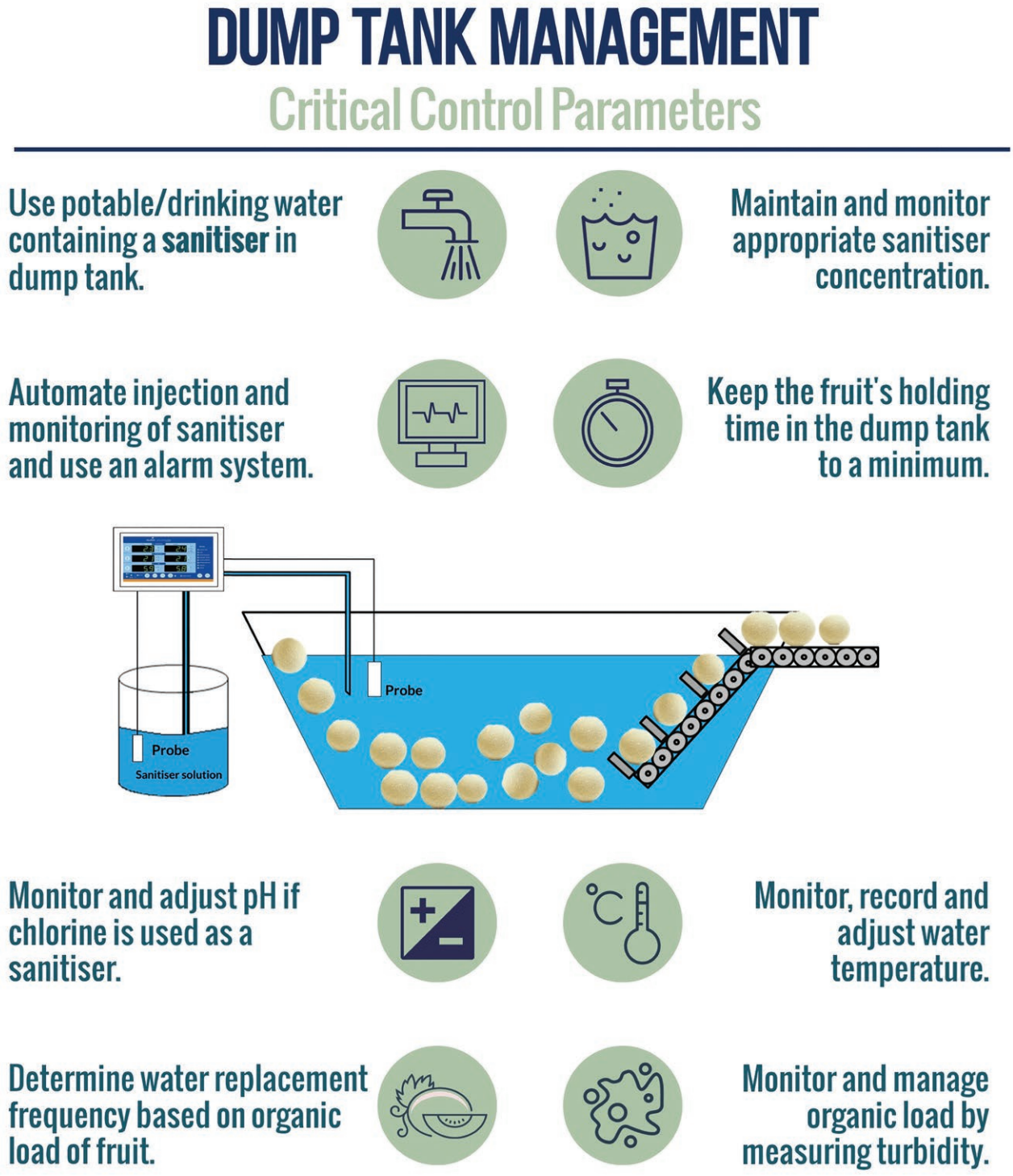


Figure 22. An overview of the critical factors involved in dump tank management.

Figure 23. An automated monitoring and alarm system to manage sanitiser levels in a dump tank.

Postharvest washing and sanitising

Rockmelons and other specialty melons must be washed and sanitised before shipping to market for human consumption. Water is a key element of postharvest washing and sanitising processes in a melon packhouse. The main purpose of washing, other than removing soil, debris and chemical residues, is to reduce the microbial load on fruit surfaces without cross contaminating the fruit. If microbial contamination of fruit has already occurred in the field, it is nearly impossible to completely eliminate foodborne pathogens from melons during washing and sanitising operations. However, microbial populations of bacteria, moulds and yeasts can be reduced through proper washing and brushing treatments with water containing a sanitiser followed by treatment with a fungicide solution. Figure 24 shows a summary of critical control parameters for fruit washing and sanitising.

General recommendations

- drinking quality water must be used for all postharvest operations. The Australian drinking water guidelines recommend no detection of *E. coli* in a 100 mL sample of drinking water; the presence of any *E. coli* indicates contamination by faecal coliforms, which is a significant microbial food safety hazard
- if the melon packhouse uses surface water sources such as rivers, dams and channels, the water should undergo proper water treatment processes such as coagulation, flocculation, sedimentation and filtration to remove organic matter and particles including microorganisms (e.g. bacteria, viruses and protozoa). It is important that such operations are optimised and controlled to achieve consistent and reliable performance in maintaining water quality
- microbiological testing of postharvest wash water should be conducted by an accredited laboratory at regular intervals as per your food safety plan

- drinking quality wash water must contain a sanitiser (e.g. chlorine) at an effective concentration. A single-use wash water (run-to-waste) system is recommended for melon washing to minimise the food safety risks
- re-circulating wash water introduces a high risk of cross-contamination, but if that water can be filtered, treated and sanitised to achieve drinking quality standards (Figure 25), it can be re-used
- introduce a pre-wash rinse step to loosen and remove dirt from the fruit surface (Figure 26) so the fruit enters the washing and sanitising zone with minimum organic load, allowing better interaction between the sanitiser and the netted skin
- preferably install an automated system for sanitiser dosing and monitoring in the wash water to maintain consistency in the sanitiser levels and eliminate the human errors. However, automated systems need to be periodically verified using digital tools.

Figure 24. Critical control parameters for fruit washing and sanitising.

Figure 25. Wash water filtration.

Figure 26. Rinsing melons before they are washed and sanitised.

Role of sanitisers in wash water

Sanitising is a critical step in food safety procedures implemented to reduce the number of viable microorganisms to an acceptable limit (Artés et al. 2009). Sanitisers are added to water during postharvest operations to help prevent human pathogens from multiplying and spreading. These are a group of antimicrobial compounds that non-specifically kill or inactivate microorganisms such as bacteria, fungi and yeasts. It is important to note that

sanitisers reduce microbial load but do not eliminate all potential microbial contaminants. Every effort should be made to limit contamination on fruit before and during harvest. The sanitiser in the wash water cannot be relied upon to decontaminate or sterilise the fruit as being safe for consumption.

The chemistry and modes of action of sanitisers vary widely and their efficacy is affected by a number of factors such as concentration, contact/exposure time, pH, temperature, water quality and organic load in the water (Figure 27). Human errors, such as inaccurate calculation and dilution of the concentrate or improper adjustment of the final pH of the sanitiser solution can also affect sanitiser efficacy. Other issues include using a concentrate that is past its expiration date, prolonged storage of the sanitiser under adverse conditions, and prolonged storage and use of diluted sanitisers. The label is the law; you must use the products only as labelled and always read the label, following the instructions for proper use.

A number of sanitisers approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA) are available for postharvest melon processing. These include chlorine, peroxyacetic acid (PAA) , chlorine dioxide, bromo-chloro compounds and ozone. Chlorine and PAA are discussed extensively here because of their widespread use in the melon industry.

Figure 27. Sanitiser efficacy is influenced by a number of factors such as concentration, contact and exposure time, pH, temperature, water quality and organic load in the water.

Validation and verification of fruit washing and sanitising

Washing and sanitising are critical processes in postharvest handling of melons (Figure 28).

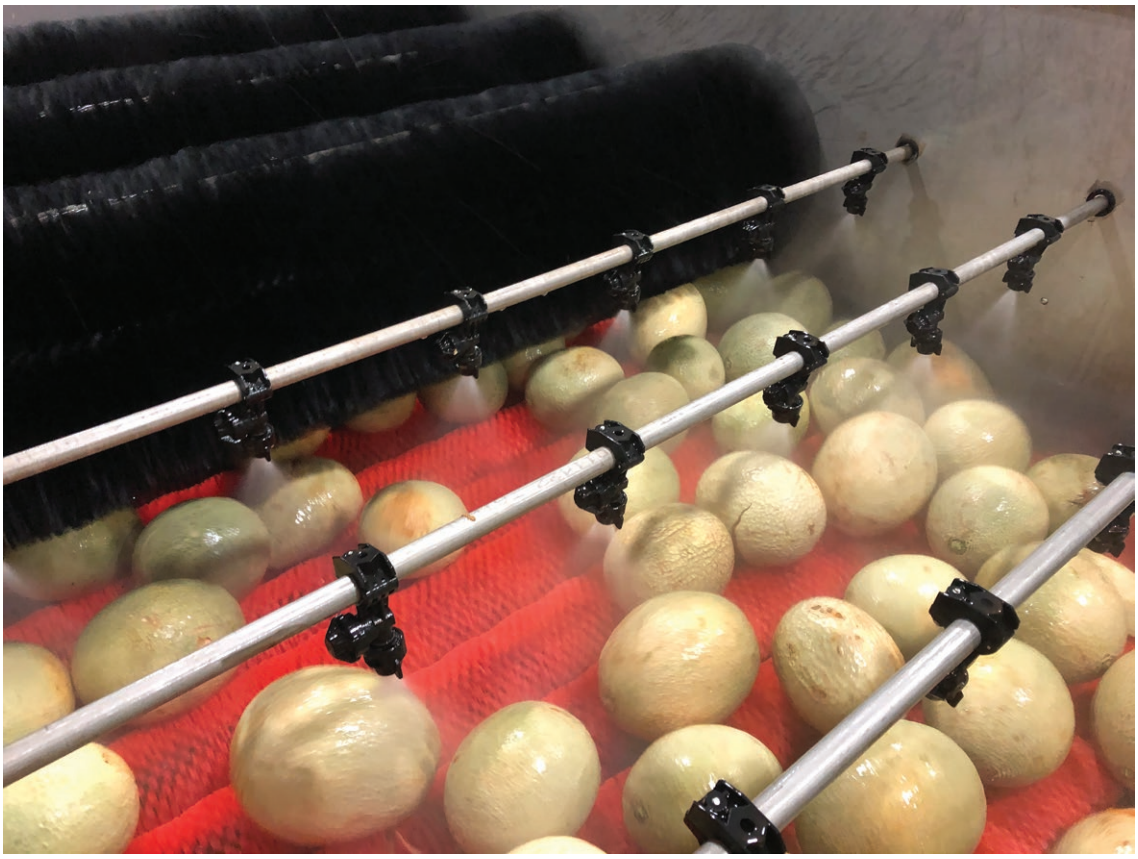


Figure 28. Rockmelons being washed, brushed and sanitised under a spray bar system.

The main objectives of washing are to:

- remove organic matter or debris from the fruit surface
- reduce the microbial load on the fruit surface through high-pressure washing and brushing with water containing an effective sanitiser.

This section is a brief guide to assist in developing validation and verification plans of fruit washing and sanitising processes in a rockmelon and specialty melon packing operation. The guide is adapted from the published '*Guidelines to validate control of cross-contamination during washing of fresh-cut leafy vegetables*' (Gombas et al. 2017) and other publications cited herein.

Validation is the process of demonstrating that the system designed can adequately control identified hazards to produce a safe product, i.e. demonstrating that the process is capable of accomplishing what you expect it to do. Fresh produce washing validation can be a challenging task (Scott 2005) because of the lack of a 'kill step' in the washing process, the inability to introduce the target pathogens into the commercial packing facilities for validation studies, lack of substitute pathogens and the costs of performing microbiological studies (Gombas et al. 2017).

Sanitiser effectiveness is mainly determined by its concentration and contact time. The most common expression of a sanitiser's efficacy in disinfection potential is the 'CT value', where C is the sanitiser concentration (in ppm) and T is the contact time (in minutes). For instance, a CT value of 200 could be achieved by exposure of the pathogen to a sanitiser concentration of 200 ppm for 1 min, 100 ppm for 2 min, 50 ppm for 4 min and so on. The CT values for inactivating pathogens in water have been globally used as a guide for water treatment for drinking and recreation purposes (Centres for Disease Control and

Prevention 2014). However, CT values for achieving postharvest disinfection of wash water and produce are largely unknown or inconclusive due to the diversity of sanitisers used, operations and equipment.

Steps in developing a validation plan

1. Identify the potential target pathogens, for example, *Salmonella* species, *Listeria monocytogenes* and pathogenic *E. coli*
2. Set the performance standards such as:
   - no detection of foodborne pathogens on fruit
   - minimum 2-log (99%) reduction of total plate count on the fruit surface
3. Define and outline all critical processes and factors affecting the efficacy of the process such as water quality, sanitiser concentration, contact time (fruit feed rate), water flow rate and pressure, overhead and flatbed brushing and organic load variation
4. Define the operational limits of each factor considering worst-case conditions, for example, minimum and maximum sanitiser concentration and contact time
5. Determine fixed and variable conditions affecting the efficacy of washing and sanitising processes. If a fixed condition is changed (e.g. sanitiser type or conveyor belt speed), the washing and sanitising processes must be re-validated
   - fixed conditions include:
     - water source
     - water treatment system
     - washing equipment (e.g. brushes, spray bar)
     - sanitiser type
     - contact time (e.g. produce feed rate, conveyor belt speed)
     - sanitiser monitoring system
     - produce type (e.g. rockmelons, honeydew)
   - variable conditions include:
     - sanitiser concentration
     - organic load
     - water pH (critical if chlorine is used as a sanitiser)

Validate the variable conditions:

- option one: minimum effective sanitiser concentrations are maintained in each washing and sanitising run (practical and easy to follow)
- option two: the produce is inoculated with a substitute pathogen to demonstrate process efficacy and prevent cross-contamination (a technical expert or microbiologist is needed).

Option one: minimum effective sanitiser concentrations are maintained in each washing and sanitising run

This validation option requires knowing the minimum sanitiser concentration and contact time (or CT values) to effectively wash and prevent cross-contamination and to be able to identify where in the wash system the sanitiser level is at its lowest using sanitiser sensors. This process involves:

- monitoring sanitiser concentrations at multiple locations in multiple scenarios
- mapping the sanitiser concentrations across the washing system and determine areas where the sanitiser is likely to be at its lowest level during normal operation

- placing sensors or collecting water samples (Figure 29) from all locations (e.g. all nozzles across the spray bars) for measuring sanitiser concentrations using calibrated equipment
- begin running the wash system with fruit as well as sanitiser and record sanitiser levels at all locations
- recording all variable conditions throughout the validation trial and run the system under multiple situations in which the variable conditions are altered to simulate a variety of circumstances the system might experience
- continuously monitor sanitiser concentrations throughout the trial to confirm where the lowest level of sanitiser occurs in the wash system. If this occurs at different locations under different situations, then multiple locations must be monitored. These locations should then become monitoring points during normal operation and the already known minimum sanitiser level becomes the critical limit
- microbiological analyses of fruit and wash water samples collected during various runs of validation must be conducted to ensure the process meets the set performance standards.

Figure 29. Wash water sampling and monitoring.

Option two: the produce is inoculated with a substitute pathogen to demonstrate process efficacy and prevent cross-contamination

This option involves inoculating produce with a substitute pathogen to ensure the wash system achieves the pre-determined washing standard. A substitute pathogen is a non-pathogenic surrogate for the pathogen of concern and is considered suitable if its behaviour, when exposed to sanitiser at levels and conditions occurring in wash water, is the same as the target pathogen. This process involves:

- the produce inoculated with the substitute pathogen being added at the beginning of the process and run through the wash system with the uninoculated product. At the end of the process, both inoculated and uninoculated produce are collected and tested for the detection of the substitute pathogen
- microbiological analyses of fruit and wash water samples collected during various validation runs must be conducted to ensure the process is meeting the set performance standards

- inoculated produce to be run through the wash system as well as access to a suitable substitute pathogen and is often not possible to be run in a commercial melon processing system. However, if resources are available this is an alternative validation option that can be performed.

