Watermelon food safety

A best practice guide and toolbox

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Watermelon food safety: a best practice guide and toolbox

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Executive summary

Food safety is fundamental to the sustainability and profitability of the Australian melon industry. It is also non-negotiable. Growers and packers should follow a continuous improvement process in their food safety systems and adopt scientific evidence-based best practice guidelines provided to them. Risk management plans and practices should be based on the principle of '***End the crisis before it begins***'. The melon industry should continue to be proactive in adopting best practice for food safety to protect the industry and consumers from food safety risks. To remain compliant with regulatory requirements in domestic and export sectors, consistent supply of safe fruit is required to maintain consumer confidence and market access. We recommend that key food safety hazards in production and postharvest handling of melons should be identified and managed using business-specific food safety plans. This guidance document is specifically targeted to assist the watermelon growers, packers, exporters and retailers in managing food safety risks along the chain.

Preharvest food safety controls that are effective in minimising microbial contamination risks in the field include:

- irrigation water quality control
- using drip irrigation systems
- using windbreaks to minimise dust load on fruit
- preventing wildlife and livestock incursions in the field
- not using soil amendments containing animal manures.

Watermelon fruit are generally not washed or sanitised before shipping to markets. At the grower level, the current practice of cleaning and wiping watermelon with a range of materials (e.g. cloths and rags) poses cross-contamination risks. However, to date there has no evidence of market failure linked to this practice, but considering the potential cross-contamination risks, the industry should be prepared to switch to washing and sanitising watermelons like other melons.

Postharvest practices that should be followed include:

- precooling
- using drinking quality wash water containing an effective sanitiser
- proper contact time of fruit with the sanitised water and brushes
- automation of sanitiser injection and monitoring.

We recommend that a robust packhouse environment management program should be followed to prevent environmental pathogens from entering and establishing within the facility. The resident pathogens pose serious cross-contamination risks in the facility. A 'seek and destroy' approach should be implemented to eradicate the resident foodborne pathogens from the facilities.

To manage food safety incidents and product recall, a digital traceability system should be followed to manage internal (inputs) and external traceability of fruit. This system should be capable of rapidly recalling the produce during a food safety emergency. Physically identifying fruit through individual labelling is strongly recommended to manage brand identity, food fraud and targeted product recall at the consumer level. To manage food safety risks at the retail stage, we recommend supermarkets and retailers wash and sanitise the watermelons before cutting into halves and quarters, label the cut melons with 'best before date' and display them in the refrigerated shelves maintained at 5 °C. Investment in training workers about the basics and importance of food safety can contribute significantly to nurturing a food safety culture in the whole chain.

Introduction

Supplying safe fruit to consumers is the fundamental requirement for all growers and stakeholders involved in the supply chain, including retailers. Preventative and proactive approaches are the most effective and economical when managing food safety hazards. Therefore, having a basic knowledge of food safety risk factors and the procedures to minimise those risks can help achieve the safe supply of fruit. This *Watermelon Food Safety Best Practice Guide* aims to strengthen the knowledge of those in the industry and enhance the adoption of best practice in watermelon food safety at every step along the supply chain. By developing evidence-based practical resources, we aim to reinforce food safety capacity and develop a food safety culture in the watermelon industry.

The melon industry supplies a range of watermelons, rockmelons, honeydew melons and other specialty melons to consumers in domestic and export markets. While the food safety risks during field production of melons are similar, the postharvest handling practices can be broadly classified into two categories depending on whether the fruit is either washed and sanitised in a packhouse or picked and packed in the field with a cleaning/wiping step. The current industry practice is to wash and sanitise all melons except watermelons. Few watermelon growers undertake postharvest washing, brushing and sanitising. Most watermelon growers harvest, clean/wipe, grade and pack the fruit in the field.

There is also a major difference in the retail practices for melons. While rockmelons and honeydew melons are usually retailed as whole fruit, watermelons are generally cut into halves or quarters for consumer convenience and to promote sales with increased confidence in internal quality.

NSW Department of Primary Industries and Hort Innovation released a '*Melon Food Safety – Best Practice Guide*' and a '*Melon Food Safety Toolbox*' in 2019. These documents covered food safety principles and practices relating to preharvest and postharvest handling of melons that are generally washed before shipping to markets. They are a practical food safety resource for growers, packers, transporters, wholesalers, retailers and others involved in the supply chain. All participants should know how to identify, assess and manage potential food safety hazards in growing and supplying melons.

As outlined earlier, the food safety risks during watermelon production are similar to other melon types. Watermelon growers should also refer to the '*Melon Food Safety – Best Practice Guide*' to learn about the preharvest risk factors in detail.

This document is intended to provide watermelon growers with guidance on best practice for reducing microbial food safety risks by identifying the potential sources and contamination routes based on science that has been proven to effectively reduce, control or eliminate microbial contamination. This guide will cover the major microbial risks and how to manage them at each step along the farm-to-fork continuum. Figure 1 shows the unit operations and steps followed in a typical watermelon supply chain. Figure 2 identifies the critical control points in a typical watermelon supply chain.

Figure 1. The unit operations and steps followed in a typical watermelon supply chain.

Critical control points along the watermelon supply chain

1 Field

- **Growing field**
  - Irrigation water
  - Soil amendments
  - Weather events (rainfall, dust storms)
- **Fruit harvesting**
  - Harvesting equipment
  - Fruit cleaning/wiping

2 Packhouse

- Precooling/cooling
- Washing and sanitisation
- Environmental monitoring
- Workers' hygiene and facilities

3 Retail

- Washing and sanitisation
- Equipment hygiene (e.g. knives)
- Fruit contact surface hygiene (e.g. preparation and cutting table)
- Labelling (Best before/ use by)
- Display conditions (e.g. refrigerated or ambient)
- Environmental monitoring

Preharvest

Reducing microbial food safety risks in watermelon production starts in preharvest because there are no postharvest processes (e.g. washing and sanitising) used to reduce microbial food safety risks in the watermelon industry. Therefore, how watermelons are grown, harvested, packed, held and distributed is vital to minimising pathogen contamination risk.

Field management, agricultural water, soil amendments and worker hygiene are just a few preharvest elements that need to be considered. Microbial contamination can occur from many sources; evaluating and managing these risks is critical to effective food safety procedures in watermelon production.

Controlling environmental factors and site location

Identifying and assessing hazards

Growing sites should be assessed for any possible contamination from the prior land use. Knowing the various potential contamination risks in the surroundings is important to minimise these risks. It is also beneficial in uncovering previously undetected or unexplained risks. Not all sites have an equal risk of food-borne pathogen contamination, nor are they suitable for producing fruit and vegetables for human consumption.

Best practice recommendations

- assess/review the production area and crop inputs before planting to identify any hazards that pose potential contamination risks to the produce. Consider:
  - can animals (domestic or wild) access the production area?
  - can animals access water sources to be used in production operations?
  - is there any overflow, leaching or leaking from manure storage areas close to the production area?
  - have there been or are there any hazardous water sites close to the production area?
  - have there been or are there any sewage treatment sites close to the production area?
  - have there been or are there any industrial or mining sites close to the production area?
  - is there any possibility of run-off from nearby fields?
  - is there a possibility or history of the production area flooding with contaminated water?
  - is there any surface water surrounding the production area?
  - are there any other sources of contamination?
- growers should request assistance from technical specialists experienced in good agricultural practice (GAP) planning and other food safety professionals
- a useful exercise is to draw a diagram of the production site and the surrounding areas to help identify details and potential hazards that might be overlooked by just looking at a map.

Climate conditions

Weather influences pathogen prevalence in the preharvest environment. Unusual weather conditions can affect the integrity of the production site and produce, and will need to be evaluated before harvest. Severe weather and climate conditions have been associated with food safety risks. For example, *Listeria monocytogenes* was more frequently detected in cooler temperatures that were above freezing before sample collection, with consistently more positive samples collected in winter (Strawn et al. 2013).

Adverse weather conditions not usually considered in routine food safety risk assessments were the likely cause of the 2018 NSW *Listeria monocytogenes* rockmelon outbreak (NSW DPI 2018b).

Heavy rain and storms can transport pathogens, potentially causing higher loads of bacteria and sediment in the water (Lipp et al. 2001; O'Shea and Field 1992). Strawn et al. (2013) identified precipitation as a factor influencing the detection of *Salmonella*-positive samples across five farms over two years.

Best practice recommendations

- consider how changes in temperature, rainfall, wind speed and air quality, as well as any damage to crops and equipment could affect contamination levels; the production site might be contaminated after severe weather
- if flooding occurs close to harvest (less than two weeks) and fruit come into contact with floodwaters, then that produce should not be consumed. If flooding occurs more than two weeks before harvest or if the produce is processed, a case-specific risk assessment should be performed (European Commission 2017)
- consider using windbreaks, cover crops and vegetative barriers to minimise the effects of adverse weather such as dust storms, strong winds, reducing water run-off and soil erosion. Windbreaks also reduce the transport of wind-borne contaminants.

Preharvest

Site plan and history

Knowledge of prior land use is essential for identifying potential undetected or unexplained hazards. It can also help determine the suitability of the site for agriculture.

Best practice recommendations

- document and review the:
  - site's previous use (e.g. production, non-agricultural purposes, waste management or livestock production)
  - any of the site's previous exposure to significant environmental events such as flooding
  - prior crop inputs such as soil amendments, biosolids or pesticides
  - site layout including production and packing areas, field sanitation stations, residential areas, active wells, irrigation systems, waste management systems, fences, roads, manure storage areas, animal activity areas (livestock and wildlife), chemical storage areas and surface water sources
- in the absence of records from past production cycles, soil testing for microbiological and chemical contamination is recommended.

Adjacent land use

Contaminants on adjacent land can increase contamination risk in the production field. Rainfall, wind, traffic, animals and people are vehicles for spreading contamination. Having a melon production area near livestock operations or pastures increases contamination risk. One of the major sources of preharvest contamination can be livestock shedding and subsequent run-off of foodborne pathogens (Nightingale et al. 2004).

Best practice recommendations

- assess the location of:
  - livestock operations, their proximity to the operation, their waste management and direction of flowing water to determine the potential for contaminating the production site

- nearby residential communities, septic tanks and field drains and their potential for wastewater run-off into the production site
- consider using:
  - fences, gates and other barriers to discourage animals and people from entering the production site
  - buffer zones to help minimise the effects of surrounding land use and these are also helpful in managing farm biosecurity (NSW DPI 2018a)
- assess any drainage issues on the production site and surrounding areas.

Case study – 2019 outbreaks of *E. coli* O157:H7 in romaine lettuce

When investigating three outbreaks of *E. coli* O157:H7 in romaine lettuce in 2019, the USFDA (2020) found that animal grazing in nearby land was a contributing factor.

Three separate foodborne outbreaks (A=167 illnesses, B=11 illnesses and C=10 illnesses) from November 2019 to December 2019 were traced back to romaine lettuce from one grower. Using faecal-soil sampling, the USFDA detected the outbreak strain of *E. coli* O157:H7 on a cattle grate less than 3.2 km upslope from the produce farm (Figure 3). They considered that cattle grazing the adjacent land was the most likely contributing factor associated with the outbreaks.

The number of cattle observed on nearby lands was far lower than the volume considered a large concentrated animal feeding operation (Figure 4). This report highlights that high-density operations are not the only factor to consider when evaluating adjacent land use (Centre for Food Safety and Applied Nutrition 2020).

Figure 3. A cattle grate less than 3.2 km upslope tested positive for *E. coli* O157:H7. Photo: USFDA.

Figure 4. The number of cattle observed on nearby land was far lower than the volume considered a large concentrated animal feeding operation. Photo: USFDA.

Field management

Best practice recommendations

- keep production areas clean by removing litter and waste
- ensure potential contamination sources are cleared from production areas and surrounds, for example, plant debris and cull piles should be removed as soon as possible
- keep production areas properly maintained by removing weeds anywhere nearby, especially those that could be attractive as breeding places or harbourage for pests
- use physical barriers such as mounds, vegetative buffers and ditches to re-direct or reduce run-off from animal production or waste management operations.

Preharvest

Site traceability

A functional traceability system should be set up to trace produce back to the field where it was grown and to trace it forward to the buyer. This means knowing which field a particular lot came from, the day it was harvested and when and to whom it was sold. This will allow timely identification of the products to be recalled. Systems should also include a harvest log and diagram or field map for reference.

A coding system can be used to assign fields and should be used on all documents from pre-plant field inspections, during harvest and up until it is sold to the consumer. These codes can be used to log the location of fields, plots, date it was harvested, packed and sold. If multiple markets are supplied, codes can be used to number markets.

Agricultural water

Agricultural water is essential for watermelon production and is used in several processes before harvest such as irrigation, pesticide application and hand washing. However, these agricultural water systems encompass not just their use but their source, storage and transport. Each component of an agricultural water system must be evaluated to ensure the quality is suitable for its intended use.

Water can be a direct contamination source, with irrigation and spray water being primary sources of pathogens when water quality is inadequate. Agricultural water can be contaminated with microbial pathogens as well as chemicals via leaks, spills or leaching of agricultural and industrial chemicals into water sources. Blue-green algae and its toxins can also contaminate agricultural water. Applying contaminated water in farm operations such as when irrigating and applying pesticides and nutrients can spread pathogens and other contaminants directly on to fruit and soil. Water can also be a vehicle for spreading contamination from one location to another in the field, facility or during transport.

Whole batches of fruit can be contaminated if microbes infiltrate the produce or adhere to the product surfaces. **If pathogens survive on produce, they can cause a foodborne illness**. Ensuring microbial water quality is adequate is thus critical to mitigating food safety risks in melon production.

Water sources

Common water sources in order of increasing risk include:

1. reticulated water or town water
2. tank water (rainwater)
3. deep groundwater from bores
4. shallow groundwater
5. surface water sources such as rivers, ponds, dams, channels and creeks (Figure 5)
6. recycled/wastewater.

Figure 5. A typical source of agricultural water.

Surface water sources are the most commonly used agricultural water source, yet they pose a very high potential for contamination. Compared to groundwater, surface water sources are highly susceptible to pathogenic contamination because they can be exposed to events such as sewage discharge, rainfall, livestock operations and wildlife (Allende and Monaghan 2015; Gerba 2009; Steele and Odumeru 2004; Uyttendaele et al. 2015).

Surface water sources also have the greatest variability in microbial quality compared to other commonly used water sources. Surface water quality is often unpredictable as upstream activity can greatly influence contamination downstream. It is also susceptible to contamination by urban and industrial pollutants such as heavy metals, carcinogenic chemicals, toxic substrates and organic materials that may harbour pathogenic microorganisms of faecal origin (Páll et al. 2013). In Australia, Ahmed et al. (2009) detected genes suggestive of the incidence of *Salmonella*, *Escherichia coli* and *Campylobacter jejuni* in tidal creek and pond water used for irrigation. 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.

Groundwater is usually considered to be microbiologically safe if infiltration via run-off or other sources of contamination close to the aquifer is avoided (Gerba 2009). When properly designed, located and constructed, groundwater provides high-quality agricultural water with little variability in microbial quality. The design of wells, nature of surrounding substrata, rainfall and depth of groundwater can all affect microbial quality. Large variation in quality can exist between shallow groundwater sources and water from deeper aquifers. Although groundwater contains less organic matter than surface water, it can contain higher loads of inorganic matter, resulting in unpleasant colours and odours. Due to the enclosed nature of groundwater, it is less prone to direct faecal contamination compared to surface water.

Reticulated or domestic water sources have the lowest contamination risk, but are rarely used for irrigation as most farms are not located near a supply and they can be costly. Growers are more likely to use reticulated water sources for spray mixtures, pesticide applications and hand washing.

These varying contamination risks mean each water source should be assessed, including where the water is sourced, how it is stored and how it is transported. Consider:

- evaluating each agricultural water source before it is used in the operation; use resources such as maps, photographs and drawings to describe and define locations of permanent fixtures and the flow of the water system. Descriptions should include all components of the agricultural system from wells, reservoirs, valves, gates and run-off prevention structures
- documenting the water source(s) for each field
- whether the agricultural water system is open or closed:
  - in open systems the agricultural water will be exposed to the outside environment (i.e. pond, canal, reservoir, uncovered water tank). If water from an open system is used for any overhead application, it should be treated and tested to ensure the quality is suitable for the intended use
  - closed systems store and transport water so that it is not exposed to the outside environment and water maintains the initial quality. The water from a closed system must still be tested at the end of the system to verify the water quality is unchanged
- identifying potential contamination sources and take necessary measures to prevent the contamination from reaching the water source
- conducting a hazard analysis to determine the microbial contamination risk to produce from each water source in use and keep a record of this analysis. Consider:
  - the type of water source
  - rainfall levels
  - the possibility of run-off
  - the topography of the surrounding area
  - the proximity to sewage/septic exposure and other sources of pollution
  - animal activity in the area
- never use water from any system that has not been microbially characterised
- keep records of preharvest water sources used for the produce
- do not use reclaimed or recycled water for melons
- ensure water suppliers provide test results that verify water quality for your records.

Water storage and conveyance

Water pipes and storage tanks can become sources of microbial contamination. It is important to ensure that water pipes are well maintained and free from breaks and cracks that can allow microbes to enter. Tanks and wells should be inspected at least once a year during use. Things to look for include:

- ensure the cap is intact and contamination has not occurred in shallow wells or those in low lying areas
- backflow devices must be installed where appropriate to prevent contaminated water from entering the main system
- application points such as spray nozzles must be regularly cleaned
- storage tanks must be constructed to prevent pests, birds or animals from entering

- if rainwater is collected, ensure that gutters and roofs are cleaned regularly and maintained
- confirm a filter is used to prevent plant material and other debris from entering the tank.

Develop a standard operating procedure (SOP) for maintaining supplementary equipment, water pipes and storage tanks. This should include:

- water holding facilities (e.g. dams and tanks) and equipment for distribution should be considered as potential contamination sources
- regularly scheduled visual inspections of all equipment connected to storage and pipes to ensure the system is in good working order and is not a contamination risk
- regular maintenance such as removing debris and weeds to maintain water quality
- checking pest access is prevented through fencing, avian deterrents and rodent monitoring
- procedures to ensure standing or stagnant water is avoided and does not pose a contamination risk; do not let water pool anywhere in the system
- using slopes and diversion ditches to prevent run-off going into the water storage
- establishing corrective action plans for non-compliance situations such as:
  - contaminated water source
  - animal intrusion
  - contaminated run-off
  - uncontrolled flooding.

Water quality

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. Growers need to consider factors such as weather, water source, animal incursion and agricultural/industrial practices in surrounding areas. Some water sources can receive water from streets and grazing lands and this run-off can be diverted to irrigation canals and surface waters such as rivers and dams.

Rainfall can create polluted run-off by washing contaminants, including faecal matter, from bank sides into the water and by re-suspending sediments containing microbes, making them easier to be picked up by a water source. Cooley et al. (2007) observed a significant increase in the incidence of *E. coli* O157:H7 when heavy rain increased river flow rates in a major produce production region in California. Likewise, increased levels of *E. coli* O157:H7 and faecal coliforms in irrigation ponds on produce farms were positively associated with precipitation and run-off (Gu et al. 2013).

Nearby practices such as manure application or high-density livestock operations can significantly alter the microbiological quality of agricultural water, especially surface water sources. Precipitation coupled with faecal deposition is associated with increased microbial population levels in run-off from agricultural lands. Increased generic *E. coli* in field run-off was associated with manure applications being timed close to rainfall (Meal and Braun 2006) but these levels can be decreased by using vegetative buffers or filter strips (Lewis et al. 2010).

Another major hazard to agricultural water is blue-green algal blooms. Blue-green algae, also known as cyanobacteria, give off a green and sometimes blue colour. Blooms occur when algal cells accumulate, discolouring the water and decreasing the water quality. When blue-green algae multiply in high numbers, toxins can be produced, causing health hazards for humans, animals and livestock that come into contact with the algae. Even after the bloom dies, cells release toxins into surrounding water that can persist for months before they degrade. Using water that has been contaminated by algal blooms for irrigation is high risk as these toxins are water-soluble and can be taken up by plant roots. When irrigating carrots, lettuce and green beans with water that was contaminated with microcystin (a toxin produced by cyanobacteria blooms), the toxin had accumulated in the edible plant parts to levels that surpassed the chronic reference dose and total daily intake guidelines (Lee et al. 2017).

The best way to manage algal blooms is to prevent them from occurring. Ideal growth conditions for an algal bloom include:

- warm temperatures (commonly the top layer of water will be warm from the sun)
- sufficient phosphorus and nitrogen levels to sustain growth
- low nitrogen to phosphorus ratio
- still water with low turbulence
- long periods of stable weather patterns.

Effective ways to prevent these ideal growth conditions include carefully managing nitrogen and phosphorus fertiliser use in areas surrounding the water source and creating turbulence and aeration to mix the warm top layers with the cool deeper layers of water.