A robust validation study requires running the washing and sanitising processes as closely as possible to the actual operating conditions. Fruit used in validation studies must not be supplied for public consumption. A summary of the validation process for fruit washing and sanitising is provided in Figure 30.

Figure 30. A snapshot of the validation process for fruit washing and sanitising operations.

Verification

Verification involves ongoing monitoring and recording to ensure that the system is being managed according to the validated plan. This involves reviewing the monitoring records and calibration checks on instruments used to control and monitor the washing systems such as sensors and automatic sanitiser dosing systems. During normal operations, the variables as determined by the validation process of washing and sanitising must be monitored at identified locations and pre-determined intervals.

- sanitiser measuring frequency should be based on the type of dosing systems (manual or automatic) and the expected variation. For example, free chlorine concentration should be measured using a digital photometer or a sensor at the beginning and then every 30 minutes
- contact time must be recorded regularly to ensure the fruit surface is being effectively sanitised as per validated CT values (Figure 31)
- regular microbiological analysis of wash water and fruit samples should be performed. Sample pre-wash and post-wash fruit for microbiological analyses (i.e. total plate count and detection of target pathogens) to be conducted by an accredited laboratory. Compare the microbiological test results with the set performance standard as part of the verification plan.

Figure 31. Recording data for verification of fruit washing in a melon packhouse.

Other observations:

- record pH values of the wash water if chlorine is used as a sanitiser
- record fruit pulp temperature before washing and sanitising; it must be maintained 10–15 °C lower than the wash water temperature
- determine and record the flow rate of wash water in spray nozzles identified during the validation study.

Sanitisers

Chlorine

Chlorine is one of the most widely used sanitisers because of its low cost and easy availability. In the melon industry, two forms of chlorine are commonly used, sodium hypochlorite (liquid) and calcium hypochlorite (powder). When sodium or calcium hypochlorite is dissolved in water, the hypochlorite will take on two forms, hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). The combined concentrations of hypochlorous acid and hypochlorite ion represent the amount of free chlorine available for disinfection. Of these two forms, hypochlorous acid is a more powerful disinfectant compared to hypochlorite ion. The relative concentration of these two forms (HOCl and OCl^-) depends upon the pH of the water to which it is added (Figure 32).

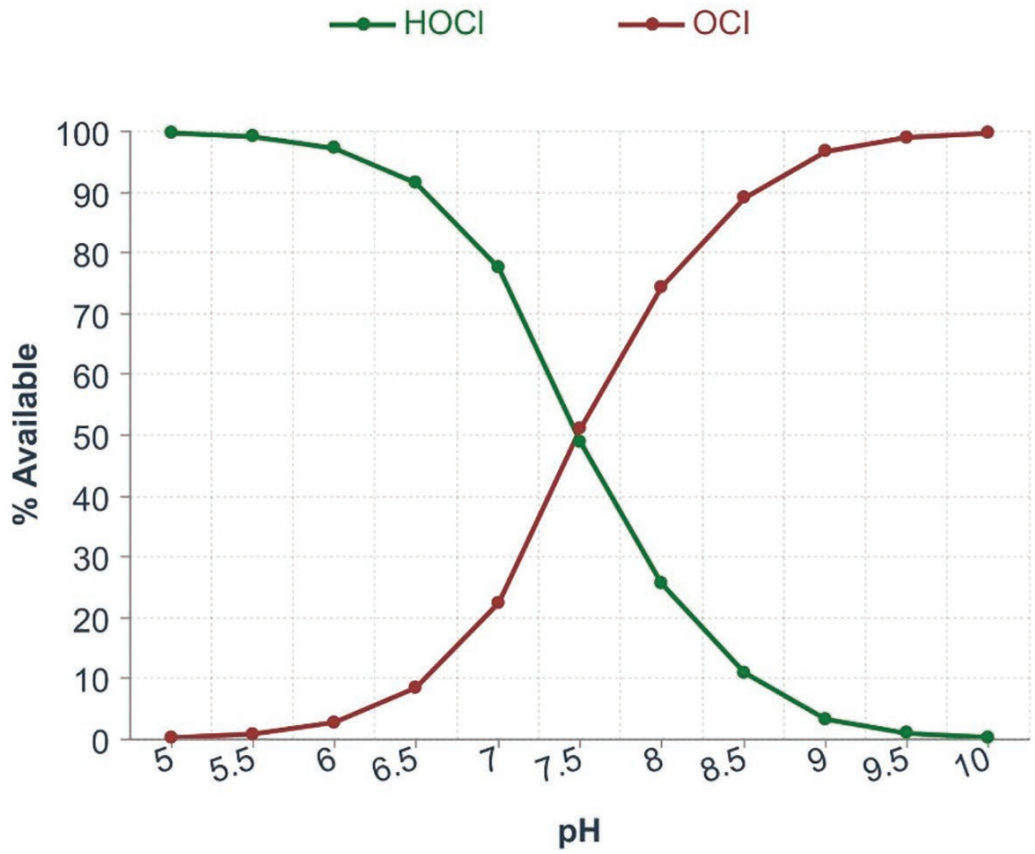


Figure 32. The relative concentration of hypochlorous acid and hypochlorite ion depends upon the pH of the water to which it is added.

At pH lower than 7.0, the hypochlorous acid predominates. When the pH increases above 7.0, the concentration of hypochlorite ions increases. When pH is maintained between 6.5–7.0, hypochlorous acid is present in higher concentrations. For most effective disinfection, the pH of chlorinated water should be between 6.5 and 7.0.

Some common terminology associated with chlorine that you should be familiar with includes:

- **free chlorine** or **available chlorine** is the amount of chlorine in the form of hypochlorous acid, hypochlorite ion and chlorine gas
- **combined chlorine** is the amount of chlorine that has reacted with nitrogen-containing compounds (e.g. ammonia) in water to form chloramines that are not effective in sanitation
- **total chlorine** is the sum of free or available and combined chlorine

- **chlorine demand** is the difference between the amount of chlorine added to water and the amount of free chlorine or combined chlorine remaining at the end of a specified time period.

Factors affecting the efficacy of chlorine

The effectiveness of chlorine is broadly a function of its concentration, contact time, pH, organic matter and temperature.

Concentration

The recommended free chlorine concentration for washing and sanitising rockmelons is 200 ppm (Materon 2003; Parnell et al. 2003; Rodgers et al. 2004). Some research on the efficacy of chlorine against foodborne pathogens has reported longer contact times (5–10 minutes) which are not feasible to achieve under commercial conditions. Based on current information, it is recommended that rockmelons and specialty melons be washed with chlorinated water containing 200 ppm free chlorine with an exposure time of one minute or 100 ppm of free chlorine for two minutes at 6.5–7.0 pH (Figure 33). With the basic chemistry of chlorine, it is critical to maintain the pH of chlorinated water at neutral (7.0) to achieve effective sanitation through the abundance of active form (hypochlorous acid) of chlorine. However, the concentration of chlorine should not be considered the only parameter of effective sanitation, other factors such as the contact time and pH are equally important.

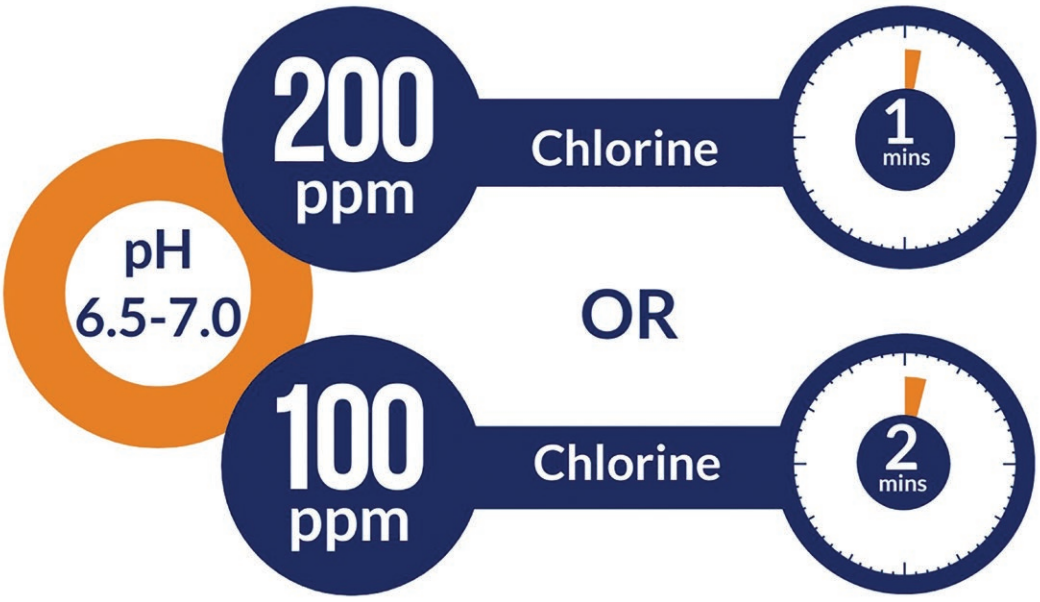


Figure 33. Rockmelons and specialty melons can be washed with chlorinated water containing 200 ppm free chlorine with an exposure time of 1 minute or 100 ppm of free chlorine for 2 minutes at 6.5–7.0 pH.

Free chlorine measurements do not distinguish between the two forms of hypochlorites (HOCl and OCl^-) present in water, thus it is important to measure the pH to determine the active free chlorine. For example, 100 ppm of free chlorine at pH of 9 has only 4% hypochlorous acid, with 96% being hypochlorite ion. The same amount of free chlorine at a lower pH of 6.0 will contain 98% hypochlorous acid and 2% hypochlorite ion, dramatically increasing the disinfection power of the same wash water solution at a lower pH.

Adding or injecting chlorine to the wash water can be done manually or automatically. Automatic and digital chlorine dosing and monitoring systems are highly recommended to exclude human errors, as well as regularly monitor and log chlorine concentration and pH. However, automated systems must be verified regularly by using digital tools for measuring chlorine concentration and pH values. High range digital photometers are recommended for

measuring free chlorine in the wash water. Similarly, a digital pH meter should be preferred over test strips to monitor the pH of the chlorinated water.

The chlorine concentration and the pH of the wash water or dump tank must be recorded; however, these records without pH values should not be accepted for validation and verification of food safety plans in a melon packhouse.

Contact time

Total contact time of the fruit with the chlorinated water influences the ability of active chlorine (hypochlorous acid) to kill or inactivate microbial pathogens. A minimum contact time of two minutes is required to achieve the desired sanitation when the concentration of free chlorine is at an appropriate level (100 ppm). However, consider other factors such as organic load on the incoming fruit, the efficacy of the pre-rinse/wash step, brushing and high-pressure washing. Determine the contact time for your packing operation based on the validation and verification of your washing and sanitising procedures.

pH

The pH is a critical factor that determines the effectiveness of chlorine as a sanitiser. The pH scale ranges from 0–14. The pH value 7 is neutral, less than 7 is acidic and more than 7 is alkaline. Adding chlorine in liquid or solid forms increases the pH of the water to which it is added (Figure 34). If the water is acidic (pH < 7), a minor increase in the pH due to adding chlorine might not have a major impact on the efficacy. However, if the water is neutral (pH 7) or alkaline (pH > 7), the pH of the solution after adding chlorine will increase towards alkaline conditions, rendering the chlorine ineffective due to a lower concentration of the active form, hypochlorous acid.

Therefore, the wash water pH must be monitored after the chlorine solution is added, then adjusted to be between 6 and 7 using food grade organic or inorganic acids such as hydrochloric acid and citric acid. If the pH is not properly adjusted, the chlorine solution will not be effective in sanitising the produce. If the pH falls below 6, it is highly corrosive to equipment. If it falls below 5, it forms chlorine gas that releases fumes irritating skin and eyes. Conversely, if the pH is above 8, it will not be an effective sanitiser.

The acceptable pH range of chlorinated water is 6.5–7.0

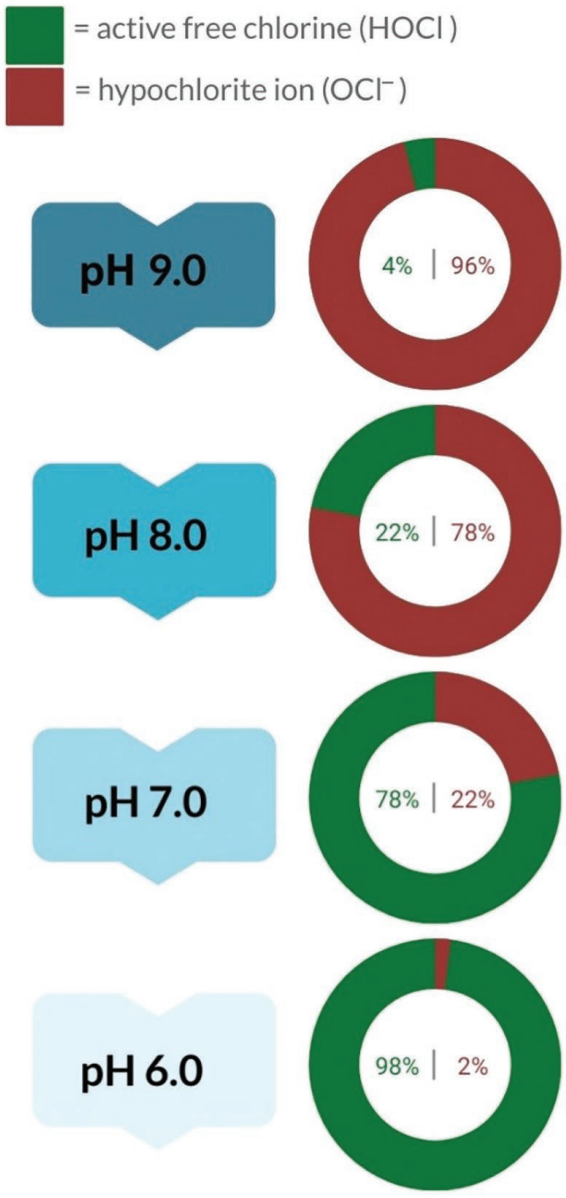


Figure 34. The relative proportions of hypochlorous acid and hypochlorite ion as influenced by wash water pH.

Organic matter

Organic matter, soil and debris on the fruit surface or in the water react with free chlorine. Soil on the fruit surface interferes with the ability of chlorinated water to achieve sanitation. Pre-washing/rinsing fruit with potable water is therefore a good practice to minimise the amount of organic matter on the fruit before it enters the washing and sanitising zone. The clean surface of pre-washed fruit should have sufficient contact time with the chlorinated water, thus reducing the microbial load on the fruit surface to safe levels. The higher the organic load present on the fruit surface or in the water, the higher the chlorine demand. Turbidity should be used as an objective measure of the cloudiness or organic load in the water.

In re-circulatory washing systems and dump tanks, calculating chlorine demand is more pertinent to achieve effective sanitation. Under some circumstances (e.g. heavy rainfall or dust storms), the organic load might be very high on the incoming fruit. The decision on water replacement frequency should therefore be made based on the ability of current sanitiser levels to compensate for chlorine demand. The fixed water replacement frequency (e.g. twice a day) is not a good practice considering variation in the organic load on the incoming fruit depending upon fruit type (honeydew versus rockmelon), cultural practices and weather.

Temperature

The greater the temperature difference between the fruit and wash water, the more likely the fruit is to absorb water from the surroundings. Dump tank water should be 5 °C warmer than the fruit pulp temperature to avoid infiltration of water into the fruit. Water temperature should be continuously monitored and recorded to ensure the difference is sufficient to prevent the water from infiltrating the porous skin of rockmelons. Heating chlorinated water can cause active chlorine to escape.