Best practice recommendations

- assess the possibilities for surface water contamination from run-off during heavy rainfall
- use structures such as drainage channels and vegetation barriers to retain any run-off
- consider the timing of manure application and storms
- carefully manage fertilisers containing nutrients such as nitrogen and phosphorus around surface water and avoid excessive use
- control any soil erosion to prevent soil particles with phosphorus attached to them from entering the surface water
- use artificial aeration to mix warm and cold layers of water and maintain high oxygen levels
- do not use water contaminated with blue-green algae and its toxins.

Nearby animal activity

Nearby high-density animal populations and animal product processing facilities increase the risk to water sources. Birds, wildlife and animal (both domestic and wild) activity are all potential sources of microbial contamination in water as faecal matter can be washed into the channels by rainwater.

Animal incursions into water sources such as dams, creeks and rivers can significantly alter the microbial quality of agricultural water. The highest risk comes from animal activity in the water, especially birds, as they can contribute pathogens such as *Campylobacter* to the water. After an animal incursion has occurred, microbial water testing MUST be conducted. Irrigation should be paused in case faecal deposits are discovered until they are contained and removed.

Best practice recommendation

- prevent animal (wild and domestic) access to water sources.

Summary

Susceptibility to run-off can significantly affect water quality. Rainfall coupled with faecal deposition increases microbial populations in run-off from agricultural lands. Therefore, water sources used in agricultural must be tested; this is a critical part of melon food safety and protecting consumers. Microbial water testing should be conducted at least annually (before the start of the season), after an animal incursion into water sources or significant weather such as flooding.

When testing your water, consider the following:

- use a reputable and accredited laboratory
- ensure a consistent water sampling protocol is established and followed;
  - wash hands before collection
  - include a consistent location and collection method
  - follow laboratory instructions for taking and submitting the sample
- record the following;
  - sampling frequency
  - who is collecting the samples
  - where samples are collected from
  - how samples are collected
  - type of test conducted
  - acceptance criteria
  - results and any remedial actions.

Levels of thermotolerant coliforms such as *E. coli* can be used as an index for faecal contamination and allow risk categorisation of water sources. Depending on the intended water use, different water quality levels are acceptable. Higher levels of organisms in a sample can indicate a higher potential for pathogens and therefore a higher risk of faecal contamination (Gleeson and Gray 1996; Uyttendaele et al. 2015).

In Australia, a few guidelines exist to ensure your practice is food safety sound (Table 1). The Australian and New Zealand Environment and Conservation Council have provided water quality guidelines (ANZECC 2000). These vary depending on the intended use of the water. If water makes direct contact with the crop, thermotolerant coliforms are limited to < 10 cfu/100 mL. If water does not make direct contact (such as drip irrigation), < 1,000 cfu/100 mL of thermotolerant coliforms is accepted.

The Australian Guidelines for Fresh Produce Food Safety (Fresh Produce Safety Centre Australia and New Zealand 2019) outlines that water in direct contact with produce that is eaten raw (e.g. melons), including water used for agricultural chemical application, must not have ≥ 10 cfu/100 mL thermotolerant coliforms nor ≥ 1 *E. coli* cfu/100 mL.

If water contains < 100 *E. coli* cfu/100 mL, it can be used before harvest without restrictions. However, water that contains > 100 *E. coli* cfu/100 mL can only be used before harvest with a 48 hour exclusion period.

If drip irrigation is used, the criterion is < 1,000 *E. coli* cfu/100 mL, ensuring that the water does not come into contact with the edible part of the produce. Testing is required at least annually but best practice would be testing monthly. In addition, water used for hand washing must not contain ≥ 1 cfu/100 mL *E. coli* (Fresh Produce Safety Centre Australia and New Zealand 2019).

Another helpful resource to follow is the USFDA's Produce Safety Rule (https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-produce-safety) which states that the microbial water quality profile (MWQP) for each untreated agricultural water source must be determined. The MWQP is established using the levels of generic *E. coli* in the water.

Surface and groundwater sources have different requirements in establishing a MWQP when being used in agricultural processes.

When collecting water samples for testing, at least 20 should be sourced from across the surface water system. These samples should be collected as close to harvest as possible over two to four years.

The geometric mean (GM) and the statistical threshold value (STV) are calculated from the samples. These values are your MWQP and are then compared to the microbial quality criteria provided in the USFDA's Produce Safety Rule. For irrigation water, the GM of samples is 126 or less CFU of generic *E. coli* per 100 mL of water and the STV of samples is 410 CFU or less of generic *E. coli* in 100 mL of water. Further information on the tools to calculate these values and agricultural water can be obtained from the following sources:

- The *Food Safety Modernization Act* (FSMA) Produce Safety Rule Online Calculator https://agwater.arizona.edu/onlinecalc/default.aspx
- UC Davis Food Safety https://ucfoodsafety.ucdavis.edu/pre-postharvest/produce-preharvest/agricultural-water

These tools also provide guidance on die-off periods if the MWQP is unacceptable and corrective measures need to be used.

Table 1. ANZCECC water quality guidelines for agricultural use[a].

Intended use	Level of thermotolerant coliforms[b]
Raw human food crops in direct contact with irrigation water (e.g. spray irrigated salad vegetables)	< 10 cfu[c]/100 mL
Raw human food crops not in direct contact with irrigation water (e.g. edible product separated from contact with water such as by peel or use of trickle irrigation); crops sold to consumers cooked or processed	< 1,000 cfu/100 mL
Pasture and fodder for dairy animals (without withholding period)	< 100 cfu/100 mL
Pasture and fodder for dairy animals (with 5 day withholding period)	< 1,000 cfu/100 mL
Pasture and fodder (for grazing animals except for pigs and dairy animals e.g. cattle, sheep and goats)	< 1,000 cfu/100 mL
Silviculture, turf, cotton (restricted public access)	< 10,000 cfu/100 mL

[a] Adapted from ARMCANZ, ANZECC (2000) and NHMRC (2000)
[b] Median values
[c] cfu = colony forming units (used to estimate the number of viable bacterial or fungal cells in a sample).

How agricultural water is used

The contamination risk from agricultural water is closely related to how the water is used. In watermelon production, agricultural water is used for irrigation, mixing of pesticides and plant protection agents, cleaning and sanitising of equipment and personnel hygiene.

Irrigation

Irrigation typically uses large volumes of agricultural water. The contamination risk to the fruit varies depending on the method used for water delivery (Uyttendaele et al. 2015). Water that does not directly contact the edible parts of the produce is considered a lower risk than water that does directly contact the edible parts of the produce.

There are three irrigation methods currently adopted by the melon industry: drip irrigation, furrow irrigation and overhead spraying. The most common practice is drip irrigation (above surface/subsurface). This involves applying water slowly to the soil surface or into the root zone below the surface using drippers, porous tubes or subsurface pipes. This method decreases the contamination risk in some crops (Song et al. 2006) by minimising the exposure of the fruit to the irrigation water.

Furrow irrigation, which is rarely used in melons, involves flooding water across the soil surface between raised trenches. This can result in contaminating produce grown close to the ground. Mootian et al. (2009) found that 12 and 30-day old lettuce plants were positive for *E. coli* O157:H7 after irrigation water containing low levels of the pathogen was applied.

Overhead spraying or sprinkler methods (e.g. irrigation or applying pesticide and plant protection agents) involve spraying water over the soil surface, mimicking rainfall. If contaminated water is used, then it will contaminate the crops and fruit, which is of particular concern if the water is applied close to harvest. In situations where water will contact the edible part of the produce, only drinking water quality should be used (< 1 *E. coli* cfu/100 mL).

While also dependent on environmental conditions, research has demonstrated foodborne pathogens persist for various lengths of time in the agricultural environment and on produce when introduced by contaminated irrigation water. In a study investigating *E. coli* contamination risk in lettuce using three different irrigation systems i.e. overhead, subsurface drip and surface furrow, investigators observed that overhead irrigated lettuce tested positive for *E. coli* for up to seven days after irrigation, where subsurface drip and furrow methods produced only one positive sample (Fonseca et al. 2011).

When using irrigation or sprinkler methods, nozzle size and condition should be appropriate for the crop to ensure excess irrigation does not occur. This reduces the chance of erosion and run-off.

The contamination risk from water used in **cleaning** and **sanitising** equipment, facilities and containers also varies:

- water used for cleaning vehicles, floors, walls, ceilings and equipment that does not contact produce should not have *E. coli* > 100 cfu/100 mL
- water used for cleaning and sanitising containers and equipment surfaces that contact produce and for hand washing should not have *E. coli* > 1 cfu/100 mL.

Best practice recommendations

- use drip irrigation to minimise fruit exposure to irrigation water
- avoid having pools of water that could come into contact with the edible portion of the produce on the soil surface or in the furrow
- if the irrigation method involves direct water contact with the edible part of the produce (e.g. overhead irrigation), high-quality water should be used
- ensure to flush the irrigation system before the irrigation season starts and after an intense or long rainy period
- if using irrigation systems, ensure to flush the main, sub-main and other irrigation lines regularly to reduce the accumulation of organic materials or biofilms.

When agricultural water is used

The contamination risk from agricultural water is also closely related to when water is applied, with the risk decreasing as the time from the last contact with water to harvest increases. Ensuring a buffer period of at least 48 hours before harvesting can help reduce the risk of foodborne pathogens remaining on the produce. If preharvest water directly contacts edible parts of produce within 48 hours of harvest, ensure:

- the water quality meets specified limits and/or an appropriate pathogen reduction step is included after harvest
- tests are conducted during times of greatest risk
- the water source is tested at least annually (best practice would be monthly).

Irrigation water sampling plan

Along with visual monitoring, a testing program is best practice for determining water quality and protecting produce from contamination. For most effective testing, samples must reflect the water at the point of use and be sampled at the end of the delivery system to ensure the water does not degrade as it moves through the system. Samples should be collected and the following tests performed:

- **Baseline microbial assessments**: these are used to determine the quality of the water sources. It is helpful to get a known quality to compare further evaluations.
- **Initial microbial water quality assessments**: these are used to test the water system before use to ensure water quality is adequate and has not degraded as it moves through the system.
- **Routine system assessments** are used to monitor the microbial quality of the water in the system throughout the season to ensure that water quality is maintained and continues to meet microbial water quality standards. This can be used to gather data and evaluate trends to gain a better understanding of the agricultural water system.

Non-routine sampling should be conducted when food safety risks are deemed higher due to specific circumstances such as weather, animal and human activities. This should also be part of an effective food safety program. Additional testing should be considered if other risk factors are observed such as manure application in a nearby field, high-density animal activity and non-routine weather.