Calculating the volume/weight of sodium/calcium hypochlorite required to obtain a specific concentration

The chlorine products used will determine how much of that chemical will be needed to achieve the desired concentration (measured in parts per million, ppm). Always consult the product label and see the percentage of the active ingredient to determine the concentration of the starting material. If the chlorine source is in the solid powder form, it will contain a different chlorine concentration e.g. calcium hypochlorite powder contains 30–35% w/w of chlorine and calcium hypochlorite granules contain 65–70% w/w of chlorine. If the chlorine is in the liquid form e.g. sodium hypochlorite, it contains a relatively low amount of chlorine (14–16% w/v). Knowing this concentration is essential for calculating how much you will need to get the desired concentration of chlorine in the wash water or dump tank. By knowing the desired target concentration, the volume of the tank size being used and the concentration of the initial chlorine product, the amount needed of the initial chlorine product can be determined using this formula:

$$\text{Volume to add} = \frac{\text{target ppm of free chlorine} \times \text{total tank volume}}{\%\ \text{NaOCl in source} \times 10{,}000}$$

For example, if you need to prepare 100 litres of a 150 ppm solution from 10% sodium hypochlorite (NaOCl), the equation becomes:

$$\text{Volume to add} = \frac{150\ \text{ppm} \times 100\ \text{L}}{10\%\ \text{NaOCl} \times 10{,}000} = 0.15\ \text{L or } 150\ \text{mL}$$

Final steps:

- adding 150 mL of 10% sodium hypochlorite solution to a 100-litre tank of potable water will provide the required 150 ppm concentration for your solution

- measure the pH of the chlorinated water and adjust it to be between 6.5–7.0, either by adding an acid, e.g. citric acid to lower the pH or adding an alkali to raise the pH
- measure the concentration of free chlorine using a high range digital photometer.

Measuring and monitoring chlorine

Once the chlorine concentration has been determined and an appropriate amount added or injected to the wash water system or dump tank, the free chlorine concentration (ppm) should be measured. There are several methods of measuring free chlorine in the water and using digital equipment is highly recommended:

Photometers

Photometers generally provide the greatest accuracy and precision for measuring free chlorine in water. Using the standard DPD method for measuring free chlorine, a chemical reagent called DPD (N, N-diethylparaphenylenediamine) is added to the water sample containing free chlorine. The DPD reacts instantly to produce a pink colour when chlorine is present, with higher concentrations producing a deeper colour. This colour change is then measured by the photometer.

Sensors

Chlorine sensors use chronoamperometry and electrochemistry to measure electrical currents generated by chemical reactions. They apply a set voltage to an electrode and record the electrical currents over time (approximately one minute). The magnitude of the current is proportional to the concentration of chlorine in the sample. These sensors are single-use and disposable, requiring no additional reagents or glassware. Readings are also not affected by sample colour or turbidity.

Oxidation-reduction potential meters

An oxidation-reduction potential (ORP) probe can be used to measure the wash water oxidising potential and provide an indirect measure of the effectiveness of chlorine as a sanitiser. The ORP value of wash water is directly correlated to the required contact time needed to destroy or inactivate harmful bacteria. Since ORP can be measured rapidly both in-line and off-line, ORP (at least 650 mV) is a convenient parameter for determining wash water effectiveness.

Test strips

Readily available and easy to use, chlorine test strips are able to measure free chlorine in different ranges of concentrations. However, they are unreliable and subject to variation between users. They are not recommended for monitoring chlorine concentrations for food safety records. It should be noted that there are significant differences between the accuracy of domestic swimming pool test strips and strips from a chemical supplier.

Others

Other products are commercially available to measure chlorine concentrations, including titration kits and colourimetric methods, both measure colour changes resulting from adding reagents to a sample.

Automated chlorine dosing and monitoring

Automated dosing and monitoring systems (Figure 35) are highly recommended for sanitiser control in the packhouse wash water. These must be verified using digital tools mentioned in the previous sections. There are a number of advantages of automation such as:

- eliminating human error and variability
- maintaining consistent sanitiser concentration and effectiveness levels
- continuous monitoring and precise control over the set levels of sanitiser (chlorine) and pH balance
- automatic logging of data for electronic record keeping.

Figure 35. An automated chlorine injection and monitoring system.

Peracetic acid

Peracetic acid, peroxyacetic acid, or PAA is an equilibrium mixture of peroxy compounds, hydrogen peroxide (H_2O_2) and acetic acid. Once dissolved in water, it breaks down into carbon dioxide, oxygen and water. PAA is an effective sanitiser that functions as a strong oxidising compound and is appropriate for washing and sanitising rockmelons and specialty melons. When applied at levels of 30–80 ppm, it effectively inactivates pathogenic *E. coli*, *Salmonella* and *L. monocytogenes*. PAA concentrations between 45–85 ppm are effective for sanitising rockmelons, however, a higher concentration (60–80 ppm) is required when used in spray bar systems (Stampi et al. 2001). Higher concentrations (>100 ppm) are more effective against microbial contaminants, but at these concentrations the PAA can begin to adversely affect the fruit (Singh et al. 2018).

Factors affecting PAA efficacy

The Australian Pesticides and Veterinary Medicines Authority (APVMA) label recommends using PAA at a concentration of 80 ppm for 45 seconds. Increasing contact time with PAA enhances killing of foodborne bacterial pathogens on the fruit surface (Rodgers et al. 2004; Singh et al. 2018). PAA is more effective against *L. monocytogenes* than other sanitisers such as chlorine (Singh et al. 2018).

For washing and sanitising rockmelons and specialty melons, 80 ppm concentration of PAA with a minimum two minutes contact time is recommended (Figure 36). As a cross-contamination control in dump tanks, PAA at 100 ppm is recommended.

Figure 36. For washing and sanitising rockmelons and specialty melons, 80 ppm concentration of PAA with a minimum two minutes contact time is recommended.

PAA is most effective at neutral pH (7); the efficacy decreases as pH increases. PAA also functions extremely well in cold conditions (4 °C). PAA is affected less by organic matter and soil than chlorine solutions (Artés et al. 2007). PAA solutions are environmentally friendly and do not produce any harmful by-products.

PAA decomposition is influenced by temperature and should be stored in a temperature-controlled environment (< 25 °C) and kept away from direct sunlight. PAA rapidly decomposes in temperatures over 45 °C, effectively reducing its efficacy if not replenished (Kunigk et al. 2001). High PAA concentrations (> 100 ppm) can affect the quality of produce due to its strong oxidising power. PAA can corrode metals it contacts and thus is not compatible with non-stainless metals; it is best kept in plastic drums (Figure 37).

Figure 37. Peracetic acid (PAA) is being dosed into the postharvest wash water in a melon packhouse.

How to calculate the volume and specific concentration of a PAA mixture

Read the product label to identify the concentrations of active constituents in the PAA mixture. Concentrations of PAA and hydrogen peroxide vary from brand to brand (Table 1).

Table 1. Examples showing varying concentrations of peracetic acid and hydrogen peroxide.

Trade name	Brand name	Paracetic acid (PAA) (%)	Hydrogen peroxide (H_2O_2) (%)
Adoxysan Peracetic Acid Biocide	Advance Chemicals	16.0	11.0
Campbell Perasan Peracetic Acid Biocide	Castle Chemicals	15.7	6.0
Pinnacle Peracetic Acid Biocide	Sopura	16.0	11.0
Tidal Surge Peracetic Acid Micro Biocide	Easyclean	16.0	11.0
Tsunami on farm Peracetic Acid Biocide (Figure 38)	Ecolab	16.0	11.0

Figure 38. The Tsunami on farm product label. Source: Infopest https://www.infopest.com.au.

Active constituents are labelled as 160 g/L (16%) peroxyacetic acid and 110 g/L (11%) hydrogen peroxide. Directions are to add 48 mL of Tsunami on farm to 100 litres of water, ensuring a minimum of 45 seconds contact time (Figure 38). To find the volume needed to obtain a specific concentration in a known volume, use the equation below:

$$\text{Volume to add} = \frac{\text{target ppm of PAA} \times \text{total tank volume}}{\text{\% of PAA in starting mixture} \times 10{,}000 \text{ ppm}}$$

$$\text{Volume to add} = \frac{80 \text{ ppm} \times 100 \text{ L}}{16\% \text{ of PAA} \times 10{,}000 \text{ ppm}} = 0.05 \text{ L or } 50 \text{ mL}$$

To find the specific concentration of PAA when following instructions from the product label, use the equation below:

$$\text{ppm of PAA} = \frac{\text{volume added} \times \%\text{PAA} \times 10{,}000 \text{ ppm}}{\text{total tank volume}}$$

$$\text{ppm of PAA} = \frac{0.048 \times 16\% \times 10{,}000 \text{ ppm}}{100 \text{ L}} = 0.05 \text{ L or } 50 \text{ mL}$$

Adding 48 mL of Tsunami on farm to 100 L of water produces 76.8 ppm of PAA.

To achieve 80 ppm, 50 mL of Tsunami on farm needs to be added to 100 L of water.

Measuring and monitoring PAA

PAA is a strong oxidiser and effective sanitiser, but it breaks down rapidly, therefore it is important to monitor PAA levels in postharvest washing operations every 30–60 minutes. Continuous monitoring using accurate inline feedback sensors and automated injection systems will be advantageous for large packing operations.

Sensors

PAA sensors use amperometry and electrochemistry to measure electrical currents generated by chemical reactions. An electrode is placed in a sample that interacts with the PAA in the sample, creating a current. The magnitude of the current is proportional to the PAA concentration in the sample. Sensors measure PAA without cross-sensitivity towards hydrogen peroxide. Readings are not affected by sample colour or turbidity.

Titration kits

Colourimetric titration offers a fast, economical and accurate method, relying on the ability of PAA to oxidise a titrant. There are three titrimetric methods commercially available: permanganate, ceric sulfate and iodometric. All are similar but the iodometric method provides the most rapid and direct PAA measurement. Iodide is oxidised by PAA to iodine, which reacts with starch resulting in dark purple–black colour. This PAA solution is then titrated with sodium thiosulfate to reach a colourless endpoint. The number of drops of sodium thiosulfate needed to reach this endpoint determines an approximate concentration of PAA in the solution.

Test strips

Digital methods of measuring PAA should be preferred over test strips because, while test strips are quick and easy to use, they are not sufficiently accurate. Test strips involve dipping strips in samples containing PAA, causing the strips to change colour according to the concentration. These colours are then compared to a printed colour chart provided that is specifically designed to represent colour reactions at various concentrations.

Chlorine dioxide

Chlorine dioxide (ClO_2) is a strong oxidiser that effectively inactivates microbial organisms, having 2.5 times more oxidative potential than free chlorine (Keskinen et al. 2009). Chlorine dioxide is less affected by organic matter and this reduces the dosage required in comparison to free chlorine.

Chlorine dioxide efficacy is less dependent on pH than free chlorine solutions. Chlorine dioxide requires short contact time but does not have an inherent cleaning ability, necessitating a pre-cleaning step (Rodgers et al. 2004). Unlike chlorine, chlorine dioxide is effective against viral and protozoan contaminants. The general recommended dosage rates for chlorine dioxide solutions are between 0.05 and 5.0 ppm (Mahmoud et al. 2008; Artés et al. 2009; Ramos et al. 2013; Svoboda et al. 2016). For rockmelons and specialty melons,

a minimum 5 ppm concentration of chlorine dioxide should be used in wash water with at least two minutes contact time (Mahmoud et al. 2008; Svoboda et al. 2016; Figure 39). Increasing exposure time can further reduce the microbial food safety risks as the efficacy of chlorine dioxide against the human pathogens increases with theincreased exposure time.

The main sources of chlorine dioxide used in the melon industry are sodium chlorite ($NaClO_2$) and sodium chlorate ($NaClO_3$) and many companies supply component kits to produce chlorine dioxide onsite. Automated dosing systems can monitor chlorine dioxide levels using sensors that give a dissolved chlorine dioxide measurement in ppm or mg/L. Portable photometers can also be used to monitor the concentration of ClO_2 in the sanitising solution.

Figure 39. For rockmelons and specialty melons, a minimum 5 ppm concentration of chlorine dioxide should be used in wash water with at least two minutes contact time.

Ozone

Ozone is a powerful disinfectant that requires less contact time and concentration to achieve effective disinfection of wash water. It readily dissolves in water and rapidly produces oxygen and hydroxyl radicals. Organic and inorganic matter in the wash water reacts with ozone to create an ozone demand. The quantity of ozone that is available for disinfection after interacting with organic and inorganic compounds is termed the residual ozone.

Ozone applied as a spray wash is effective in reducing the microbial load. The size of ozone bubbles diffusing into the water is a critical factor and should be adjusted carefully. Finer bubbles rise more slowly and have a larger surface area per unit volume of ozone, ensuring maximum ozone transfer. Ozone has higher stability at pH 5 and its efficacy starts decreasing as the pH increases (Kim et al. 1999).

Ozone concentrations of 2–3 ppm are generally recommended for spray washing. An understanding of ozone degradation during the various stages of its spray application is important to maintain its concentration at effective levels. For example, the amount of ozone gas injected into the water could be 5.0 ppm, but because the ozone transfer efficiency is always less than 100%, the ozone concentration in the pressurised line to the spray nozzles will be less than 5.0 ppm, possibly as low as 3.0 to 4.0 ppm. After the spray nozzle, the pressure will decrease to atmospheric levels. At lower pressure, some of the ozone will escape out of the solution and the water in contact with the fruit's surface might be 2.0–2.5 ppm.

For sampling and measuring residual ozone, a short detention time is important due to the rapid decay rate of ozone. A sampling system must minimise the detention time of the samples and allow easy collection of grab samples without affecting on-line instrument measurements while keeping a consistent and sufficient flow. Accurate residual ozone

measurements are required to determine the disinfectant's efficacy on the pathogens. Sensors and photometers are available to measure ozone concentration in water. Using an ORP probe also gives an indirect indication of the ozone's disinfection potential.

Bromo-chloro-dimethylhydantoin

The bromo-chloro-dimethylhydantoin (BCDMH, traded as Ym-Fab Nylate) compound contains one chlorine (Cl) and one bromine (Br) group. The BCDMH chemistry is mainly bromine-based despite the presence of chlorine. When this compound reacts with water, there are two active forms present: HOCl (hypochlorous acid) and HOBr (hypobromous acid). The breakdown products of BCDMH are chloride and bromide ions or salt as Cl^- and Br^-. The bromide ion is reactivated by the chlorine in another dose of BCDMH to form more hypobromous acid.

The manufacturer recommends a 5–10 ppm concentration to achieve effective pathogen control. BCDMH is effective in wash water at a broad pH range of 7.0–8.5. Haloamines (also called bromamines) are formed when the HOBr contacts organic nitrogen compounds. In contrast to the chloramines, bromamines have two specific advantages; they are very useful disinfectants at low levels over a wide range of pH levels and are much less offensive to staff on the packing line. The option for automation and digital control of sanitiser injection and monitoring is commercially available.

Postharvest fungicide treatment

Postharvest fungicide treatment, through either aqueous spray or immersion, extends the storage or shelf-life of fruit by inhibiting the growth of decay-causing moulds (Figure 40). The fungicides specifically kill or inactivate mould and mould spores but unlike sanitisers, do not necessarily have bactericidal effects. Fungicides provide residual protection and are effective over extended periods. Sanitisers, on the other hand, are not target specific and are effective against a broad range of microbes including fungi, bacteria and yeasts. Unlike fungicides, sanitisers have no residual effect and rely on destroying microbes on contact.