Corrective actions

If acceptance criteria are not met, TAKE REMEDIAL ACTION IMMEDIATELY and:

- discontinue all agricultural production until the water returns to compliance levels
- examine the water source and water systems to determine the contamination source to be eliminated
- after corrective actions are taken, re-test the water at the same sampling locations
- continue daily testing for five days at the point closest to use
- if any of these samples do not meet acceptance criteria, repeat the evaluation of water sources/systems and remedial action
- do not use this water system until the water meets the acceptance criteria for the intended use
- if water that did not meet acceptance criteria was used for crop production, sample and test products for Shiga toxin-producing *Escherichia coli* (such as *E. coli* O157:H7) and *Salmonella* before harvest
- if crop testing indicates presence of either pathogen, DO NOT HARVEST FOR HUMAN CONSUMPTION.

Water treatment methods

If water is potentially contaminated and alternative cleaner water is not available, then the water needs to be treated to minimise risk. The goal of sanitising water is to kill the pathogens in it, preventing them from contaminating fruit. Once fruit is contaminated, it is difficult to reduce the microbial load.

There are several different disinfectant treatments for agricultural water, including chlorination, peroxyacetic acid, ozone, iodine, electrolysed water and UV treatment (Fresh

Produce Safety Centre Australia and New Zealand 2019; Suslow et al. 2003). When deciding on the best water treatment method to use, consider the:

- type and number of pathogens likely to be present
- amount of organic material in the water
- water pH and temperature
- presence of salts and sediments in the water
- concentration of sanitiser
- contact time.

Other considerations such as operational costs, the complexity of the technology, the amount of monitoring needed and the safety of the technology will also influence the water treatment method selection (van Haute et al. 2015).

Treat water only with antimicrobial treatments approved for use in agricultural applications and always follow label specifications and guidelines for use. Ensure the treatments and how they are used meet all federal, state and local regulations. Follow appropriate water treatment methods and regularly test the microbiological quality of water to ensure it is consistent with food safety certification standards.

Each sanitising method has its advantages and disadvantages as well as different ways of monitoring concentration and effectiveness.

Best practice recommendations

- follow appropriate water treatment methods and regularly test the microbiological quality of water to ensure it is consistent with food safety certification standards
- check the efficacy of water treatment equipment that is in use.

Remember

DO NOT STORE raw manure or any type of compost near irrigation water sources or systems.

Reduce risk further by:

- preventing livestock access to water sources and pumping areas
- using barriers and fencing to prevent wildlife access to any water used
- only using drinking quality water for applying agricultural chemicals to minimise the microbial and blue-green algal toxin contamination risks
- ensuring water sources contaminated with toxic algae are not used
- treating produce that contacts flooded or pooled water with a pathogen reduction step and then further testing
- ensuring potentially contaminated water does not contact recently damaged produce
- establishing drainage pathways to reduce temporarily puddled areas that can become potential habitat or drinking areas for wildlife.

ASSESSING AGRICULTURAL WATER FOR MELON PRODUCTION

At preharvest, agricultural water is used in crop irrigation and pesticide application. However, this water can carry and distribute human pathogens leading to foodborne illness outbreaks. Sources such as surface water (e.g. creeks, rivers, and dams) are more likely to be contaminated than ground water. Water distribution systems are also of concern, because these systems distribute water throughout the farm and can become contaminated if pipes, backflow devices are not in good condition or not functioning properly. It is important that each component within your control is assessed and evaluated to ensure the quality of agricultural water used is known, adequate for its intended use and records are kept.

1 Determine water systems and source

Conduct an agricultural water assessment to determine and evaluate each water source. Inspect all water sources and distribution systems. Resources such as maps, photographs, and drawings can be used to describe and define locations and flow of water systems. Descriptions should include all components of system such as wells, reservoirs, valves, gates and run-off prevention structures.

2 Conduct hazard analysis

Conduct a hazard analysis to determine the risk of microbial contamination of produce from each water source in use and keep a record of this analysis. Consider **HOW** your agricultural water is being used (e.g. sprayers, overheard sprinkler, furrow or drip irrigation. Consider **WHEN** agricultural water is being used, how close to harvest is agricultural water applied.

3 Assess hazards

Consider the type of water source, rainfall levels, the possibility of run off, the topography of the surrounding area, the proximity to sewage and other sources of pollution, animal activity in the area and upstream of water source.

4 Test & measure water quality

Contact an accredited laboratory to test your water for microbiological analysis. Water testing should be conducted prior to use and routinely throughout the season in accordance with your quality assurance scheme. Ensure a consistent water sampling protocol is established and followed e.g. consistent location and method of collection. Record the frequency of sampling, who is sampling, where samples are collected, how samples are collected, type of test conducted, acceptance criteria and results recorded.

5 Determine and prioritise response

Results of water quality testing will determine response. If acceptance criteria of water quality is met, then no further action is necessary and water may be used in field operations. If acceptance criteria is not met, remedial actions need to be taken. Investigate the water source and distribution system, re-test water at same sampling point. Do not use water until water can meet outlined acceptance criteria for its use, especially when the crop is ready for harvesting.

6 Implement management plan

Develop a SOP for the maintenance of water systems used during watermelon production. Regular scheduled visual inspections of source, its storage and all equipment connected including pipes to ensure the system is in good working order and does not pose a contamination risk. Regular maintenance such as clearing of debris, trash and weeds. Check pest access is controlled through fencing and pest deterrents. Procedures to ensure standing and stagnant water is avoided across the whole system Establish corrective action plans for non compliance situations such as contaminated water source, animal intrusion, contaminating run-off and uncontrolled flooding.

Agricultural soil and soil amendments

Agricultural soil can naturally contain certain pathogens such as *Listeria* spp. (Nicholson et al. 2005) or it can receive them when soil amendments are applied. This can directly contaminate produce that is grown on the soil as the soil particles are splashed on to the produce by rainfall or sprinklers. Agricultural soils are constantly vulnerable to direct or indirect sources of microbial contaminants including contaminated irrigation water, animal intrusion, animal faeces, run-off, municipal sewage and other waste.

Types of 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 and animal by-products, seaweed extract, rock phosphate, lime, gypsum or sawdust.

Using manure and compost 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 re-contaminated manure might contain pathogens with significant health risk that can contaminate produce. Several pathogenic bacteria can persist in manure for some time, although their survival depends on certain factors such as moisture content, pH, source of manure, treatment method, aeration, type of soil that was amended and the extent of manure application (Ingham et al. 2004; Semenov et al. 2011; Wood 2013). The risk of contamination from untreated or inadequately treated manure increases for watermelons because they are grown in contact with soil and are eaten raw.

Best practice recommendations

- human effluent and biosolids MUST NOT be used as soil amendments
- avoid storing soil amendments close to the production site
- use adequate physical barriers to prevent run-off or leaching from soil amendments in surrounding land or water (surface and ground)
- farm vehicles should be controlled to prevent cross-contamination of production areas.

Treating soil amendments

Microbial contamination risks are reduced when soil amendments containing manure are treated and they are exposed to extended periods of high temperatures, killing pathogenic microbes. Physical, chemical or biological treatment methods such as composting, pasteurisation, heat drying, UV irradiation, alkali digestion, sun drying or combinations of these can be used to reduce the risk of potential human pathogen survival in manure, sewage sludge and other organic fertilisers.

If purchasing treated fertiliser and soil amendments, evidence of appropriate treatment must be obtained from the supplier (e.g. be certified in accordance to Australian Standard AS 4454-2012 or, if non-certified, information including treatment method and microbial testing results must be available).

When treating on-farm, ensure effective composting techniques are being used. Compost heaps should be kept aerated, where the outer layers are turned in to the centre and all organic materials are exposed to temperatures > 55 °C for three consecutive days. The pile should be turned and this process repeated at least three times.

Best practice recommendations

- soil amendments containing untreated or raw animal manures MUST NOT be used in watermelon production fields
- if purchasing soil amendments, ensure to document the evidence of appropriate treatment
- avoid using treated composts containing animal manures or poultry litter
- improving soil health through crop-based manures and crop rotation are safer alternatives.

Survival of pathogens in soil

The survival and incidence of pathogenic bacteria in agricultural soil are reliant on several factors such as the nature of the soil, pH, moisture levels, temperature, presence of organic material and cultivational activity. *Salmonella* can survive in soil from 7–25 weeks depending on the type of soil, moisture level, temperature and source of contamination (Erickson et al. 2010; Guo et al. 2002; Lang and Smith 2007; Zhang et al. 2009). Fields that contain animal manure are more likely to be contaminated with enteric pathogens because of their ability to survive in soils for months or years (Doyle and Erickson 2008). The survival of pathogens in soil is relative to time; therefore, the longer the interval between when the contamination source is applied (e.g. manure) and the date of harvest, the greater the likelihood that the produce would not be contaminated (Doyle and Erickson 2008).

Ground contact

Being nearby or having direct contact with soil increases the chances of melons having surface contamination from pathogens such as *Listeria* spp. and *Salmonella* spp. that are found in soil. While in contact with the ground, watermelons develop ground spots, which are thin and have an undeveloped rind, resulting in increased susceptibility to fungal and bacterial growth. These ground spots can allow microbes to penetrate during postharvest washing (Castillo et al. 2009). Using plastic mulch (Figure 7) reduces the:

- risk of pathogen attachment at ground spots
- risk of soil-borne microbial contamination
- amount of soil and dirt on fruit when harvested.

Best practice recommendation

- use plastic mulch to minimise direct contact between the ground and fruit.

Figure 7. Using plastic mulch reduces the risk of pathogen attachment at ground spots, soil-borne microbial contamination and the amount of soil on fruit when harvested.

Microbial testing and record keeping

To ensure the soil and soil amendments used for watermelon production are safe, microbial testing, standard operating procedures and record keeping need to be conducted regularly. Record keeping is a crucial component of safe standard operating procedures.

Best practice recommendations

- if compost is applied, document the source of the compost and its microbial quality test report; include the origin, product used, amount used, application date, treated area and application method
- ensure you have a detailed standard operating procedure for each part of the composting process
- if unusual events such as flooding occur, they should be recorded
- if purchasing compost from a supplier, all of the above record keeping should be presented in a certificate of analysis.

Wildlife and animal activity

All animals, birds, reptiles and insects are potential sources or vehicles for contamination of fresh produce with pathogens. They can harbour many pathogens in their hair, feathers, skin and mouthparts as well as internally in their respiratory and gastrointestinal systems. Faeces is the main source of pathogenic contamination from animals. Often animals will appear healthy even though the pathogens they carry can cause severe disease in humans such as *Salmonella enterica* and Shiga toxin-producing *E. coli* (Li et al. 2018). The only effective means of eliminating these hazards is to exclude all animals from production areas, however this is often not possible. Therefore, it is important to limit the access and intrusion of wildlife and animals to minimise their contamination risk.

Preharvest

Determine if wildlife and animals have been in the crop

It is important to include procedures to determine if wildlife and animals have been or are present in the production areas. Before harvest, inspect fields for signs of wildlife such as crop damage or faeces. Physical damage caused by animals to fruit surfaces reduces fruit quality and can also provide a point of entry for pathogens. Fruit flies contaminated with *E. coli* transferred the bacteria to uncontaminated apple wounds (Janisiewicz et al. 1999). In Australia, *Salmonella* spp. has been isolated from faecal samples of western grey kangaroos (Potter et al. 2011) with Shiga-toxigenic strains of *E. coli* being isolated from a range of native marsupials including kangaroos, possums, bandicoots and wombats (Rupan et al. 2012). Some animals pose a greater risk than others. Cattle, chicken, deer and pigs are much more likely to be carrying high-risk pathogens compared to animals such as rats, horses, sheep, goats and dogs.

Best practice recommendations

- note periods of increased wildlife activity and consult with experts on potentially problematic species and critical steps in managing these risks
- conduct preseason and preharvest environmental risk assessments
- regularly check for signs of wildlife such as faeces, damage to fences and equipment
- take corrective actions when evidence of animal intrusion in production areas is found.

Entry and distribution of pathogens

Contamination from domestic and wild animals can occur through several routes. Run-off or bioaerosols from nearby animal operations, contaminated agriculture water from animals entering streams or dams, wild animal intrusion/defecation in production areas and field drains as well as insect vectors can all be routes of pathogenic contamination to produce (Hooda et al. 2000). Intensive animal operations can even produce bioaerosols which allow pathogens to become airborne and be deposited on land, facilities and water sources by wind. Handling and using slurry and solid biowastes along with compost turning are other sources of bioaerosol generation (Berry et al. 2015).

Best practice recommendations

- control the movement of livestock, ensure farm animals are confined or far away from water sources, growing fields and storage areas
- establish buffer zones between livestock operations and crop/water sources
- do not spread manures before heavy rainfall
- use dedicated tools for farm animal activities and crop activities
- store material and equipment off the floor
- routinely clean areas behind and under equipment as well as storage areas for containers and packing materials

- where practical, store open containers upside down
- compost biowaste to reduce microbial load before use.

Animal control and exclusion

Limiting animal and wildlife access to production areas is critical for minimising their contamination risk. Harbourage sites and wildlife habitats near production areas need to be evaluated and cleared to help discourage animals from making homes near fields. Access control and practices such as using trails, walkways, fences and barriers are effective in protecting produce as well as resources such as agricultural water. Trails and walkways allow management of human and animal movement to protect soil and water resources.

The effectiveness of these measures depends on the type of animals and their natural behaviour in the area. Limiting wildlife access to open crop fields and orchards can be challenging. Studies have suggested that no-harvest zones can reduce the spread of *E. coli* from faeces to fresh produce and the per cent of *E. coli* transferred can decrease with time after faecal placement (Jeamsripong et al. 2019; Weller et al. 2017).

Best practice recommendations

- keep production areas clean to reduce unwanted pests
- keep livestock movement away from water sources, fields and storage areas
- fence upstream water sources off from animals and livestock
- ensure that produce is not grown close to wildlife habitats by incorporating buffer zones
- prevent wildlife intrusion by using physical barriers such as fencing
- establish no-harvest zones where produce may be contaminated by animal activity or faeces
- plant low-risk crops as a buffer between high-risk crops and pathogen sources
- plant non-crop vegetation around fields to filter pathogens from run-off
- use repellent equipment such as those emitting noise or calls; sonic fences can reduce animal activity
- use mechanical traps, scarecrows and reflective strips to deter birds and pests.

Record keeping

Ensure that records are kept including times and dates of inspections and descriptions of any corrective actions taken. Also, record the history of land use including adjacent land, to help develop an effective risk reduction strategy.

Workers and training

Watermelons are manually handled at nearly every stage of the supply chain (Figure 8) and workers pose a significant risk for food safety; several food contamination incidents have been traced back to workers and their handling practices. Workers, contractors and visitors can become sources of contamination whether it is microbial, chemical or physical through personal hygiene practices, illness and cross-contamination.

Figure 8. Watermelons are manually handled at nearly every stage of the supply chain and workers can be a significant risk for food safety.

Hand washing

The easiest and most effective food safety practice is hand washing (Todd et al. 2010b). 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, all workers must be 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, coughing, touching their face, touching dirty surfaces, eating or smoking, touching animals, handling waste, performing maintenance on equipment, handling cleaning materials, handling chemicals and any break from work. Poor hand hygiene has contributed to outbreaks of produce contamination by transferring pathogens onto produce (Todd et al. 2010a). Contaminated hands of workers were connected in the transfer of *E. coli* O157:H7 on strawberries (Shaw et al. 2015) and carrots (Monaghan and Hutchison 2016) as well as *S. enterica* serotype Enderitidis on lettuce (Waitt et al. 2014).

Best practice recommendations

- 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
- conduct hand washing training to all workers
- ensure there is clear and easy to understand signage of proper hand washing technique
- managers should ensure compliance.

Personal hygiene

Workers should be considered contamination hazards as they can transfer pathogens via their hands, body and clothes. Agricultural workers have a critical responsibility in reducing or avoiding produce contamination. Clothes should be clean, hair and beards must be secured and jewellery should not be worn. Some behaviour is also considered hazardous such as spitting, coughing and sneezing. Maintaining high personal hygiene standards and wearing appropriate and safe clothing are all important in minimising contamination risk.

Clothing can 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. Hair and beards raise the risk of physical contamination and should be secured in hairnets during fruit packing. 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 workers in packhouses. It must be emphasised that cuts, wounds and sores must be covered securely with dressings and bandages and covered with a glove.

Best practice recommendations

- clean clothing must be worn
- personal effects such as jewellery should not be worn or brought into production areas
- suitable protective clothing and footwear should be worn
- hazardous behaviour such as spitting, chewing gum, coughing and sneezing must be avoided
- workers who have direct contact with produce must maintain a high degree of personal cleanliness
- if standard practices require utensils or small objects such as knives to be used, they should be numbered and identified.

Gloves

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 they are an effective way 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.

Best practice recommendations

- disposable gloves are preferred and they should be discarded when they become torn or soiled
- if reusable gloves are used, they should be made of material that is easy to clean and disinfect; they should be cleaned regularly and stored in a dry clean area.

Workers' facilities

Workers 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. Workers' facilities should be clean and conveniently located for workers to use and enable compliance with personal hygiene requirements. Before workers 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 workers and visitors in the field and packhouses. Providing these facilities, in particular in harvesting fields, follows proper field sanitation practices, which helps reduce possible contamination risk of produce and protects both workers and consumers from foodborne diseases. Having a toilet close by reduces the chances of workers 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. Workers should also be allowed to use these facilities when they need to and not just during scheduled breaks.

Best practice recommendations

- sanitation facilities should be placed close to fields and indoor premises to encourage their use (maximum 400 metres or within 5 minutes walking distance) and reduce the likelihood that workers will relieve themselves in the field
- facilities should be designed in such a way to ensure hygienic waste removal and avoid contamination of production areas
- be regularly cleaned and maintained
- growers should assess where it is safe to place portable toilets.

Illness

Unwell workers, contractors and visitors pose direct and indirect contamination risks. 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 or 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. Workers should be trained to inform and notify supervisors of any illness that could affect food safety.

Recovering workers 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 workers. Workers recovering from a cold should take extra precautions preventing contamination through coughing, sneezing and nose blowing. Hand washing frequency should be increased and workers should remain vigilant in managing their hygiene.

Best practice recommendations

- any sick person should immediately report their illness or symptoms to the manager and must not work in contact with produce
- establish a clear policy that prohibits workers who are observed to have any illness from activities that may contact watermelons or watermelon contact surfaces.

Workers' hygiene training

Workers should be trained to understand the effects of contamination and in procedures and protocols for its prevention. This should include hand washing, good hygiene, procedures for using workers' facilities, cross-contamination as well as cleaning and sanitising procedures.

Workers should be educated to understand the consequences of contamination and trained in procedures and protocols for its prevention. This should include hand washing, good hygiene, procedures for using workers' facilities, cross-contamination and cleaning and sanitising procedures. Training is a critical part of managing the food safety risks linked to workers in the field and processing facilities. It is important to teach workers about food safety and their role in preventing contamination. Workers should feel a sense of responsibility in their role in minimising risks and in turn follow correct protocols. Training should include:

- hand washing techniques and their significance
- what good hygiene is and why it is important
- procedures for using workers' 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.

Training should be provided to all workers in a format and language that is easily understood. Refresher courses should be run so that all workers can stay up-to-date with the procedures and protocols. There should also be occasional audits to determine if workers 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.

Best practice recommendations

- keep a record of workers who have received hygiene training
- ensure that workers stay up to date with procedures and protocols.

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.

Food defence

Food defence is the effort to protect food from acts of intentional adulteration that could cause wide-scale harm to public health, including acts of terrorism targeting the food supply. Such acts, while not likely to occur, could cause illness, death, and economic disruption of the supply chain.

Both food safety and food defence involve activities to ensure consumers have access to safe food. However, the term 'food defence' is used to protect food from intentional acts of adulteration, while food safety is concerned with the unintentional adulteration of the food supply.

A deliberate act of sabotage through contamination/adulteration is a continuing food safety risk for horticultural industries. Needles being inserted into strawberries was a typical example of sabotage. 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. Workers, ex-workers, visitors and contractors should be considered as risk factors when developing a sabotage prevention plan.

Workers are the FIRST line of food defence against sabotage. The USFDA suggested the 'FIRST' acronym approach to make it easy to remember the role that workers have in the food defence:

- FOLLOW business's food defence plan and measures
- INSPECT your work area and surrounding areas
- RECOGNISE anything out of the ordinary
- SECURE all ingredients, supplies, and finished product
- TELL management if you notice anything unusual or suspicious.

FOOD SAFETY RISKS- ENVIRONMENTAL FACTORS

Site Location

Site locations should be assessed for possible contamination hazards and risks. Knowledge of site's history

- Use a site diagram as a reference for evaluating site features and their hazards- include site layout, topography, animal activity areas, residential areas, fences, roads, irrigation systems and waste management sites.
- Document site's history include previous uses in risk evaluation.