For food safety, general recommendations for postharvest treatment with fungicides are:

- postharvest treatment with sanitisers and fungicides should be conducted in two separate steps
- drinking quality water should be used for preparing the fungicide solution/emulsion
- fungicides and sanitisers should not be mixed unless recommended by the manufacturers and/or permitted by the label
- mixing 'incompatible' fungicides and sanitisers might compromise the efficacy of both, resulting in the waste of resources without significant positive effects
- fungicides (e.g. imazalil and guazatine) registered for postharvest use on rockmelons should be used following label recommendations; fungicide selection should also consider its acceptance and maximum residue limits on the fruit in the destination market
- fungicide use should be rotated to minimise the risk of resistance developing (fungicide resistance is the ability of fungi to survive and reproduce in the presence of a fungicide)
- high-volume drenching with a fungicide is more effective and provides a more uniform application than a low-volume spray that requires wet brushes for proper application
- spray application of fungicides with no recirculation (run-to-waste) can be expensive but is the best practice to further alleviate microbial food safety risks

Figure 40. Postharvest treatment of melons with a fungicide.

- filtration is an important step to minimise the accumulation of fine particulate matter in the fungicide solution, which can cause choking of spray nozzles
- applying fungicides uniformly at recommended rates is essential to achieve effective postharvest disease control and to minimise fungicide resistance developing
- strip-out rates should be determined to replenish or top up the fungicide rates in the tanks. Monitoring tank solutions and recording losses against throughput rate of fruit is a reasonable approach to determine the strip-out rate
- hot fungicide treatment (50–55 °C) is generally more effective than treatment at ambient temperature because the synergistic effects of heat and fungicide enhance postharvest disease management in the supply chain
- contamination of the fungicide solution with foodborne pathogens might result in cross-contamination as some packers recirculate postharvest fungicide solutions
- fungicide tanks (Figure 41) can be a hotspot for cross-contamination due to the potential of foodborne pathogens. The cleaning and sanitising of fungicide tanks should be included in the packhouse cleaning schedule.

Figure 41. A fungicide tank.

Cold storage

Maintaining cool chain during postharvest handling, storage, transport and distribution steps is critical for fruit quality and minimising food safety risks. Rockmelons can be stored for up to 21 days at 5 °C (Figure 42) but sensory qualities of the product might be impaired. Honeydew and other specialty melons can be stored at 7–10 °C. Typically 12–14 days of storage life is attainable at the optimum storage temperature (5 °C for rockmelons and 7–10 °C for other speciality melons). Short-term exposure of fruit to temperatures below optimum might result in chilling injury (Agblor and Waterer 2001), including pitting or sunken areas, failure to ripen, off-flavours and increased surface decay. Sensitivity to chilling injury decreases as melon maturity and ripeness increases.

High relative humidity (90–95%) is essential to maximise postharvest quality, prevent desiccation and minimise chilling injury. Water loss through scuffed and damaged surface netting can be significant during extended periods of storage even at higher humidity. Condensation on the fruit surface can also encourage the growth of stem-scar and surface moulds as well as potentially pathogenic microorganisms.

The general recommendations for cold storage are:

- cool rooms should be clean, functional and devoid of any offensive odours. Cool room walls, floors and curtains should be regularly cleaned and sanitised following standard operating procedures to ensure consistency
- cooling unit drip pans and condensation can be reservoirs for microbial growth and need good drainage systems. Their service and maintenance schedule should include proper cleaning and sanitising steps

Figure 42. Processed and packed fruit should be held in a cool room prior to shipment.

- possible cross-contamination from other products stored in cold storage should be avoided. Contamination can come from other products stored in the same area as the packed rockmelons, either previously or simultaneously. Such contamination can occur via transfer from airflow, surface contact and water
- packed/processed fruit should not be directly stored or held under cooling fan units where the possibility of condensation and water dripping is highest
- cold storage temperatures need to be monitored and kept consistent; spikes in temperature can make organisms more likely to survive and multiply
- low temperatures can inhibit *Salmonella* species growth, but *Listeria* species are capable of growing in cool room temperatures. *Listeria* can remain dormant but not grow on melons pre-sanitised and stored at 4 °C for 15 days (Ukuku and Fett 2002)
- increases in storage temperatures have been related to *Listeria monocytogenes* survival rates on rockmelon stem scars. Research shows that it takes five days for microbial counts to increase at 4 °C, while active growth occurred immediately at higher temperatures (Nyarko et al. 2016)
- it is difficult to thoroughly clean and decontaminate a cold room using liquid sanitisers. Therefore, a gaseous sanitiser (fumigant action) would be more suitable. These sanitisers would be dispensed as an aerosol that remains suspended in the air for several hours and is deposited on exposed surfaces.

Packhouse environment control and monitoring

Controlling and monitoring the packhouse environment is an important element of food safety systems to ensure the melons are safe for consumption. A successful program focuses on the fundamentals of good hygiene and manufacturing practices. These are instrumental in assisting with the control of foodborne pathogens and are foundational to any food safety program. A potential source of *L. monocytogenes* or *Salmonella* contamination can be introduced by fruit and any unprocessed material entering the packhouse.

Packhouse environmental control

Packhouse design

The location, design and structure of a packhouse are important considerations when managing foodborne pathogens in the processing environment. Packhouse and processing facilities need to have extensive controls on their processing systems. These include but are not limited to:

- a packhouse must be a fully enclosed structure (Figure 43). No area of the packhouse should be exposed to the outside environment including pre-processing areas such as washing, brushing and sanitising zones
- the areas around the packhouse should be sealed, making sure they are adequately drained and maintained in a clean and tidy manner
- the entire packhouse should have a high degree of hygiene control, but zoning can be done to clearly demarcate high-risk and low-risk areas. The high-risk areas include where the washed and sanitised fruit is handled, packed and stored. The cleaning and sanitising equipment for such areas should not be used in other areas marked as low-risk
- Low-risk and high-risk areas should be physically separated. Where this is not possible, measures to prevent cross-contamination through materials, equipment and staff from low-risk to high-risk areas should be put in place (e.g. using a visual reminder such as a red line)
- consider using positive air pressure systems in high-risk areas
- install suitable decontamination facilities between high and low-risk areas
- allow adequate space in between equipment to allow for effective cleaning and sanitising of both the facility and equipment
- ensure the interior design allows easy access for cleaning and sanitising, sufficient drainage and prevents water from pooling
- doors, windows and other entry and exit points should be sealed appropriately, in particular for high-risk areas
- avoid installing overhead fixtures and equipment where dust and foreign matter can accumulate; e.g. fans in the hot air tunnels could be hard to reach and clean.

Equipment design

Good hygienic design and construction of processing equipment will help reduce contamination risk by minimising sites that conceal and allow pathogens to grow. These sites could involve either direct or indirect product contact surfaces. Consider the following:

- equipment should be used correctly and only for the intended purpose with good hygienic design and construction, particularly in high-risk areas

- equipment should be designed to provide easy access for cleaning and sanitising; e.g. movable equipment and simple/fewer parts
- 'dead' spaces should be avoided as they can permit the build-up of ingredients or product and are difficult to clean and sanitise e.g. self-emptying/draining
- all fruit contact and non-contact surfaces should be smooth and non-porous
- leaking taps, hoses and water/steam/condensate lines should be repaired immediately as they can contaminate the environment and food contact surfaces
- cooling units, refrigerators and insect control devices should not be placed above any product processing area. The processed product should not be exposed to contamination from above (e.g. condensate on overhead pipes)
- only use food grade lubricants and consider the need for additives (e.g. sodium benzoate).

Figure 43. Packhouse location, design and structure have a major role in managing foodborne pathogens in the processing environment.

Packhouse cleaning and sanitising programs

A key process used in controlling and eliminating *L. monocytogenes* and *Salmonella* in the processing environment is an effective cleaning and sanitising program, although these should be seen as two distinct processes where:

- **cleaning** is the removal of waste, dirt and grease from equipment, premises and vehicles and can include dry or wet cleaning using detergents
- **sanitising** is the process of reducing the number of microorganisms present on equipment and within the premises and it can include using chemicals, hot water or steam. An overview of steps in packhouse cleaning and sanitising is shown in Figure 44.

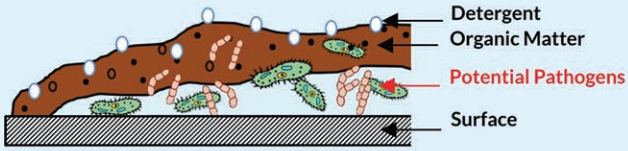
The way the equipment and the processing environment are cleaned and sanitised depends on many factors and the program should be tailored to the individual businesses. Important points to consider include:

- Standard Operating Procedures (SOP) for cleaning and sanitising are essential to ensure the program is consistent and effective, especially for high-risk areas
- bacteria need specific conditions for growth and survival such as water, temperature and nutrition; inadequate and inefficient cleaning and sanitising can provide bacteria with these conditions
- all staff must be trained to understand the importance of the program and a training register should be kept
- the program needs to include all equipment and items that are used by the business in the processing environment, including harvesting equipment and transport vehicles
- potential hotspots for cross-contamination should be identified in the packhouse so that more attention can be given to cleaning and sanitising these locations and equipment
- only appropriate detergents and sanitisers should be used in the food processing environment. They should be approved for use on food contact surfaces and meet all federal, state and local requirements for that use. Manufacturer's instructions should be followed, including product concentrations
- before being used in production, equipment should be thoroughly cleaned and sanitised, also after any maintenance or repair work has occurred
- equipment manuals or suppliers' advice should be referred to regarding the extent to which equipment should be dismantled to enable its adequate cleaning and sanitising
- high-pressure spray hoses should not be used in the production area as they present an even higher risk of cross-contamination through aerosols
- keep separate cleaning materials for pre- and post-sanitation areas.
- packers should identify potential hotspots for cross-contamination in their packhouses (Figure 45) and include them in their packhouse cleaning and sanitising programs.

- Cleaning and sanitising are two distinct processes to achieve pathogen control in packhouse environments.
- Cleaning is the complete removal of soil, debris and food particles using detergents under recommended conditions. A surface must be cleaned before it can be sanitised.
- Sanitising is the substantial reduction in the number of microorganisms using chemical sanitisers with appropriate concentrations and contact times.
- Develop and follow sanitation standard operation procedures for fruit contact (e.g. harvest bins, conveyors) and non-fruit contact surfaces (e.g. walls, floors). Wear appropriate personal protective equipment (e.g. gloves, footwear, safety glasses).
- Food grade detergents and sanitisers should be used for fruit contact surfaces. Avoid high pressure washing to prevent spreading of contaminants through aerosol formation.

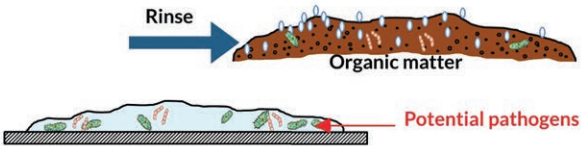
1. Clean

Pre-rinse target surface with water to loosen and remove soil and debris. Apply detergent and scrub the surface properly. Mechanical force, concentration, time and temperature are four factors influencing cleaning efficacy.



2. Rinse & Inspect

Perform a post-rinse step to remove detergent and remaining soil and debris loosened by washing. Rinse equipment and other surfaces from top to bottom. Conduct a visual inspection to assess effectiveness of cleaning.



3. Sanitise

Use approved chemicals sanitisers at recommended concentrations and contact times for effective sanitisation. A proper cleaning step ensures interaction of sanitiser with potential pathogens present on surface.

4. Validation and verification

Validate your cleaning and sanitisation schedule as per the food safety plan. May use adenosine triphosphate (ATP) swab analysis to verify the surface has been effectively cleaned and sanitised.

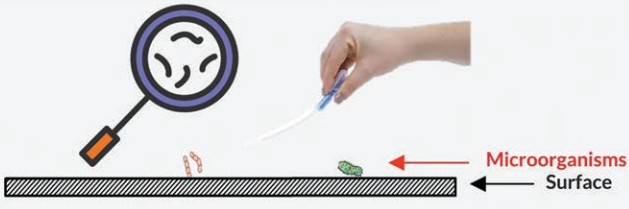


Figure 44. An overview of cleaning and sanitising packhouse facilities and equipment.

Figure 45. A list of potential hotspots for cross-contamination in the packhouse.

Environmental monitoring program

Environmental monitoring is critical in preventing fruit from contamination during postharvest processing and packing operations (Figure 46). A successful environmental monitoring program (EMP) can deter foodborne bacterial pathogens such as *L. monocytogenes* and *Salmonella* from establishing and growing in the processing environment. Other viral pathogen risks associated with staff can also be minimised by adopting a good EMP, which will not only validate the processes and control measures that are set in place, but will also provide assurance of the quality and safety of the product. Additionally, a good EMP will be able to identify any arising problems by giving an early warning of a breach in hygiene systems and barriers. Identifying the problem early allows for quick and direct action to rectify it (Malley et al. 2015).

Figure 46. A typical packhouse environment showing packing tables and conveyor belts where microbial pathogens can survive and form biofilms.

'Seek and destroy' foodborne pathogens

The environmental monitoring program should detect foodborne pathogens before they are established and become a source of contamination. Therefore, the program should be designed to 'seek' (find) the pathogens present, followed by immediate and direct action to 'destroy' (remove) them from the environment. The program uses an aggressive and systematic approach to identify harbourage sites and niche locations where these pathogens can survive and persist despite cleaning and sanitising measures. The majority of positive results do not come from harbourage sites but routes of transfer such as an employee's gloved hands. When a positive result occurs, it is important to increase sampling frequency and scope to find the source, be it a harbourage site or niche. Detecting these pathogens should mean the program was successful in identifying the source of contamination and thus allowing its elimination.

If a pathogen is undetected it does not necessarily mean that the processing environment is free from pathogens; it might indicate that the design and implementation of the program is not adequate to detect the target pathogen. This also means that it is therefore unable to prevent the establishment and growth of the microorganisms. Remember, if you are not finding positives, you might not be sampling hard enough.

Environmental monitoring program design

The EMP should be business-specific and based on contamination risks, considering the facility's history of human pathogens, the target consumers and the complexity of the processing environment. Each facility needs to have a customised environmental sampling plan that identifies the sites in the processing environment from which the samples will be collected, the number of samples to be taken, how frequently the sampling will occur, the types of samples that will be taken and the method of testing these samples.

Sample sites

Sample sites are generally selected based on their potential to come in contact with food (Figure 47). Site selection should be risk-based and should favour areas where pathogens are more likely to grow and be transferred, such as niches and harbourage sites. An ideal niche would be somewhere that provides the essentials for bacterial growth or a place that is difficult to clean or that is infrequently cleaned. The selection of sample sites is a critical part of food safety advice and training (Figure 48).

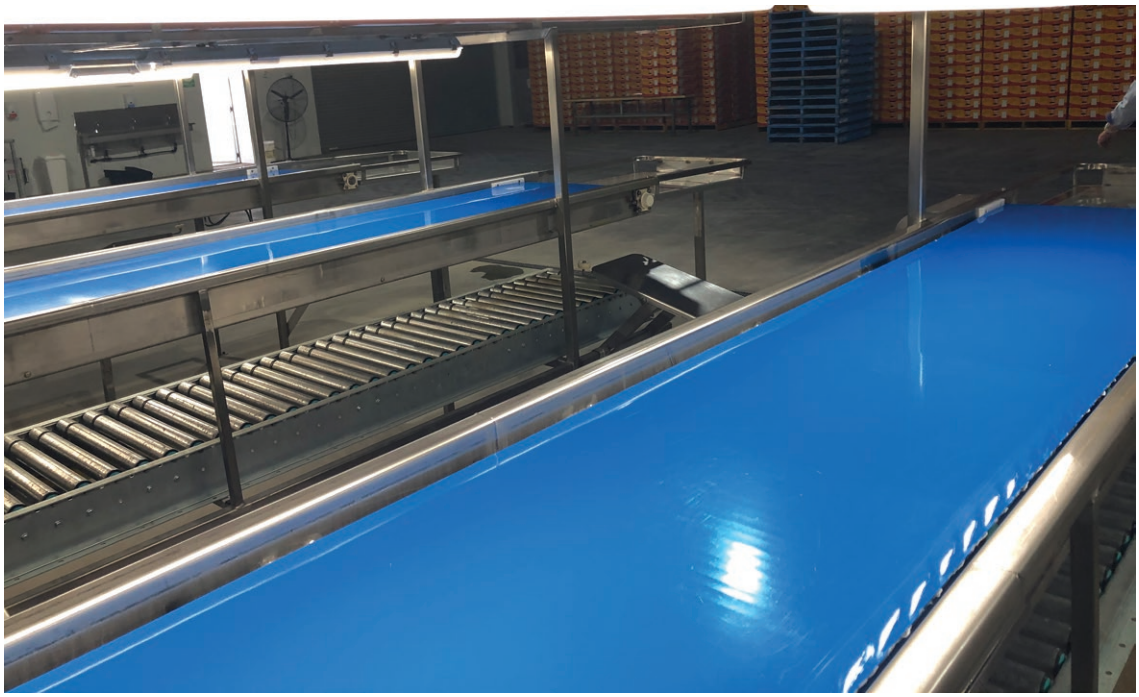


Figure 47. A clean conveyor belt in a melon packhouse.