Climate Conditions

Unusual weather events or conditions may affect integrity of field and produce and need to be evaluated before harvest. Consider changes in:

- temperature
- rainfall
- runoff and flooding
- dust storms
- drought's impact on water quality
- crop health (e.g. fruit cracking)

Soil Amendments

Contamination risks vary depending on the composition, origin and treatment of soil amendment.

- Human waste poses the highest risk and should NEVER be used.
- Animal waste should only be used if treated with a pathogen reduction step.
- Soil amendments containing raw animal manures (e.g. poultry litter) MUST not be used in melon fields.

Agricultural Water

A number of different processes including irrigation, pesticide application and hand washing involve water. Unacceptable water quality is a direct source of contamination and is also a vehicle for spreading contamination from one location to another. Agricultural water should always be evaluated before use and should include hazard analysis and microbiological testing

Animals and Wildlife

All animals are potential vehicles for contamination. It is critical that:

- Animals are excluded from production areas and water sources.
- Fields are inspected for animal activity
- Animal incursion related hazards are evaluated and records are kept.

Workers and Training

Agricultural workers have a critical responsibility in reducing or avoiding contamination of produce.

- Ensure staff are properly trained
- Provide staff with appropriate facilities
- Ensure staff do not come to work when presenting symptoms of illness.

Harvest

Harvest is a manual process and the most labour-intensive part of watermelon production (Figure 9). Many production practices at harvest have the potential to contaminate fruit.

Figure 9. Harvest is a manual process and the most labour-intensive part of watermelon production.

Preharvest assessment

During harvesting, there are relevant hazard control points that include field worker hygiene, sanitation of the field, equipment, containers, packing material, water, transport and temperature control. Evaluating any safety risks that may affect the potential for watermelons to be contaminated must be done before harvest because it might be the last opportunity to do so (Mena et al. 2004; Todd 2004). The field manager or other personnel responsible should ensure the assessment is performed before any harvest operations commence.

The assessment should consider the following safety risks:

- **irrigation** – before harvest, ensure the water used for irrigation has been documented and food safety criteria have been met
- **fruit pickers and handlers** – consider their training, practices and compliance with hygiene policies
- **field and perimeter**
  - no animals or wildlife should be present in the field
  - no signs of wildlife including droppings or evidence of recent animal activity should be present in the field
  - if an animal intrusion is detected, corrective actions should be taken to remove or prevent the harvest of any potentially contaminated product
  - there should be no signs of recent flooding from nearby creeks, streams and rivers or overflowing manure storage tanks and septic systems
  - run-off from any nearby animal operations needs to be prevented
- **hand washing and toilet facilities**
  - appropriate toilet facilities should be available and accessible
  - toilet facilities need to be clean and equipped with hand washing stations
  - hand washing stations must be adequately supplied
  - portable toilet facilities must be located far enough away from production areas that they cannot become a source of contamination
  - greywater from portable hand washing stations must be diverted away from production areas
- **produce contact containers, packing materials, equipment and tools**
  - harvest containers should be stored so they do not become contaminated before use
  - containers must be cleaned according to the food safety plan being followed
  - harvest containers must be inspected and be free from splinters, exposed nails or signs of contamination
  - equipment and tools should be cleaned according to the food safety plan being followed
- **additionally**
  - ensure procedures used to identify and mitigate risks have been documented, followed and are reviewed
  - if watermelons are harvested multiple times, fields should be assessed sufficiently to assure that new risk factors have not emerged.

Figure 10. Watermelons being cleaned, wiped and packed in the field.

Harvesting

Fruit maturity

To ensure good quality fruit is being supplied to markets, watermelon should be harvested at full maturity. There is no further development in internal colour or sugar content after the fruit is removed from the vine. Commonly used maturity indicators include:

- fruit size
- skin colour
- colour of ground spot
- the sound of fruit when tapped
- the condition of tendrils closest to the fruit.

Ideally at least three of these methods should be used to confirm harvest maturity.

The harvesting process

Current industry practice is for watermelons to be packed in the field without any postharvest activities such as washing, brushing or sanitising, which are common in rockmelon postharvest handling.

In Australia, watermelons are harvested manually, making it labour intensive. Using knives, workers go through the field cutting ripe watermelons from the vine. The fruit is then turned 'ground spot up' so workers loading harvesters know which fruit is off the vine and ready to be collected. These watermelons are then placed onto conveyor belts attached to tractors with trailers that move through the field. While on this conveyor belt, the watermelons are cleaned and wiped using clean cloths or rags (Figure 10) that have been sourced from local warehouses (Figure 12). They are then graded and packed into cardboard bulk bins, ready for market.

Harvesting after rain should be avoided since the fruit would be more susceptible to postharvest diseases. Wet conditions during harvest can result in complications because sand and soil adhere to the fruit surface when it is wet. This not only leaves an unattractive appearance but if the sand or soil is smeared on the watermelon surface during handling, the chances of mechanical damage and the risk of contamination are increased.

Handling melons

When fully mature, watermelon stems do not 'slip' off or freely separate from the vine and therefore need to be cut off with a sharp knife or pruner. Using sharp knives ensures cuts are clean and there is no injury to the fruit or stem from pulling or tugging. Watermelons should never be pulled, twisted or broken off the vine as this can cause rind tissue to be removed, which can result in decay around the damaged area. Watermelons with open wounds are prone to postharvest rot such as bacterial soft rot.

Watermelons need to be handled with care to avoid bruising. Any fruit that is dropped during handling, even if it did not break, split or crack, should not be loaded. Watermelons bruise easily and the flesh will soften after impact (Figure 11). That is why field sacks should not be used and walking or riding on top of a load of watermelons should not be permitted. Stacking the watermelons on their side rather than on their end also reduces the risk of cracking. Internal flesh is more susceptible to vibrational damage if the fruit is stacked on the stem or blossom end. Fruit bruising can be reduced by ensuring that stacking depth does not exceed 1 metre.

Care should be taken to ensure that watermelon contact surfaces are not contaminated by exposure to soil or manure; this includes conveyor belts, loading tables and packing materials. Ensure that unformed or empty containers are stored off the floor or soil surfaces to prevent contamination. Dirt and debris from harvest containers, trailers or gondolas should be removed between harvests or more often as needed. This should be done outside the packing facility and isolated from any water sources used for postharvest handling.

Figure 11. A watermelon with bruising to the bottom right quadrant.

Cleaning

Watermelons are cleaned in the field at harvest. Using rags to remove dirt and debris from watermelons ensures the fruit has a clean and polished look ready for market. Wiping watermelons before packing is a quick and cost-efficient method but is only effective if limited dirt and debris are present. If the fruit is heavily soiled, washing and brushing are more appropriate. Wiping is essentially the only postharvest process these watermelons go through before being transported and distributed to the market.

Wiping with cloths or rags can pose a microbiological cross-contamination risk. While the type of cloth or rag has no significant effect on transferring microorganisms, once a cloth is damp, it absorbs more microorganisms from the surface of the watermelon.

Wiping with a damp cloth also increases the risk of transferring microorganisms from one watermelon to another.

The materials used for wiping and their risk for contamination

Wiping is done using rags or used cloths that can be purchased in bulk. These are usually bought as a bag of mixed cotton rags that have been recycled from clothing and sheets, which have been laundered and cut into pieces. These rags are affordable, readily available and highly absorbent, making them ideal for polishing. One rag is used for wiping multiple watermelons on a conveyor belt, with no more than a few seconds being spent to wipe a single watermelon.

Using recycled clothing as rags can be a potential route of contamination, with studies showing they can spread infection. *Salmonella* typhimurium, a foodborne pathogen, can survive on several different fabrics including cotton sheeting and clothing. If the material has direct contact with the pathogen, *Salmonella* typhimurium can survive on cotton clothing for up to six weeks (Wilkoff et al. 1969). This is a concern because *Salmonella* was the most common aetiology of foodborne illness associated with melon outbreaks in the United States from 1973 to 2011 (Walsh et al. 2014).

As well as spreading bacterial pathogens, rags can also spread viral pathogens. Studies have shown enteric viruses such as hepatitis A and rotavirus surviving on cotton clothing even after laundering. Washing contaminated cotton clothing with detergent had little effect in reducing the concentration of viruses on the clothing. Perhaps even worse, viruses are readily transferred from contaminated cloths to uncontaminated cloths. This means that one item of heavily contaminated clothing can contaminate an entire laundry load (Gerba and Kennedy 2007).

Considering that recycled rags are sourced from a variety of sources and laundered before they are supplied in bulk, it is highly possible for a bag of rags to be contaminated.

We recommend sourcing new and clean cloths to use as wiping material on watermelons during harvest.

How wiping materials become contaminated and the potential for cross-contamination

Even if the rags are clean before use, there are many ways they can become contaminated. Workers are a primary contamination source because watermelons are manually handled at nearly every stage of the supply chain. People carry bacteria on the surface of their skin and in their bodies. These bacteria can easily be spread to the rags used to clean the fruit and then to the fruit.

Pathogen transfer from hands to cloth was demonstrated by Sattar et al. (2001). They examined how *Staphylococcus aureus* could be transferred by two types of fabrics, a 100%

cotton fabric and a polycotton fabric (50% cotton + 50% polyester) to hands and other fabrics. Moist and dry conditions were compared along with applying friction during transfer. They found a higher level of pathogen transfer when hands and fabrics were moist and when friction was applied.

Fruit can be contaminated in the field by soil, animals and workers. The fruit then contaminates the rag when it is wiped. If these rags become moist, then through the friction created during wiping and polishing, pathogens can be released on to the fruit's surface. A rag has the potential to contaminate multiple watermelons through wiping and with no decontamination step in the supply chain, contaminated fruit can be supplied to the consumer.

In a study examining tomato wiping during harvest, Sreedharan et al. (2014) investigated bacterial transfer via cloths used to remove dirt and debris. Using a cocktail of *Salmonella* strains, the transfer from inoculated tomatoes to uninoculated cloths and from inoculated cloths to uninoculated tomatoes was examined. Clean, dirty-dry and dirty-wet cloths were compared over single and multiple touches. They found that *Salmonella* transfer was highest when the inoculum was wet, and this was not affected by the condition of the cloth (clean or dirty). When an inoculated clean wet cloth was touched with 25 tomatoes, significantly high levels of *Salmonella* were transferred to subsequently wiped tomatoes. This shows the potential contamination risk when the same cloth is used multiple times for cleaning, especially under high moisture levels.

We recommend changing cloths when they become damp and follow harvest practices that encourage reducing moisture on fruit.

Our studies examining how wiping materials affect *Salmonella* typhimurium transfer to watermelons showed similar findings. Investigating pathogen transfer from inoculated cloths (various cotton rags and Chux® wipes) to watermelons and from inoculated watermelons to uninoculated watermelons in wet and dry conditions, we found that the type of fabric used had no significant effect but the dampness of the cloth did make a difference.

All the wiping materials tested in dry conditions had minimal effect in removing microorganisms from the watermelon surface. They also did not transfer detectable levels of *Salmonella* typhimurium to subsequently wiped watermelons. In comparison, moist wiping cloths removed more microorganisms and also transferred more to subsequently wiped watermelons. This highlights the increased risk of cross-contamination when wiping material is moist.

The contamination risk from wiping is accentuated by the absence of any decontamination step after harvesting, including in the packhouse, supermarket or greengrocers. It is common for whole watermelons to be purchased by the consumer straight out of the cardboard bulk bin into which they were originally packed in the field. Overall, improved food safety is needed across the supply chain. A postharvest washing and sanitising step would be ideal, either immediately after harvest or before retail.

Moist fabric can remove more microorganisms from contaminated fruit surfaces resulting in more microorganisms being transferred to subsequently wiped fruit.

Current international watermelon cleaning practices

There is currently no international standard for watermelon cleaning practice. International standards for fruit and vegetables are provided by the Organisation for Economic Co-operation and Development (OECD). These aim to facilitate the common interpretation of standards regarding the quality of various fruits and vegetables traded internationally.

Minimum quality requirements (OECD 2013) state that watermelons must be:

- **Intact** – watermelons must not have any damage or injury such as cuts, punctures or other significant physical damage
- **Sound** – must be free from disease or serious deterioration which affect appearance, edibility or keeping quality
- **Clean** – practically free of any visible foreign matter such as soil, dust or chemical residue
- **Practically free from pests** and free from damage caused by pests affecting flesh
- **Free of abnormal external moisture** – does not include condensation on produce following release from cool storage
- **Free of foreign smell** and/or taste
- **Able to withstand transportation and handling** and arrive at their destination in satisfactory condition.

In the USA, federal and state guidance documents are provided to the industry. While these documents do not provide a standard cleaning process, they do provide recommendations related to cleaning processes that may be used. Some of these include:

- water used in watermelon washing should be of sufficient microbial quality and must be changed as necessary
- sufficient water disinfectants should be used to reduce cross-contamination risk and must be registered with the US Environmental Protection Agency (US EPA 1994)
- if cloths are used repeatedly for cleaning watermelons, they should be replaced after each box packed and if re-used, must be washed in hot water (> 60 °C).

Written policy and documentation should be available to workers (Morrissey et al. 2008).

Dry brushing machines are used in some countries such as the USA, Italy and Spain. These can either have flat roller brushes along which the watermelons are fed, similar to those used in the Australian rockmelon industry, or helical brushing machines, where the watermelons are fed through and rotated for a whole surface polish. In both machines, the brush bristles remove dirt, soil and dust, thereby cleaning and polishing the surface of the watermelons. The absence of water in dry brushing machines prevents cross-contamination through water but means that no sanitiser is used to reduce microbial loads. It is recommended that growers and processors adopt a washing and sanitising step in their processing systems. Compressed air can be used in some countries to clean watermelons (Figure 12).

Watermelon postharvest handling systems can be viewed at the following links:

- Watermelon Processing Line by KW Automation, Australia https://www.youtube.com/watch?v=dQwynXcjCkk
- Melon processing, sorting and grading machines/lines by Unitec, Italy, Australian branch in Victoria https://en.unitec-group.com/fruit-vegetables-technology/melon-processing-sorting-grading-machines/
- Helical brushing machine by Meccanica Malavasi, Italy https://www.youtube.com/watch?v=8RJNwUBarLE
- Compact washer and dryer by Dinox, Spain https://www.youtube.com/watch?v=bMdL8DWqyyc

While washing and sanitising are not commonly conducted in the watermelon industry, they are standard industry practice in the rockmelon industry. Washing, brushing, spraying and drying melons removes excess soil, enhances the appearance for market and can reduce any microbial loads. However, postharvest water is a potential contamination source, therefore it should be drinking water quality and properly sanitised to reduce the potential for cross-contamination.

Chorine is commonly used as a wash water sanitising agent in the rockmelon and specialty melon industries as it is cost-effective and readily available. When dissolved in water, the hypochlorite will take on two forms: hypochlorous acid and hypochlorite ion. Hypochlorous acid is the sanitising agent and is present at higher concentrations when pH is between 6.5 and 7; if pH gets higher than 7, the concentration will be greatly reduced and efficacy will be low. It is essential that pH levels are adjusted when chlorine is added to wash water for high sanitising efficacy.

McGlynn et al. (2003) assessed the effect of a 200 ppm sodium hypochlorite dip (limited contact time) solution on whole watermelons, observing an initial two log reduction of total aerobic counts. Concentrations of 100 ppm with a contact time of 2 minutes or 200 ppm with a contact time of 1 minute is recommended. Manufacturers' recommendations may differ and might not be based on their efficacy to reduce specific pathogens on specific produce, but are more likely recommendations intended at keeping wash water effectively sanitised to prevent cross-contamination.

As wash water is used and becomes contaminated with soil and other organic matter, the sanitising efficacy is reduced. Therefore, wash water must frequently be changed and filled with clean water. Alternatively, a single-use wash water system is recommended and is considered the best practice in mitigating microbial food safety risks.

Packing

Watermelons are packed in the field by directly loading them onto the bed of a truck or trailer in cardboard bins (Figure 13), then they are transported to market. Many farms use conveyor belts to move the melons from the field to the truck for grading and packing.

Harvest conveyor belts are a direct contact surface for watermelons and need to be cleaned before use with drinking quality water and sanitised. Watermelon contact surfaces should be in good condition so the melons are not damaged when on them, as wounds can provide entry points for pathogens. Packing materials need to be stored in such a way to prevent them from being contaminated before use.

Transport from the field

Watermelons should be removed from the field as quickly as possible because exposure to direct sunlight for even a few hours can lead to sunburn.

Transport in open trucks or inside non-refrigerated vans is not ideal for maintaining fruit quality during distribution. Fruit on top of the load in open trucks is susceptible to sunburn and fruit loaded in enclosed vans is subject to overheating during hot days.

Best practice recommendations

- watermelons should be picked when the fruit surface is dry
- dirt, stems and leaves should be removed in a way that does not pose any contamination risk
- adhering soil in the ground spot area and other surface stains should be removed at harvest with a soft cloth or cotton gloves
- if cleaning materials such as cloths are used repeatedly for cleaning watermelons, steps must be taken to ensure they do not become a source of direct or cross-contamination
- ensure that wiping materials and gloves are dry, as once moist, cloths can contribute to cross-contamination between fruit
- wiping material should be replaced frequently (i.e. after each box is packed)
- facilities should have a written policy for sanitising wiping material used for cleaning watermelons
- wiping material should be washed in hot water and sanitised before re-use; a validated procedure for eliminating potential contamination should be followed
- documentation of training workers in the appropriate use of wiping materials for cleaning watermelons should be available
- watermelon fruit should be washed and sanitised following the best practice guidelines outlined in the 'Melon Food Safety – Best Practice Guide' and a '*Melon Food Safety Toolbox*'.

Figure 12. Watermelons being hosed with compressed air.

Figure 13. Watermelons packed into cardboard bins in the field at harvest.

FOOD SAFETY MANAGEMENT DURING WATERMELON HARVESTING

Watermelons are grown in close proximity to the ground, hand picked, cleaned/wiped with cloths/rags and then packed in bulk bins for the market. Along this process, watermelons encounter a multitude of microbial contamination risks. Many of these risks come from the direct contact of fruit with ground, contact surfaces and workers which can lead to the transfer of harmful pathogens.

1. Ground contact

Use plastic mulch to minimise contact between ground and fruit.
Reduce microbial contamination risk of soil from organic fertilizers and water.
Prevent wild or domestic animals from entering the growing site.
Don't harvest melons immediately after rainfall.

2. Human contact

Workers practice personal hygiene including hand washing with soap and using clean gloves and knives.
Provision of workers facilities at harvest site is critical.

3. Harvesting equipment

Clean and sanitise conveyor belts and other contact surfaces of harvesting machinery after use.
Follow cleaning and sanitisation recommendations in **NSW DPI Melon Food Safety Toolbox 2019.**

4. Wiping and cleaning material

Use clean wiping cloths or chux to ensure material used does not become a direct source of contamination.
Avoid using wet wiping material and replacing with dry cloths to reduce spread of any bacteria picked up in the cleaning process

5. Grading and packing

- Damaged and bruised fruit should be culled and removed.
- Packing material should be safely stored to prevent getting contaminated.
- Ensure to stack watermelons to the side rather than on their end to reduce risk of cracking.

MICROBIAL FOOD SAFETY RISKS WITH WIPING OF WATERMELONS

Current industry practice is to hand pick watermelons, clean/wipe with cloths/rags to remove dust and organic matter and then pack in bulk bins for shipping to the markets. Generally watermelons do not receive any further postharvest treatments such as washing, brushing and sanitising.

Wiping materials are often rags sourced from local warehouses. Wiping material such as used cloths and rags can become a vehicle for cross-contamination when the same cloth is used to wipe multiple watermelons as illustrated in the diagram above.

MICROBIAL FOOD SAFETY RISKS WITH WIPING OF WATERMELONS

The reusable cloths and their contribution to contamination has been investigated in industries such as hospitality and healthcare. Studies have found that reusable cloths carry high amounts of contaminants (Sifuentes et al., 2013), with cotton cloths being able to pick up more bacteria than other materials (Koo et al., 2013).

NSW DPI investigated the cross-contamination potential of wiping material in watermelons. Different types of materials in either damp or dry form were tested for their potential to pick up and transfer *Salmonella Typhimurium* from fruit to fruit. Testing a range of different materials including Chux wipes, cotton cloth and mixed material rags, it was found that the type of material had no significant impact on the transfer of bacteria. However, damp material compared to dry material showed significant differences in transfer potential.

Results

- A dry cloth/rag is less effective in removing microorganisms from the surface of the watermelon, but at the same time there is less potential for transferring bacteria to another watermelon when used again.
- A wet/damp cloth on the other hand is more effective in removing microorganisms from the surface of the watermelon, but with an increased potential for transferring bacteria to other fruits when used again.