Number of sites and frequency of sampling

The type of produce, size of the facility, number of staff and resources are a few variables that need to be considered when determining sampling sites and frequency. The very minimum requirement, even for the smallest processors, is five samples across both zones at any one time, with three sites in Zone 1 (fruit contact) and two sites in Zone 2 (no fruit contact; Table 2). An ideal case would be the detection of *L. monocytogenes* and *Salmonella* in Zone 2 leading to its elimination, preventing the contamination of Zone 1. A weekly sampling frequency is generally recommended for foods that can support *L. monocytogenes* and *Salmonella* growth and the shelf-life is greater than five days (e.g. rockmelons).

Table 2. Classification of environmental sampling sites.

Priority	Examples of sample sites within the priority zone
Zone 1 – fruit contact surfaces	Harvest bins, conveyor belts, rollers, brushes, graders, packing tables
Zone 2 – non-fruit contact surfaces	Floors, walls, ceilings, drain outlets, cold rooms, floor joints, condensate from refrigeration evaporators, pallets, forklifts

Figure 48. Training growers and packers in microbiological sampling is fundamental to implementing a packhouse environmental monitoring program.

Sampling method

Samples should be taken from Zone 1and Zone 2 areas within a packhouse using suitable sterile sampling methods. Sampling should be done by swabbing sites using sterile moistened swabs and/or sponges. Sponges are recommended for general sampling (Figure 49), with swabs being used only for hard to reach places and niches.

Procedures should be developed and written down, detailing exactly how to conduct the sampling to ensure the process is consistent. Staff should be trained in the procedures, with particular emphasis in ensuring swabs are not contaminated by the person conducting the swabbing or from other surfaces not swabbed.

It is best practice to start sampling in critical hygiene areas (e.g. packing tables) and move progressively out to standard hygiene areas (e.g. fruit dumping conveyor, harvest bin) to help avoid introducing contamination from standard hygiene areas (low-risk). Samples should be taken during full production or before equipment clean up.

Figure 49. Sponges are recommended for general sampling using sterile gloves.

Samples should not be taken immediately after equipment has been cleaned, unless verifying the effectiveness of the cleaning program. If samples must be taken during non-production, wait several hours after cleaning and sanitising for chemical residues to become inactive. Areas to be swabbed should not contain any chemical residues that might inhibit or interfere with the growth of bacteria being swabbed; in this case, sampling should be aborted or the sample should be submitted noting that presence of residues were suspected.

Consider *L. monocytogenes* and *Salmonella* as 'fish to catch' when collecting samples from the processing environment and look in the areas that you know they like to lurk, such as moist areas, nooks and crannies, as well as areas that are hard to clean and use a swabbing technique that is more likely to trap them. If these pathogens are present in a biofilm, they will be harder to pick up with a swab and more physical effort might be required.

Sampling equipment

There are a few elements to consider when developing the right sampling method for your environmental monitoring program. Now that you know where and when you will be sampling, the next step is to determine the right equipment for the task. There are many different products available for environmental sampling and not all of them will suit your facility or the facility that will be analysing the samples. The two main considerations revolve around collection broth and material used to take the samples.

Collection broths

Collection broths, also known as 'rinse', 'transport' and 'wetting' solutions, are the media used to moisten devices used for sampling such as pre-moistened sponges. Collection broths contribute significantly to the success of an environmental monitoring program and must:

1. not interfere with the laboratory tests performed on the sampling device
2. neutralise any sanitiser that might be present on the surface being sampled; if a sanitiser is picked up by the sampling device, microorganisms exposed to the sanitiser might die before the sample is processed in the laboratory resulting in false negatives
3. maintain the viability of all microorganisms collected by the sampling device until the sample is processed by the laboratory. It is critical that the organisms are placed into favourable and stabilising environments in order to survive transport to the laboratory.

A range of collection broths is available including neutralising broth, Letheen broth, buffered peptone water and Dey-Engley (D-E) neutralising broth.

Sampling material

The ideal sampling collection material needs to meet the following requirements:

1. be sterile and clean, free of toxic substances that could cause injury or kill microorganisms after the surface sample has been collected and before the sample has been processed
2. have sufficient roughness so that the surface can be vigorously scrubbed in order to disrupt and lift biofilms without the material disintegrating
3. be effective at collecting microorganisms from a surface and releasing them during a procedure designed to count levels of microorganisms
4. it should not impede diagnostic tests performed on the sample nor produce false results.

The two primary materials used in environmental sampling are cellulose and polyurethane. Cellulose is a plant-based material that varies in size, thickness and roughness. It has been the preferred sponge material for surface sampling for the last 50 years, is the most studied material and cellulose sampling kits can be easily sourced. However, it has been known to rip and fray on rough surfaces.

Polyurethane is a synthetic material and has a high level of consistency. It also has higher flexible strength and is more likely to stretch rather than rip, making it easier to use on rough surfaces. Polyurethane is compatible with newer generation diagnostic tests that are more sensitive to contaminating materials that can be found in less controlled materials such as cellulose.

Implementing an environmental monitoring program

The steps and strategies to implement a packhouse environmental monitoring program are shown in Figure 50.

Sampling using a sponge

Sponges for sampling can be purchased moist or dry and can be used with handles or a gloved hand. Sponges are ideal for sampling large areas (< 1,000 cm^2) such as bench tops, floors, conveyors, packing tables, drip trays and flat surfaces under or behind equipment.

Both sides of the sponge can be used and a reasonable amount of force can be applied to sponges to remove particles such as dust or bacteria. Samples from the same zone can be combined to reduce test costs. However, when a positive result is returned from an area where samples were combined, each site will subsequently need to be tested individually to pinpoint where the organism came from. Samples from different zones should never be combined. General instructions for sampling with a sponge are:

1. label the sample bag with sufficient details (e.g. date, sample site, sample number, zone, bacteria that is being sampled for)
2. remove the sponge from the plastic bag by using the handle, sterile forceps or a gloved hand; if using a sterile glove to handle the sponge, do not allow the glove or sponge to contact any surface other than the sampling surface
3. sample the chosen surface in two perpendicular directions, changing the face of the sponge, then return the sponge to the plastic bag
4. remove and dispose of gloves without contaminating other possible sample sites
5. all sponges should be kept at 4 °C during transport
6. always follow manufacturer's instructions when using commercially available sampling kits.

Sampling using a swab

Swabs are used for sampling inside equipment, e.g. fins on cooling units, motor housings, and bearings on conveyors, inside hollow rollers and in smaller niches. A wide variety of swab stick tips are commercially available including cotton, alginate, dacron, rayon and viscose. There are ideal for sampling areas up to 100 cm^2 but are not as absorbent as sponges and can get overloaded if used to sample more than this. This is why they should only be used for hard to reach areas and niches and not for general sampling of surfaces. General instructions for sampling with a swab are:

1. label the swab tube with sufficient details (e.g. date, sample site, sample number, zone, bacteria that is being sampled for)
2. remove the swab stick from the sterile wrapping
3. moisten the tip, if required, by immersing it in a tube containing dilution liquid
4. press the tip of the tube against the inside wall of the tube to remove excess fluid
5. press the tip of the swab onto the surface and streak in two perpendicular directions of the area to be sampled (Figure 51) while rotating the swab stick between thumb and forefinger
6. put the swab back in the tube with the dilution material and aseptically break or cut off the stick
7. clean the sampled area with an alcohol wipe
8. all swabs should be kept at 4 °C during transport.

Key points for sampling technique

- handle the sponge or swab carefully to avoid contamination
- ensure there is sufficient contact between the surface and the sampling equipment (sponge or swab) and that you use the entire sponge or swab
- when swabbing, apply downward pressure while simultaneously rotating the bud of the swab to ensure sufficient contact between the swab and the surface being sampled
- do not touch near the swab or bud, only use the handles
- use a zigzag motion across the surface area, making sure the zigzags are close together to cover as much of the surface area as possible (Figure 51)
- once a sample has been taken from the surface area once, repeat the process at a 90° angle to the original swabbing and place the swab or sponge in the bag. This technique can be used with a sponge with a handle or a gloved hand.

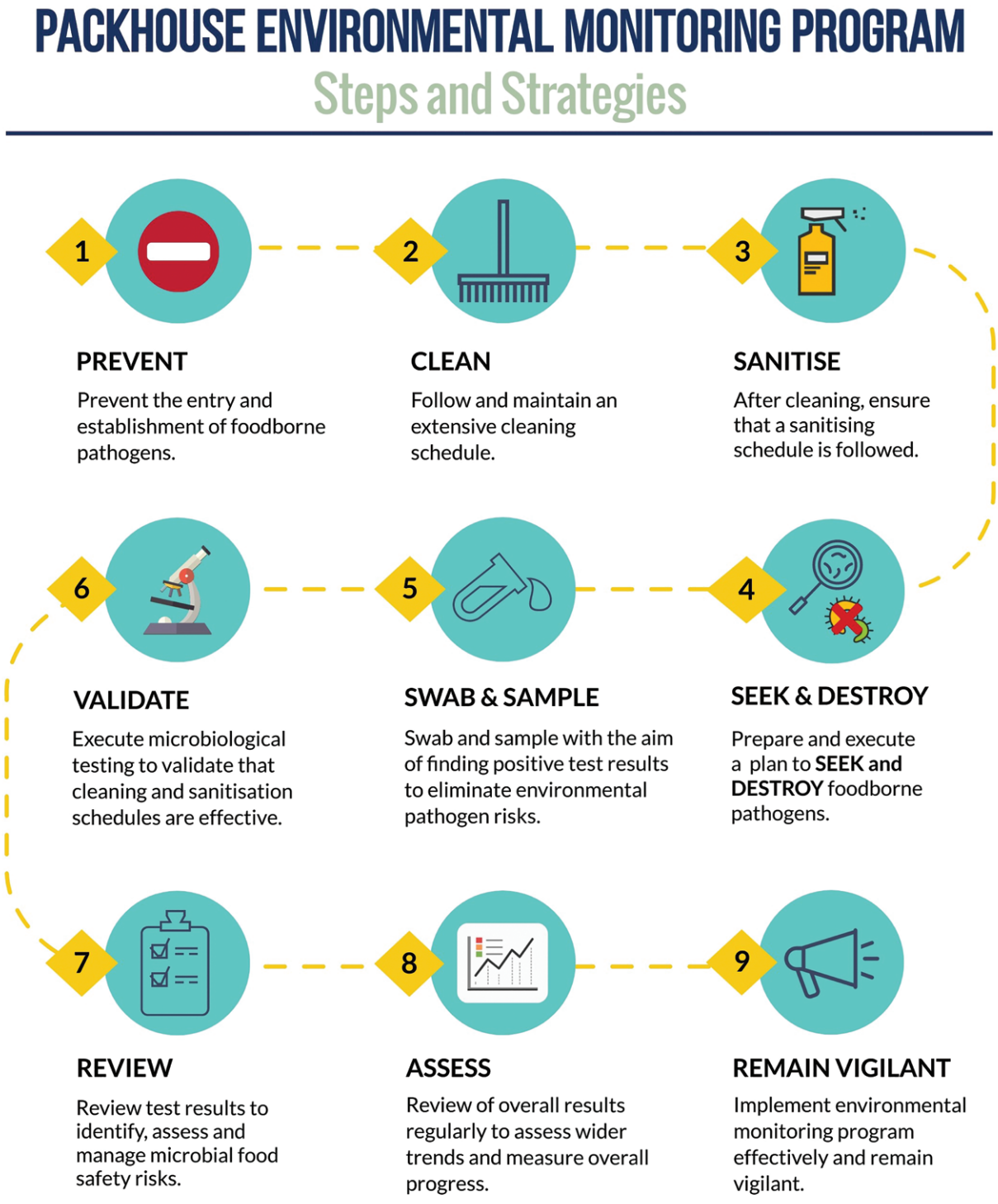


Figure 50. Steps and strategies to implement a packhouse environmental monitoring program.

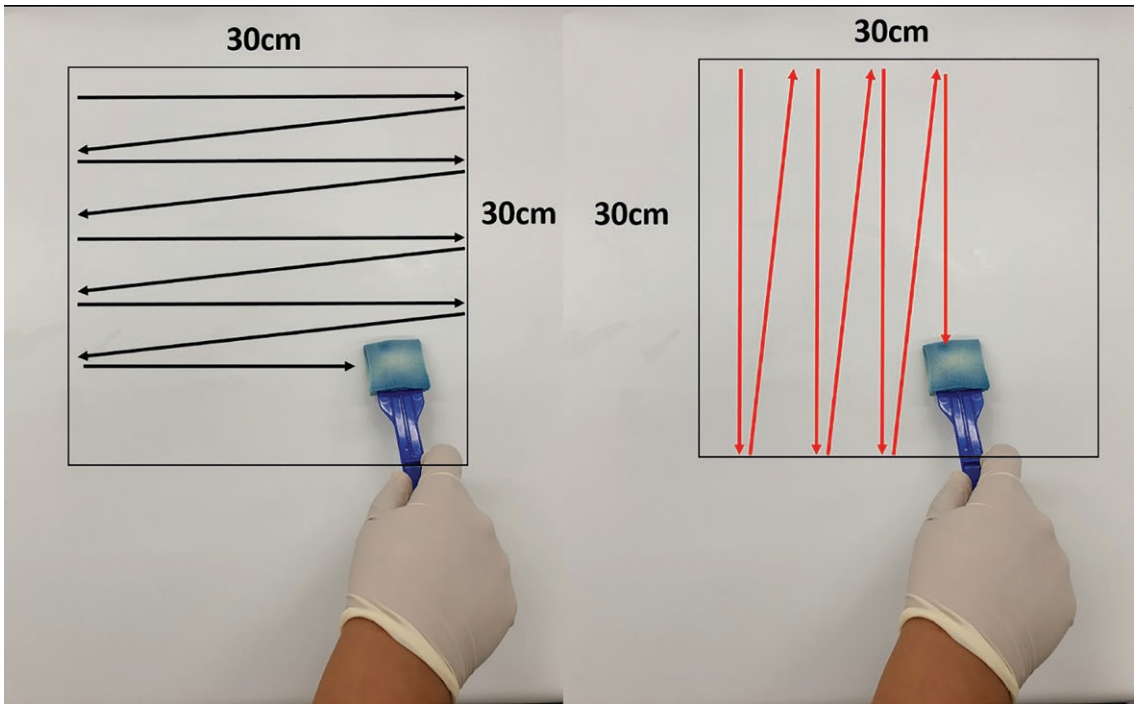


Figure 51. Correct sampling technique with a sponge or swab.

Testing samples

Testing can be done at a laboratory (Figure 52) that is accredited for testing environmental samples for target foodborne pathogens.

Figure 52. A view of the NSW DPI's Horticultural Food Safety Research Laboratory at Ourimbah, NSW.

Actions due to positive results (response or corrective actions)

When target pathogens such as *L. monocytogenes* or *Salmonella* are detected in an environmental sample, corrective actions should commence immediately to eliminate the pathogen. The corrective actions taken must be documented as part of the HACCP/food safety program. Whenever there is a positive environmental sample from a Zone 1 or Zone 2 surface, the packhouse should increase the frequency of environmental testing to daily until three consecutive negative results are obtained. This will monitor the effectiveness of the corrective action undertaken. It might also be useful to consider whether the frequency of testing or the sites to be tested should be altered for the future.

When positive results are obtained from Zone 1 (high-risk) sites, the following actions should occur:

1. postharvest processing should cease immediately
2. the surrounding area and equipment are to be cleaned and sanitised
3. all product processed since the day of swabbing should be tested
4. before recommencing processing, swabbing is to be repeated in both zones and if the result is:
    - negative – recommence processing, increase environmental monitoring
    - positive – dismantle all equipment and conduct a deep clean of the area and equipment. Re-assemble equipment and sanitise. Repeat swabbing, cleaning and sanitising until a negative result is obtained. Sites other than the normal environmental monitoring sites might be required to be tested in order to determine the contamination source

When positive results are obtained from Zone 2 (low-risk) sites, the following actions should occur:

1. the implicated areas are cleaned and sanitised
2. before recommencing processing, swabbing is to be repeated (Zone 2) and if the result is:
    - negative – increase environmental monitoring
    - positive – conduct a deep clean of the area. Repeat swabbing, cleaning and sanitising until negative result obtained.

A flow chart illustrating the steps in responding to microbiological test results is shown in Figure 53.

Reviewing results

The laboratory test results should be reviewed immediately and responded to if necessary. All laboratory records should be kept together and the overall results should be reviewed at least once a month to detect problems and trends that might emerge. Keep a record of results on a map or floor plan of the packhouse and examine if there are specific areas or equipment where contamination is re-occurring. If problem areas are identified, a concentrated monitoring effort will help pinpoint the exact contamination source.

If pathogens are detected, take corrective and preventative actions to prevent re-occurrence. This can include repairs and maintenance, intensive cleaning and sanitising or replacing worn equipment to eliminate the contamination source. Results might even require modifying the EMP to ensure these problem areas are swabbed more frequently, especially in Zone 1 (high-risk food contact areas).

Product testing

Microbiological testing of fruit is useful for monitoring and verifying control measures being implemented. However, fruit testing alone is not enough to demonstrate food safety because it is possible that pathogens on fruit may not be detected even when large sample numbers are tested. Foodborne pathogens such as *L. monocytogenes* and *Salmonella* species should not be detected in a 25 g fruit sample.

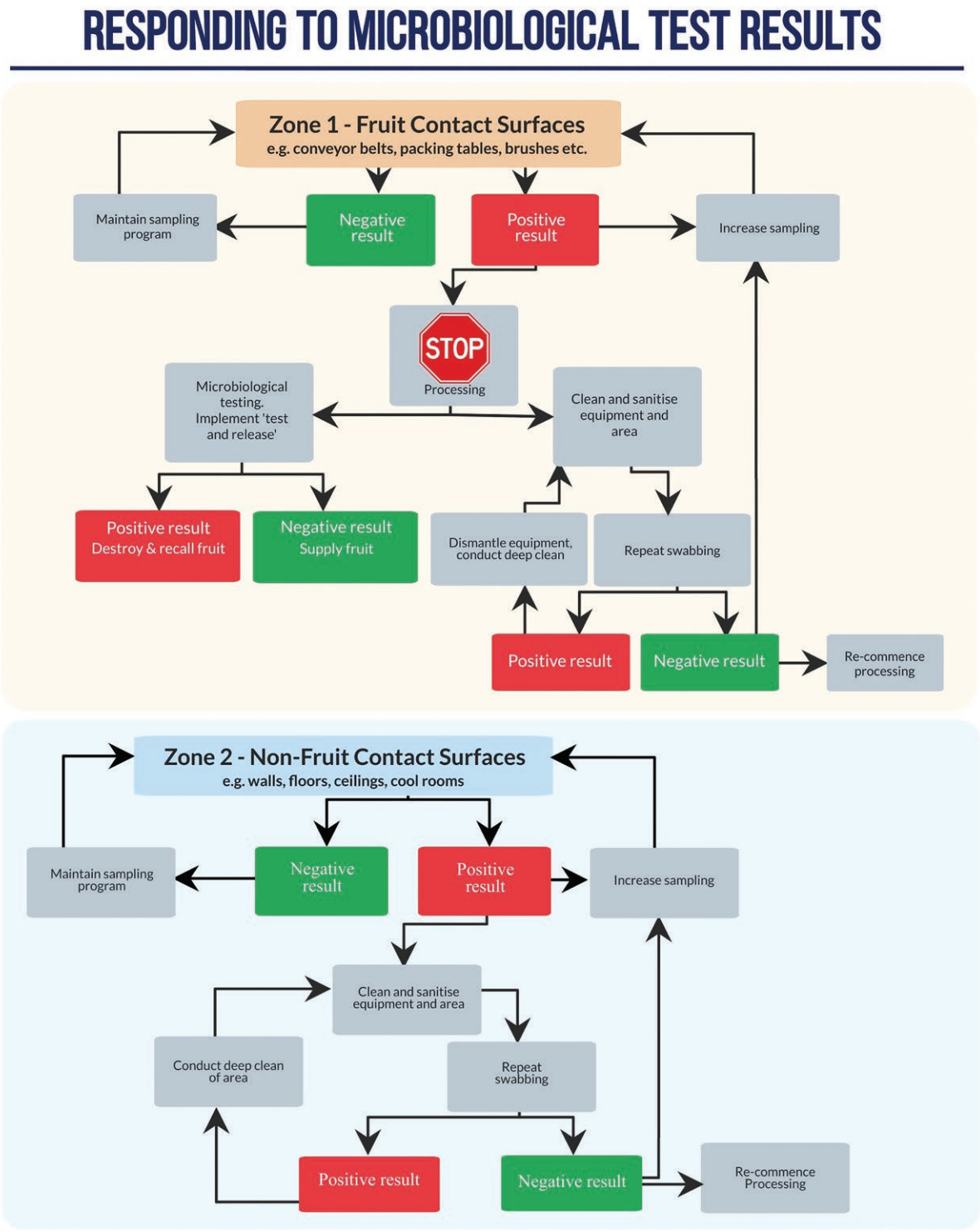


Figure 53. A flow chart to illustrate steps in responding to microbiological test results.

Transport and distribution

Transport is an important component of the melon supply chain. It involves tractors and trucks transporting melons from fields to packing and storage facilities as well as distributing packed melons to markets and retailers. There are a number of risks associated with transport that contribute to produce contamination such as the faeces of birds and pests that might nest in the vehicles, animal faeces if the vehicle was previously used to transport animals and the water used to clean the vehicles that might have been contaminated. Chemical contamination risk can occur from any chemical spills such as pesticides, fuel and oil that might have been transported in the vehicle. Physical hazards include screws, glass, metal/plastic pieces and other foreign material from a damaged or poorly maintained transport vehicle.

Every step in the transport and distribution chain needs to be effectively managed to control and eliminate contamination risks. This involves:

- preparing SOPs for loading and unloading processes including vehicle inspections to ensure that food safety needs are met, evaluate the condition of the trailer, cleanliness (walls, floors) and structural condition and take steps to ensure that previous loads cannot contaminate melons during transport
- vehicle operators should have written sanitation procedures (i.e. how often the procedure should be performed, areas and items to be cleaned and what types of sanitisers are used) for vehicle cleaning in addition to a cleaning schedule log (i.e. who performed the cleaning and when) which can be readily referred to
- inspections and maintenance should be performed regularly, including documentation of any findings and actions to be taken
- ensuring that loading and unloading practices minimise physical damage to the fruit (Figure 54)
- maintaining refrigeration units (Figure 55) in good condition to achieve optimum temperatures for the duration of transit
- cooling melons before loading into the trucks and the temperature should be measured and recorded before loading, during loading and during transit.

Figure 54. Truck ready for loading.

Figure 55. Refrigerated transport.

Supermarkets, wholesalers and retailers

Like melon growers and packers, wholesalers, supermarkets and retailers have equal responsibility as part of the melon supply chain to provide safe melons to consumers. How the produce is handled, packaged, stored and displayed can contribute to its contamination risk. It is a requirement for food retailers and businesses to follow food standards to ensure the fruit does not become unsafe during in-store handling, storage, display and sale. It is recommended that:

- rockmelons and specialty melons should be kept at 5 °C on refrigerated shelves (Figure 56)
- fruit must be handled carefully to avoid any physical injuries. Fruit showing any signs of decay, mould or bruising should be discarded

Figure 56. Rockmelons in a Japanese supermarket displayed at 4 °C.

- pre-cut fruit must be kept at 5 °C or below with an indication of best before time and date. Cut small batches frequently rather than storing large batches for longer
- fruit must be washed and sanitised before cutting into halves or quarters. Ensure all fruit-contact equipment and utensils such as cutting boards, knives and benches are thoroughly cleaned and sanitised
- records should be kept of packers and suppliers (e.g. grower's name, address, date of harvest, lot identification) to help isolate the source of contamination should an outbreak occur
- personal hygiene of staff handling fruit should be ensured; train the staff to handle rockmelons and specialty melons as a high-risk food
- minimise fruit contamination risk from shoppers through providing food safety information, antibacterial hand wash and vigilant inspection of produce by employees. The shoppers might touch the fruit and put it back on display (Figure 57), or when the fruit is exposed to sneezing and coughing.

Figure 57. Rockmelons and specialty melons on display in an Australian supermarket.

Traceability and product recalls

Product traceability

Product traceability refers to the ability to follow the movement of a batch of fruit through specified stages of field production, picking, cooling, washing, packing, processing and distribution. Tracing information about fruit facilitates tracking the physical movements from their original source through to their final recipient and tracking the product from the final recipient back to the source. This is colloquially known as the 'one step forward, one step back' system. All supply chain participants should know where the fruit is coming from and where it is going. Though not a preventative measure on its own, effective product tracing systems are an important element of a comprehensive food safety program and should be verified periodically for effectiveness. If properly implemented, they can help to minimise the fallout of a recall if required.

It is recommended that:

- each rockmelon or any other specialty melon should be labelled for traceability, branding and provenance claims (Figure 58). The label can include a quick response (QR) code to provide the consumer with information about the source of fruit (i.e. melon farm) and food safety practices

Figure 58. Rockmelons packed individually in nylon nets and labelled by a melon grower.

- a documented traceability program should be established and implemented for every melon farm/packhouse
- records that enable reconciliation of product delivered to recipients (one step forward) should be maintained
- records should be maintained that link the product with the source of the fruit (one step backwards)
- batch or lot identification records should be kept
- any other relevant production and supply records that can assist in the event of a food safety failure should be maintained.

Product recalls

Recall programs are procedures to remove the product from stores when there is a reason to believe that the product is or might be contaminated. The ability of supermarkets and retailers to remove contaminated or potentially contaminated fruit is vital to both businesses and consumers. It is recommended that all farms and packhouses have a documented recall program, including complete written procedures. The documented program should include a designated recall team who can be contacted at any time if a product requires recalling. A contact list of key regulatory officials that may need to be notified if a recall is warranted as well as a list of commodity organisations and trade association experts that could be called upon to provide technical help if needed should also be kept.

With proper documentation and reporting in place, recalls can be minimised in terms of size and effect, as the specific cause and particular produce affected can be identified and located. Such actions can mean the difference between a batch recall and an industry-wide recall. Product recalls are triggered for a number of reasons such as public health risks, material tampering, inadequate shelf-life, inaccurate food preparation instructions, cross-contamination, inadequate food safety protocols and improper packaging or labelling.

To be prepared for food safety outbreaks, each farm should have:

- a documented incident management plan that is practised at least once a year
- the ability to trace any potential risks to the food safety of the produce
- a recall plan, detailing what to do if a recall is required
- a communication plan, detailing who needs to be contacted in a recall
- a proactive attitude towards product identification, traceability and recall
- a preparedness and action plan for the unexpected.

If improperly managed, product recalls can lead to long-term damage to the brand and reputation with stakeholders, consumers, customers, shareholders and regulators.

Developing standard operating procedures

Standard Operating Procedures (SOPs) are documented step-by-step instructions that describe a specific procedure or task. Information necessary to complete the procedure such as what is needed, who will conduct the procedure and how exactly to perform the procedure is included. SOPs are operation-specific and might differ for the same task from business to business.

This section provides guidance on developing standard operating procedures specific to your practice. There is a great deal of work and effort from growing to retail distribution in order to provide high-quality melons to the consumers. SOPs provide consistency and allow different people to always complete the same tasks consistently and safely. SOPs also offer a number of other benefits including:

- improving communication as SOPs clearly inform employees of their responsibilities and how they can fulfil them
- reducing system variation as variation often leads to mistakes, lower quality production and efficiency
- helps training by providing a reference document and reduces training time
- guiding relief staff when filling in to perform the task
- providing an overview for quality control and performance evaluation
- along with training they help ensure that all staff are safe at work and provide legal protection and reference if an incident should occur
- reducing biosecurity risks of the operation by eliminating variation
- encourages regular evaluation and continuous improvement of the tasks.

Principles of developing an SOP

1. determine your goals for the procedure as SOPs are more successful when they are developed to achieve specific results. The goal for an SOP for cleaning and sanitising equipment would not be to ensure that equipment is cleaned and sanitised in a similar manner, but to reliably prevent and minimise the chance of equipment becoming a source of contamination and facilitating the transfer of microorganisms to the fruit
2. select the appropriate format for your SOP. There are a number of different formats such as a simple set of steps, hierarchical steps, graphical or flowcharts and you need to make sure you choose the right format for the procedure (Table 3). Ask yourself how many steps are in the procedure; if less than 10, use a simple step format. If there are more than 10 decisions to make throughout the procedure, a step format might end up being too hard to follow, so a flowchart would be more appropriate. If the activity is long, graphic format using pictures or diagrams to illustrate the procedure can be very helpful

3. identify key areas of concern for your operation where SOPs might be useful, for example, cleaning and sanitising equipment. A helpful activity is to observe someone performing the process as it is currently performed and write down everything they do. This will form the first draft of an SOP
4. ask staff for their input by showing them a copy of the draft SOP and ask them to review it and for any suggestions they might have, especially anything that would make it easier to understand or more accurate. An easy to follow and accurate SOP will result in improved performance
5. have your SOP externally reviewed. Consult with technical advisers such as microbiologists, researchers and quality assurance staff. They can provide assistance and give advice based on their scientific knowledge and experiences. Ask them to provide any changes that could make the SOP more effective
6. testing the SOP is a great way to ensure it is effective. Have someone follow the SOP exactly as it is described and observe what they do, taking down any notes. Then have someone unfamiliar with the task to follow the SOP. Any steps that might have caused confusion should then be revised and reviewed
7. once the final draft of the procedure is produced, ensure that it is available and posted in the appropriate places. Ensure there is a copy in the workplace area where the procedure is conducted. A copy should be kept in a master SOP file for reference. It is also useful to include essential SOPs in employee handbook materials. Any workplace copies should be printed in text large enough to ensure it can be followed while completing the task
8. ensure that there is a process in place to keep SOPs up to date
9. use the SOP in training or retraining as necessary. Ensure that staff are trained to follow the procedure exactly. This helps to ensure that certain steps are not interpreted the wrong way. Employee training is critical in ensuring standard operating procedures are successful.

A summary of steps in developing an SOP for melon packing operations is given in Figure 59. Important tips for writing the SOP are shown in Figure 60.

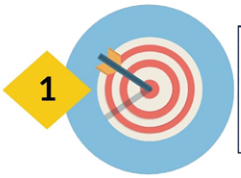
Table 3. Format choice for standard operating procedures.

Many decisions?	More than 10 steps?	Best format to use
No	No	Simple steps
No	Yes	Hierarchical or graphic
Yes	No	Flowchart
Yes	Yes	Flowchart

Source: Stup 2001.

DEVELOPING A STANDARD OPERATING PROCEDURE (SOP)

A standard operating procedure (SOP) is a documented set of instructions that describe a specific procedure or task. The SOP provides essential information including what is needed, who is responsible for the procedure and how exactly to perform the procedure. SOPs are operation-specific and SOPs for the same task will differ from farm to farm. SOPs are essential in ensuring different people are able to complete the same task consistently and safely.



Determine goals for SOP

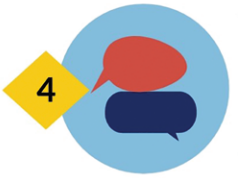
- For example, the goal of an SOP for cleaning and sanitation of an equipment would be to reliably prevent and minimise the chance of equipment becoming a source of contamination rather than to ensure that equipment is cleaned and sanitised in a similar manner.

Select SOP format

- Formats include simple set of steps, hierarchical steps, graphical or flowcharts.
- Determine the number of steps in the procedure. If less than 10, use simple step format. If there are a lot of decisions throughout the procedure use a flowchart or graphic format.

Identify key areas of concern for your operation.

- Identify key areas of concern for your operation e.g. sanitiser concentration or cleaning and sanitisation of equipment.
- Observe someone performing the process and take note of everything they do. This becomes the first draft of an SOP.



Review SOP internally and externally

- Ask workers to review the draft SOP and suggest changes to make it easier to understand
- Consult with technical advisers such as microbiologists, researchers and quality assurance specialists.

Validate/test SOP

- Ask someone to follow the SOP as it is described. Observe and take down notes. Also ask someone unfamiliar with the task to follow the SOP.
- Steps that cause confusion should be revised and reviewed.

Document and place SOP appropriately

- Place a copy of SOP in the area where the procedure is conducted and in QA documentation.
- Essential SOPs can be included in employee handbooks.
- Periodic review of SOP to ensure any changes are updated.

Figure 59. Steps to developing a standard operating procedure for melon packhouses.

TIPS FOR WRITING A STANDARD OPERATING PROCEDURE (SOP)

- Use objective and active language e.g. "Measure sanitiser concentration" instead of "the concentration should be measured".
- Write steps as short sentences and list in chronological order.
- Ensure SOPs are direct and concise.
- Ensure any acronyms used are defined or well known.
- Avoid providing too much detail that the SOP becomes impractical.
- Ensure that there is enough detail to complete the process and all essential information is provided.
- Be sure steps can be easily implemented and followed.
- Ensure that the SOP is task specific, avoid including too many activities in one SOP.

Figure 60. A list of important tips for writing a standard operating procedure.

An example SOP for cleaning and sanitising harvest bins

Disclaimer: this sample SOP is included for educational purposes and may not be suited to procedures on individual farms. Please read thoroughly and use these as guidance documents.

Standard operating procedure	
Business name:	
Title:	Maintenance, cleaning and sanitising harvest bins
Procedure number:	
Number of pages:	
Function:	e.g. Quality Assurance, Environmental Monitoring Program
Implementation date:	
Revision number:	1.0
Author name:	
Signature:	
Date	
QA Officer/coordinator:	
Signature:	
Date:	
Approved by (name):	
Signature:	
Date:	
Approved by (name):	
Signature:	
Date:	

Purpose

Describes how harvest bins are to be cleaned and sanitised.

Scope

This procedure applies to all farm staff.

Safety and health

Risk assessment

- handling bins and lugs might pose risk of musculoskeletal injury if manual handling is involved in their movement, the risk being greater if containers are over stacked
- do not stack pallets and bins too high as this might lead to serious injury if stacks were to fall on anyone.

Definitions

[Enter any definitions that will assist any needed clarification here]

Responsibilities

- staff are responsible for following and conducting the SOPs to properly clean and sanitise containers, bins and lugs

- farm owners and food safety managers are responsible for training staff on proper technique, providing necessary resources such as tools, potable water, detergents and sanitisers, and making sure the cleaning and sanitising steps are followed correctly.

Materials

- personal protection equipment (e.g. gloves, shoes)
- high-pressure hose
- detergent [insert name of brand]
- sanitiser [insert name of brand]
- container(s) as needed for mixing and using detergent(s) and sanitiser(s) or for washing tools
- clean water (potable)
- brushes.

Procedure

1. inspect all harvest containers at least weekly for damage and repair before being used in the field. Take out of circulation and dispose of any unrepairable containers
2. follow a cleaning and sanitising schedule after each product is harvested or at the end of each shift, whichever occurs most often
3. steps for the cleaning and sanitising procedure:
    - hose harvest containers with potable water (microbiological equivalent to drinking water)
    - remove any visible dirt and debris by brushing or rinsing
    - prepare detergent [add preparation and mixing procedure here as per manufacturer's instructions] and add it to the water used on harvest containers in order to dissolve organic loads such as soil
    - apply the prepared detergent solution and scrub surfaces (for large equipment scrub from top to bottom)
    - rinse the container with clean water until all soap is rinsed away (for large equipment do this from top to bottom)
    - prepare sanitiser [add preparation and mixing procedure here as per manufacturer's instructions]
    - apply the prepared sanitiser solution and allow it to sit for [insert duration of time as per sanitiser manufacturer's instructions] minutes
    - rinse with clean water
    - let the surface air dry.
4. only use cleaned and sanitised containers for harvested fruit. DO NOT store non-produce items in harvest containers. Employees should be informed that it is unacceptable to store personal items in harvest containers; this includes clothes, lunches and water bottles.
5. use a clean sealed area or pallets to stack and store clean harvest containers and new boxes. Stored containers should be covered with plastic when not in use. Wash all harvest bins including old and new at the beginning of production.

Melon preharvest food safety checklist

Preharvest	Yes	No	N/A	Comments
Field assessment (location and history)				
Does previous use of the melon growing site present any physical, chemical or microbial contamination risks?				
Do fields adjacent to the site present any physical, chemical or microbial contamination risks?				
Do adjacent fields and their activity pose potential microbial risks?				
Does the field's surrounding environment promote run-off to the plantings? (e.g. elevated surrounding areas, slopes)				
Are there potential contributors to spray drift either in production areas or in adjacent fields?				
Are there buffer zones to mitigate risks of run-off, spray drift and wildlife presence in and around fields?				
Are there physical barriers such as fences to exclude animals and wildlife from production site?				
Are the records of land history, hazard analysis, pre-plant field inspections and tests such as soil tests kept?				
Has the site been inspected for any physical contamination?				
Agricultural water				
Has the water source been tested for its microbiological quality to meet compliance with the quality assurance program?				
Is the water source (e.g. pond, dam) protected from run-off or flooding?				
Is the water source protected from animal incursion and subsequent contamination?				
Are there steps in place to minimise contact between irrigation water and the fruit? (e.g. drip irrigation)				
Is there other activity associated with the water source? (e.g. livestock, wildlife or human activity)				
Is drinking/potable water quality used to make up and deliver chemical sprays to plants?				
Are records kept of the water source, water tests and associated activities?				
Has a hazard analysis been conducted for the water source?				
Are any bores or wells maintained and enclosed?				
Are water storage tanks constructed with materials that will not contaminate the water?				
Are water storage tanks clean and secured from any potential contamination (including deliberate contamination i.e. sabotage)?				
Has irrigation equipment been flushed before use?				
Fertilisers and soil amendments				
Do you use raw animal manure? (Not recommended)				
Do you use compost containing animal manures?				
Is the compost used in fields appropriately treated and tested in accordance with Australian Standard AS 4454-2012 or equivalent?				
Is the compost stored properly?				
Are approved and certified compost suppliers used?				
Are compost application and its microbiological quality test report documented?				

Agriculture chemicals				
Are agricultural chemicals (herbicides, pesticides, fertilisers) labelled and stored correctly?				
Animal and wildlife management				
Is animal movement controlled to prevent microbial contamination?				
Does the area have a high population of birds and wildlife?				
Have you taken the necessary measures to manage wildlife risks?				
Have you trained staff not to harvest the fruit with bird droppings?				
Have you trained the field staff to report the signs (e.g. footprints, faeces) of animal and wildlife incursion to the farm manager?				
Harvest				
Harvest bins and boxes				
Are appropriate harvest containers used? (appropriate size, material)				
Are containers regularly inspected and replaced?				
Are containers and harvest bins regularly cleaned and sanitised?				
Harvest equipment				
Is the equipment used for harvesting (such as gloves, clippers and conveyor belts) regularly sanitised following an SOP and schedule?				
Is the equipment used for harvest constructed with materials that can be cleaned and sanitised?				
Is harvest equipment only used for harvesting and not allowed to be used for other tasks?				
Is there a means of disposing of culled melons that will not attract animals and pests?				
Sanitary and wash stations				
Are field staff provided with sanitary stations including wash stations having soap and paper towels?				
Is there proper signage including hand washing technique?				
Are toilets within a 5-minute walk or 400 m of all staff?				
Are toilets and wash stations adequately supplied and maintained?				
Staff health and hygiene				
Are staff trained in the personal hygiene and field hygiene policies of the business?				
Do staff understand their role and feel responsible for food safety?				
Do staff have access to clean water, soap and single-use paper towel?				
Is drinking water available for staff?				
Are separate areas provided for field staff to use for tea breaks and meals?				
Is there a toilet facility for every 20 staff?				
Are reusable gloves cleaned and sanitised daily?				
When using gloves, are they used appropriately and replaced regularly?				
Is there a process to prevent staff who show signs of illness or have open wounds from handling produce?				
Is there a staff illness and injury reporting system?				
Do staff wear clean clothes daily?				
Are field staff aware of cross-contamination risks and are they trained in its prevention?				

Melon postharvest food safety checklist

Postharvest	Yes	No	N/A	Comments
Packhouse				
Are cold storage and pre-cooling facilities regularly cleaned and sanitised?				
Is the packhouse closed off to the outside environment?				
Are storage facilities kept free of pests including signs of pests e.g. droppings?				
Are there rodent controls (e.g. baits) put in place and are they regularly maintained?				
Are there any locations in the packhouse that could encourage birds to roost or nest?				
Are there any bird controls put in place?				
Are there any means for dust control? (e.g. plastic curtains)				
Is the building and layout of the packhouse designed to prevent cross-contamination?				
Is there direct access from the unprocessed fruit handling area to the processed fruit handling area?				
Is sanitation equipment cleaned and sanitised regularly?				
Is sanitation equipment stored correctly and kept separate from other equipment?				
Postharvest water				
Is drinking quality water used during processing and cleaning fruit contact surfaces such as harvest bins and conveyor belts?				
Is postharvest water tested by an accredited laboratory?				
If dump tanks are used, is water regularly replaced based on an objective measure of turbidity as per validated food safety plan?				
Is the frequency of dump tank water replacement based on the potential organic load on fruit depending upon weather such as dust storms and rainfall?				
Is the sanitiser concentration monitored and maintained regularly in the dump tank as per your validated food safety plan?				
Is the dump tank water temperature monitored?				
Are roller brushes (overhead and flatbed) maintained and regularly cleaned and sanitised?				
Are all roller brushes in contact with sanitised water sprays?				
Are there successive washing steps rather than a single wash?				
If tanks are used for storing water, are they sealed and designed in such a way to prevent animals and pests from entering?				
Are appropriate concentrations of sanitisers used for wash water?				
Are there appropriate methods (e.g. digital photometers and sensors) put in place to monitor sanitiser concentration at regular intervals?				
If chlorine is used as a sanitiser, do you monitor the pH of the chlorinated water to ensure it is maintained between 6.5 and 7.0?				
Is water ever recycled during the processing?				
If water is re-used, is there a provision of water treatment to ensure drinking quality is maintained during its re-use for fruit washing?				
Is water temperature monitored and recorded regularly?				

Postharvest	Yes	No	N/A	Comments
Postharvest water monitoring				
Are sanitiser concentrations regularly measured and monitored?				
Have there been any undesirable results?				
If yes, was any corrective action taken?				
Packhouse and equipment hygiene				
Are staff trained in a cleaning and sanitising program?				
Is a training register kept?				
Is there any equipment being used that is damaged or worn?				
Is the equipment that is used for postharvest processing of fruit maintained, inspected and repaired regularly?				
Are there any porous surfaces (generally used for cushioning) in the packing line?				
Are fruit contact surfaces such as harvest bins, conveyor belts and brushes sanitised with approved food grade sanitisers and detergents?				
Does the design of equipment allow for easy cleaning and sanitising?				
Is there regular inspection and scheduled cleaning of racks and forklifts?				
When garbage and waste are stored, is it covered?				
Are packing materials stored in a hygienic manner?				
Has a microbiologist/food safety expert been consulted to validate cleaning and sanitising procedures?				

Appendix: microbial food safety risks

This section describes potential microbial food safety hazards associated with fresh produce including melons. The aim is to provide basic knowledge of the microbial hazards and their key control measures to effectively prevent contamination. There are different types of microbial food safety hazards including bacteria, viruses and parasites that can contaminate the fruit and could cause serious illnesses among consumers.

Foodborne bacterial pathogens

Listeria monocytogenes

Listeria monocytogenes is a bacterium found ubiquitously in natural and manmade environments. It is one of several species in the *Listeria* genus and is responsible for human disease. First described in 1923, *L. monocytogenes* was primarily recognised as an animal pathogen associated with contaminated silage for cattle and sheep. Though known to be capable of causing human illness, *L. monocytogenes* was recognised as a foodborne pathogen in 1981. In recent decades it has emerged as a major foodborne bacterial pathogen. The World Health Organisation (WHO) estimated there were 23,150 cases resulting in 5,463 deaths (23.6%) in 2010 (de Noordhout et al. 2014).

L. monocytogenes can lead to listeriosis; an infection that is contracted by consuming foods contaminated with *L. monocytogenes*. At high doses it can affect anyone, but there are well-defined high-risk groups that are more likely to develop infection. These include pregnant women, children, immunocompromised adults and the elderly. Though responsible for a relatively small number of illnesses and foodborne outbreaks, *L. monocytogenes* is a major concern because listeriosis has a high mortality rate.

L. monocytogenes prevalence in soil was reported as high as 20% over 44 years ago (Weis and Seeliger 1975). It is an opportunistic pathogen, growing in a wide range of temperatures (0–45 °C), moist areas, and it survives under cold conditions. Its adaptability to diverse environmental conditions means it can survive for extended periods in the environment. Its resilience makes it more difficult to manage than other foodborne pathogens such as *Escherichia coli* and *Salmonella*. It can be easily transferred into packhouse environments through fruit, equipment, harvest bins, farm vehicles and personnel.

Once *Listeria* is present in the processing area, it will find suitable niches or harbourage sites to reside and multiply. These sites are often damp, hard to reach places such as hidden surfaces inside equipment and machinery. If cleaning and sanitising programs are not comprehensive or areas are kept moist and not exposed to sanitisers, *Listeria* can become established and form a biofilm, making it tougher to remove. It has the ability to attach to many different surfaces found in the processing environment such as stainless steel, rubber and glass (Nyarko et al. 2018).

Some control measures for *L. monocytogenes*

- develop an environmental monitoring program that aims to remove *Listeria* before it establishes and becomes a source of contamination
- look for places where water is pooling or dripping and where condensate is collecting
- implement and maintain a thorough cleaning and sanitising schedule that targets sites where *Listeria* could establish
- ensure all floors, equipment and food contact surfaces are in good condition with no niches or porous surfaces
- assess damaged, worn out, hard to clean and difficult to get to equipment, tools, sites and points of attachment
- make sure all equipment or machinery is thoroughly cleaned and sanitised before bringing it into the processing area.

Some key points about *Listeria*

- *Listeria* prefers moist, damp, hard to reach places to inhabit and grow
- *Listeria* can survive and grow in cold rooms
- *Listeria* is found in soil and can be present at higher rates than *Salmonella* and *E. coli*
- any *Listeria* species presence indicates the potential for *L. monocytogenes* to be present.

Salmonella

Salmonella are predominantly zoonotic, having the ability to transmit from animals to humans and cause disease. The *Salmonella* genus is made up of two species, *Salmonella enterica* and *Salmonella bongori*. *Salmonella enterica* alone has over 2,600 different serovars/serotypes, each with their specific selectivity for vertebrate hosts that range in severity and are present in different environments. Broad-host-range serovars colonise the digestive tracts of a wide range of animals. Well-known strains of this group include *S. typhimurium* and *S. enteritidis*.

Gastroenteritis is the most common form of salmonellosis linked to contaminated foods. Most people infected with *Salmonella* develop salmonellosis when the bacterium colonises on the gastrointestinal wall. Symptoms arise 12 to 72 hours after exposure and include diarrhoea, fever and abdominal cramps. Septicaemia or bacteraemia associated with salmonellosis emerges after gastroenteritis as the pathogen survives in the host tissue and makes its way into the bloodstream. Once there, it gains access to the rest of the body, potentially leading to long-term consequences or even death, but these cases are rare.

In the natural environment, *Salmonella* is transmitted through domestic and wild animals, birds, rodents and humans and is spread easily through water and soil. *Salmonella* foodborne contamination is predominantly associated with poultry or egg products but can originate from a wide variety of food products and different *Salmonella* serotypes. *Salmonella* can be found in various environments that have been exposed to faecal contamination. It is able to survive for several months in faeces and manure and thus cause contamination in fields, soil and water. Packhouses can be contaminated by water or soil containing manure from animals that are carriers. Dust storms and aerosols also facilitate the movement of pathogens from off-site locations into the fields and processing areas.

Some control measures for *Salmonella*

- do not use raw animal manures or untreated composts containing animal manures or poultry litter
- implement measures to prevent livestock and wildlife entering production fields and processing areas
- train staff to spot animal incursions in the field and to report them to farm management
- regularly test the microbiological quality of the water used for irrigation, chemical sprays and postharvest washing
- develop an environmental monitoring program to validate cleaning and sanitising protocols in packhouses
- regularly clean work surfaces, floors, equipment, doors and handles
- make sure anything brought in to the processing area (e.g. new or repaired equipment) is thoroughly cleaned beforehand.

Escherichia coli

Escherichia coli (*E. coli*) bacteria are found in the gastrointestinal tracts of humans and warmblooded animals. Most strains are harmless and make up part of normal intestinal flora, but there are a few strains that are pathogenic and cause gastrointestinal diseases. The pathotypes (specific groups based on virulence and pathogenicity, differentiated by serotyping) most often transmitted via contaminated food and water include enterohaemorrhagic *E. coli* (EHEC), enteropathogenic *E. coli* (EPEC), enterotoxigenic *E. coli* (ETEC) and enteroinvasive *E. coli* (EIEC).

E. coli O157:H7 is the most implicated strain of EHEC and its shiga-toxin causes serious illnesses that include bloody diarrhoea (with no fever), blood-clotting problems, kidney failure and death. Symptoms include acute abdominal cramps and bloody diarrhoea occurring every 15–30 minutes. The incubation period ranges from 1–9 days after ingestion and the illness can last from 2–9 days. A very small amount (10–100 cells) of *E. coli* O157:H7 is needed to cause infection and transmission is faecal–oral e.g. ingesting contaminated food and water. *E. coli* O157:H7 has been linked to many different types of produce including processed meats, unpasteurised milk, fresh produce and drinking water.

E. coli routes of transmission are complex, involving many different facets including human, animal and plant interactions within the ecosystem. ETEC, EIEC and EPEC are more prevalent in areas with poor sanitation and hygiene. Their transmission is facilitated through consuming contaminated food and water as well as through cross-contamination via direct human contact. Conversely, the emergence of foodborne pathogenic *E. coli* such as EHEC has increased in areas with better developed sanitation and hygiene. Outbreaks of EHEC and in particular *E. coli* O157:H7 in recent years have been associated with fresh produce such as lettuce, spinach and sprouts. Contamination can occur in the field from using manures and compost, sewage-contaminated water for irrigation and droppings from wild animals and birds.

Control measures for *E. coli*

Pathogenic *E. coli* associated with fresh produce is an increasing health concern. Considering a broader similarity in the contamination sources and routes of *Salmonella* and *E. coli*, refer to the control measures suggested for *Salmonella* on page 81.

Foodborne viral pathogens

Viruses are microorganisms much smaller than bacteria and can only be seen through an electron microscope. There are a number of viruses that are transmitted through foodborne routes with the most significant being norovirus (NoV) and hepatitis A (HAV). These viruses come into contact with humans in a number of different ways including consuming contaminated food, usually through the faecal–oral route, colonising in the small intestine where they replicate, and are then shed in the faeces of the infected. Both NoV and HAV can remain infectious for extended periods on soiled surfaces. Harvest and postharvest melon operations involve extensive handling of fruit by staff, which can increase the risk of contamination with these foodborne viral pathogens. An understanding of their nature, transmission and control is thus necessary.

Noroviruses

Noroviruses (NoV) are a group of viruses that are responsible for causing gastroenteritis and are collectively known as 'the stomach bug'. They are highly contagious, hard to kill and very easily transmitted from person to person but also through contaminated food and water. Norovirus is prevalent in Australia; an estimated 1.8 million cases are reported each year affecting all ages, but the illness can be more severe for children and the elderly (Hall et al. 2005). Symptoms of norovirus illness usually start 1 or 2 days after eating the contaminated food but can start within 12 hours. These symptoms include vomiting (that is often characterised as being projectile), watery diarrhoea, headache, mild fever and muscle aches. The infective dose of norovirus is low (1–10 viral particles), so even a small amount spread via person-to-person contact, contact with contaminated surfaces, direct contact with infected persons, stool or airborne particles from vomit can lead to infection. Norovirus is renowned for spreading quickly through an enclosed population such as nurseries, cruise ships, prisons and dormitories. Personal hygiene is extremely important in protecting from infection.

Hepatitis A

Recently linked to frozen berries and pomegranate recalls in Australia, hepatitis A is a resilient virus that infects the liver. It is very stable under a wide range of conditions

including freezing, heating, chemicals and desiccation. It is able to survive several months of being inactive. The virus is transmitted via person-to-person contact and through consuming contaminated food or water. The incubation period ranges from 15–50 days before symptoms such as inflammation of the liver occurs. Other symptoms include headaches, diarrhoea, vomiting, nausea, low appetite, muscle aches and jaundice. In rare cases, the illness causes severe liver damage and death.

Control measures for foodborne viral pathogens

Unlike bacterial pathogens, viral pathogens cannot grow or multiply on fresh produce. There are a number of steps and routes that viral pathogens can take to enter the melon supply chain but there are two main ways of contamination. Firstly, fruit can be contaminated in the field from contact with inadequately or untreated manures or sewage sludge used as soil amendments or contaminated water used for irrigation. Alternatively, contamination can occur during harvesting, postharvest handling, storage, distribution or final preparation directly from infected staff or food handlers who are carriers of the virus. As viruses cannot multiply outside a host, staff hand hygiene and control of infected food handlers are the main prevention measures. Others include:

- use personal protective equipment (PPE) such as gloves and hair nets
- maintain a routine environmental cleaning schedule
- maintain hand hygiene and cough etiquette practices
- provide adequate hand washing facilities for staff and food handlers and ensure that these facilities are used, including by pickers and packers
- provide a hands-free washing station for staff
- ensure that staff do not work while they are ill i.e. showing symptoms of gastroenteritis, coughing and sneezing
- clean and disinfect equipment and workspaces
- enforce regular hand washing e.g. at least before and after packing shifts
- clean and sanitise work surfaces including harvest bins after each shift to ensure contamination does not spread
- clean frequently touched surfaces, such as door handles, bathroom taps, washrooms, tables, phones, toilet seats, flush buttons and hand wash basins.

Foodborne parasitic pathogens

Parasites are organisms that live in or on other organisms, being dependent on their host for survival at the expense of the host organism (Centers for Disease Control and Prevention (CDC) 2016). Foodborne parasites are generally transmitted through consuming food and water that contains parasites in the transmission stages (spores, cysts, oocysts, ova, larval and encysted stages), with infection causing a range of illnesses in humans. There are many different foodborne parasites but those that concern the food industry are Giardia, *Cryptosporidium, Cyclospora* and Toxoplasma. With the increased consumption of fresh fruit and vegetables, foodborne parasitic outbreaks have increased worldwide.

Giardia

Giardia is a single-celled protozoan parasite regularly connected with consuming contaminated water. It has also been found in vegetables such as carrots. This parasite causes giardiasis, a gastrointestinal illness in humans, infecting people of all ages with the most susceptible being infants, children and young adults. The infection is sometimes asymptomatic but when symptoms are present they include malodorous diarrhoea, malaise, abdominal cramps, flatulence and weight loss. These symptoms are self-limiting, but can last over two weeks, although this is rare. Giardia is infectious during its cyst phase when it is highly resistant to extreme stressors such as cold temperatures and chemicals e.g. chlorine concentrations typically used in postharvest rinsing do not kill the cysts, which are also hard to wash off produce with rough surfaces.

Cryptosporidium

Cryptosporidium parvum and *Cryptosporidium hominis* are two of several species that cause cryptosporidiosis. They require a host to grow and reproduce, with *C. hominis* needing a human host specifically. They are transmitted by their infectious oocysts, which are shed in faeces. Notably *C. parvum* is a parasite whose oocyst has resistance to most chemical disinfectants such as chlorine i.e. after 90 minutes of contact with chlorine, viable organisms are barely reduced. It is however, susceptible to drying and UV sunlight. Human exposure to these parasites occurs after ingesting contaminated water or food that was irrigated or washed with contaminated water. As few as 10–100 oocysts are needed to cause infection and the main symptom is extreme diarrhoea.

Cyclospora

Cyclospora is a parasite that consists of one cell (unicellular) and cannot be seen with the naked eye. It causes cyclosporiasis, an intestinal infection that can affect people of all ages and is more common in tropical and sub-tropical environments, with travellers to these areas at increased risk. *Cyclospora* is transmitted orally when food or water contaminated with infectious sporulated oocysts from stool are ingested. A very small dose of 10–100 oocysts is needed to cause illness. Hosts shed unsporulated oocysts that need to develop into sporulated oocysts in order to become infective. This takes a few days in the environment outside of the host. For this reason direct person-to-person (faecal–oral) transmission is unlikely to occur.

Toxoplasma

Toxoplasma gondii are ubiquitous parasites that grow and reproduce inside their hosts. It has been estimated that over one-third of the human population has been exposed to *T. gondii*. Toxoplasmosis is usually mild or asymptomatic but can occasionally cause serious illness in the more vulnerable population such as the immunocompromised and unborn babies. They also have the ability to travel to other parts of the body including the heart, brain and eyes. *T. gondii* can be contracted from eating raw and uncooked meat containing the parasitic cyst or from food contaminated with cat faeces. Cats are the definitive hosts and are the only animal in which the parasite replicates sexually.

Control measures for foodborne parasitic pathogens

- maintain high levels of personal hygiene including washing hands vigorously for at least 20 seconds, rubbing all areas of the hand
- use drinking quality water to process produce
- prevent wildlife from entering the processing area where they might contaminate the line with faeces
- have systems in place that verify operating procedures such as sanitiser concentration in washing water
- regularly clean working surfaces, floors, equipment, doors and handles
- make sure anything brought in to the processing area (e.g. repair equipment) is thoroughly cleaned beforehand.

Recent foodborne illness outbreaks associated with rockmelons

Melons, specifically rockmelons, have been identified as a vehicle for pathogen contamination. They have in recent years been associated with a number of foodborne disease outbreaks involving *Salmonella*, *E. coli* O157:H7, *Campylobacter*, Norovirus and more recently *Listeria monocytogenes*. Here are some brief summaries of recent outbreaks that have occurred and the lessons learnt from the respective investigations:

Jensen Farms, Colorado, USA (2011)

The 2011 outbreak of *L. monocytogenes* at Jensen Farms, Colorado, USA, was widespread. The Centre for Disease Control and Prevention (CDC) reported that 147 people in 28 states had been infected, with 33 deaths and 1 miscarriage as a result. It was the deadliest outbreak of a foodborne pathogen in the USA since a 1985 outbreak of *Listeria* on cheese. After an investigation, the Jensen Farm was found to be the source of the contamination. The United States Food and Drug Administration (USFDA) then conducted environmental assessments of the facility to identify how *L. monocytogenes* was introduced into the supply chain (USFDA 2013). Some issues they found that could have contributed to the outbreak were:

- a lack of pre-cooling to remove field heat
- an inability to easily clean the packing facility floor and equipment
- building design issues that allowed water to collect in close proximity to equipment and employee walkways
- using washing and drying equipment that was originally used on a different farm and produce
- inadequate foresight and auditing that did not consider FDA guidance on melon processing.

After further investigation, the FDA concluded that the new equipment that was sourced from a different farm and the decision to use a packing and washing technique that used non-chlorinated water were two probable causes of the outbreak.

Chamberlain Farms, Indiana, USA (2012)

An outbreak in the USA involving strains of *Salmonella typhimurium* and *Salmonella newport* on rockmelons originating at Chamberlain Farms in Owensville, Indiana, sickened 261 people in 24 states. There were 94 hospitalisations and three deaths connected to the outbreak (Centers for Disease Control and Prevention 2012). During the USFDA's investigation, 50 environmental samples were taken to pinpoint the location of the contamination. They discovered several of the farm's practices that contributed to the outbreak:

- organic material harbouring bacteria on multiple locations on the conveyor belt tested positive for the outbreak strain
- rubbish, standing water, mud and dirt was found under the conveyer belt
- pooling water containing algae was found on the floor below where the melons were washed and rinsed
- the water used to process the melons was positive for Coliforms and *E. coli*
- bird faeces was found above the fruit processing equipment and it had dropped onto the processing line itself
- the processing area contained difficult to clean surfaces such as carpet, with samples testing positive for the outbreak strain at the end of the grading table
- indications of poor sanitary practices in the farm's rockmelon packhouse which were demonstrated by environmental swabs and product samples that tested positive for *Salmonella*
- failure to clean as frequently as necessary to protect against contamination of food
- the farm was not monitoring the effective levels of the chlorine sanitiser in the water within the concrete dump tank of the rockmelon processing line.

Red Dirt Melons, Northern Territory, Australia (2016)

An investigation into a spike of cases involving a rare strain of *Salmonella hvittingfoss* led to Australian food regulatory authorities connecting the outbreak to Red Dirt Melons in the

Northern Territory. At least 150 people were affected across the country, but there were no deaths. Although this incident was contained to one farm, it resulted in a national level product recall and this had a huge impact on the melon industry, resulting in decreased consumer confidence in the product.

Rombola Family Farms, New South Wales, Australia (2018)

In Australia, the most recent outbreak involving rockmelons was reported at the end of February 2018. *Listeria monocytogenes* was the cause of the outbreak, with 22 reported cases of listeriosis, resulting in seven deaths and one miscarriage. A multi-jurisdictional outbreak investigation commenced to identify the source of the outbreak. NSW Food Authority reported that the probable cause of the outbreak was a combination of environmental conditions and weather contaminating the surface of the fruit with low levels of bacteria persisting after the fruit was washed at the farm (NSW Food Authority 2018).

Caito Foods, pre-cut melon, Indiana, USA (2018)

In July 2018, the CDC reported 77 cases in 9 states with 36 hospitalisations caused by *Salmonella Adelaide* (Centers for Disease Control and Prevention 2018). Illnesses occurred from April 30 to June 3, 2018, in a range of ages up to 97 years; the median age was 67. Investigations using epidemiological and traceback evidence pointed to pre-cut melons supplied by Caito Foods, LLC (Indiana, USA) to be the source of the outbreak. On June 8, 2018, Caito Foods recalled fresh-cut watermelon, honeydew melon, cantaloupe, and fresh-cut fruit medley products containing one of these melons that were produced at the Caito Foods (USFDA 2018).

Caito Foods, pre-cut melon, Indiana, USA (2019)

On April 12, 2019, Caito Foods recalled pre-cut watermelon, honeydew melon, cantaloupe, and pre-cut fruit medley products containing one of these melons supplied at the Caito Foods LLC facility in Indianapolis (Centers for Disease Control and Prevention 2019). The CDC reported a total of 117 people were infected with *Salmonella carrau* across ten states resulting in 32 hospitalisations. Illnesses occurred from March 4 to April 8 2019, and most involved adults over 50 years. Investigations using epidemiological and traceback evidence indicates that pre-cut melons supplied by Caito Foods LLC were the likely source of the outbreak.

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Suggested reading

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Melon food safety

A best practice guide for rockmelons and specialty melons

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