References:
Koo, O.-K., Martin, E. M., Story, R., Lindsay, D., Ricke, S. C., & Crandall, P. G. (2013). Comparison of cleaning fabrics for bacterial removal from food-contact surfaces. Food Control, 30(1), 292–297
Sifuentes, L. Y., Gerba, C. P., Weart, I., Engelbrecht, K., & Koenig, D. W. (2013). Microbial contamination of hospital reusable cleaning towels. American Journal of Infection Control, 41(10), 912–915.

WATERMELON WASHING AND SANITISING
Critical Control Parameters

Use potable/drinking water containing a **sanitiser** for washing the fruit.

Sanitiser must be **effective** and at an appropriate **concentration.**

Regularly maintain, **monitor and record** the sanitiser concentration.

Maintain, monitor and record fruit's **contact time** with sanitised water.

Monitor and adjust pH **if chlorine is used** as a sanitiser.

Monitor and record **water and fruit flesh** temperature.

Sanitised water spray must **cover all** fruit and brushes.

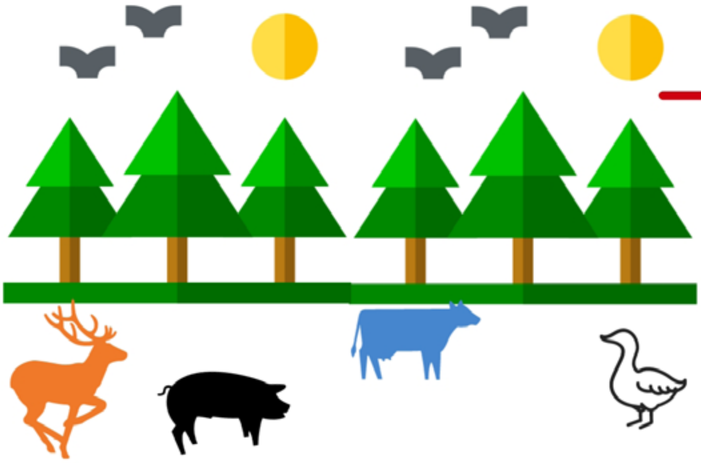
Distribute nozzles for **uniform washing** across all rollers and brushes.

Maintain uniform wash **water flow and pressure.**

Brushes must be kept **clean and debris-free.**

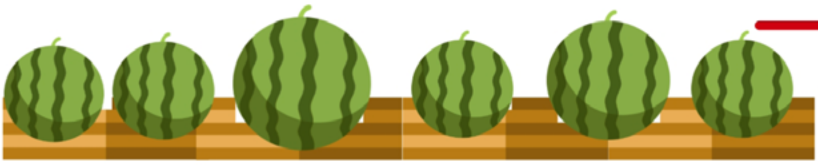
POTENTIAL VECTORS AND ROUTES OF TRANSFER OF PATHOGENS INTO MELON FIELDS AND PACKHOUSES

Environment



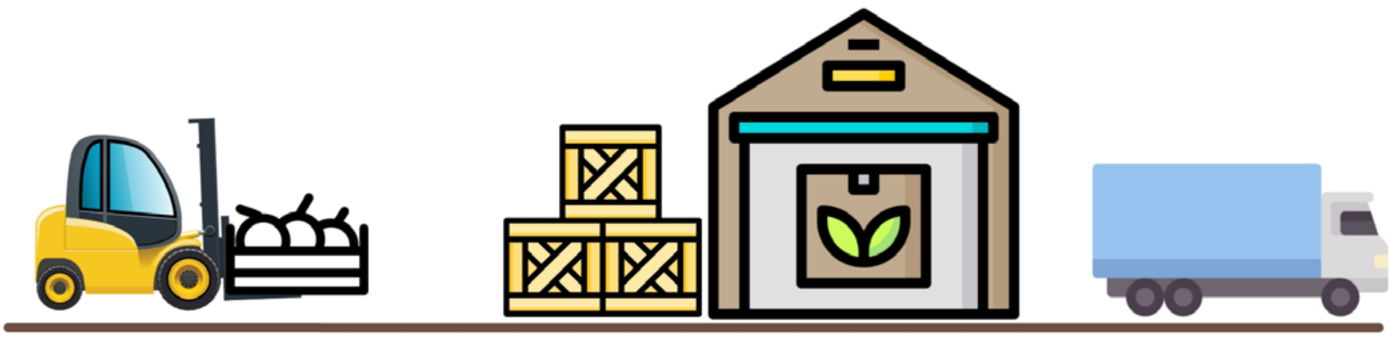
- Agricultural water
- Soil amendments
- Duststorms
- Flooding
- Wildlife
- Livestock

Field



- Harvested fruit
- Machinery
- Equipment
- Workers
- Wind/dust storms
- Pests

Packhouse



Postharvest

Packhouse and storage

After being wiped, watermelons are packed into cardboard bins based on their size. The watermelons are then generally stored at ambient temperatures before being transported to supermarkets and greengrocers. Precooling is not a common practice in watermelons, although supermarkets and greengrocers store watermelons in cold rooms before displaying them for sale (Figure 14).

Figure 14. Watermelons stacked in storage.

PACKHOUSE ENVIRONMENTAL MANAGEMENT PROGRAM

1 Packhouse layout and design

2 Postharvest processing flow

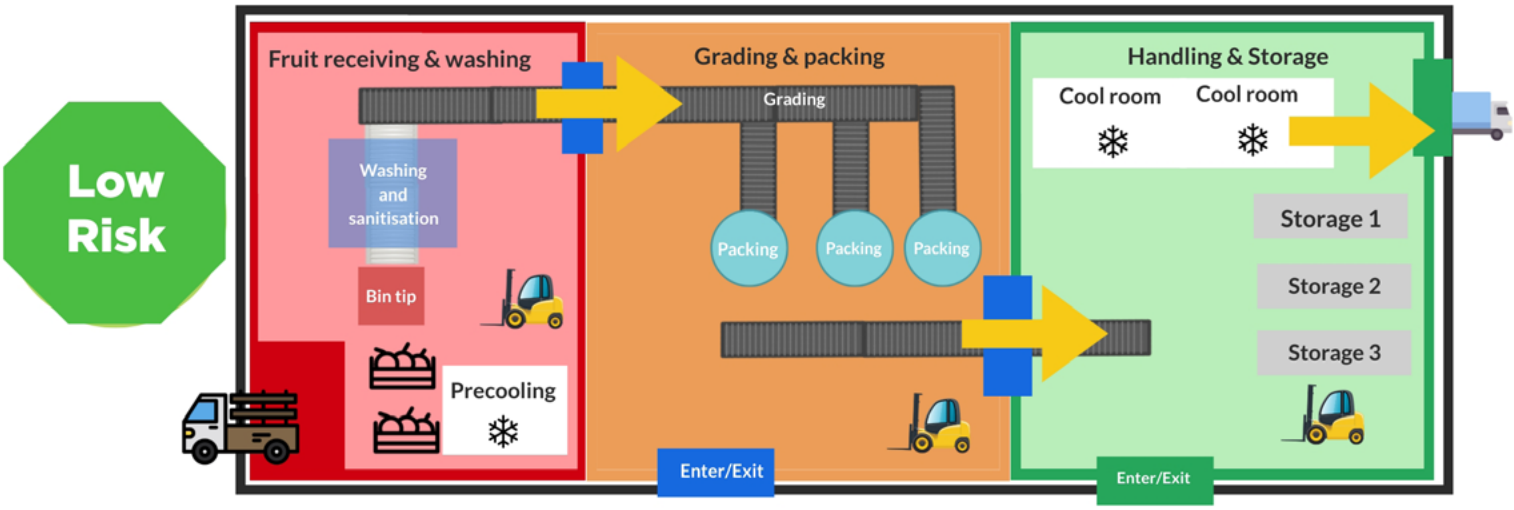
3 Equipment design

4 Cleaning and sanitisation

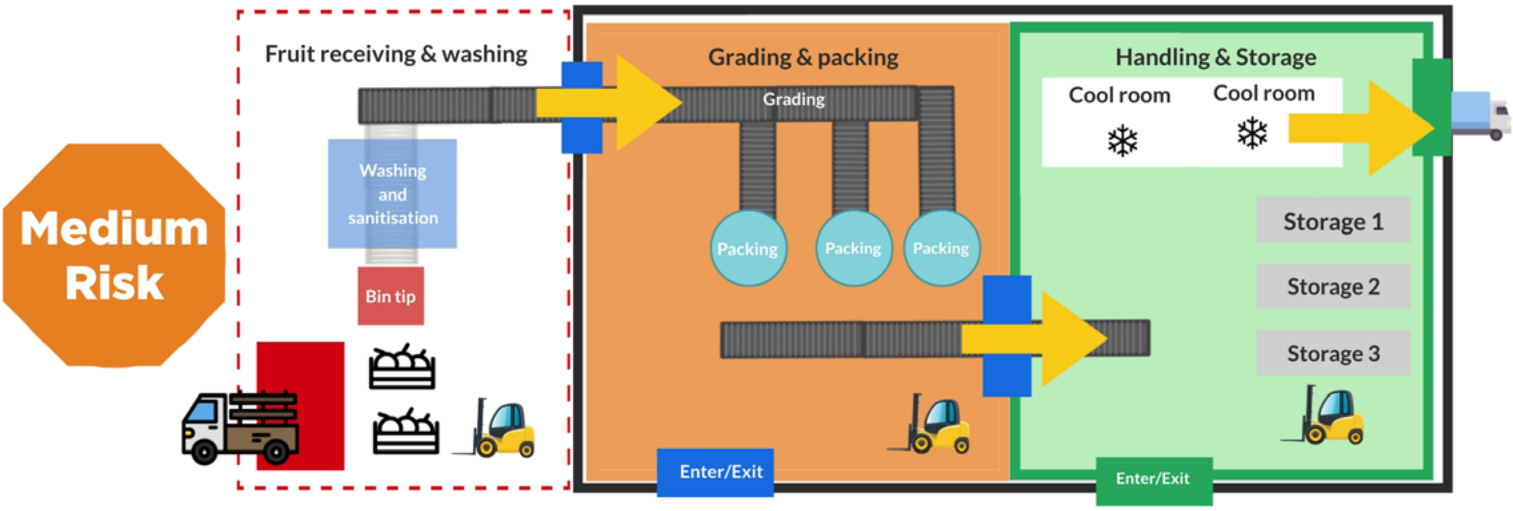
5 Environmental monitoring

PACKHOUSE LAYOUT & PROCESSING FLOW

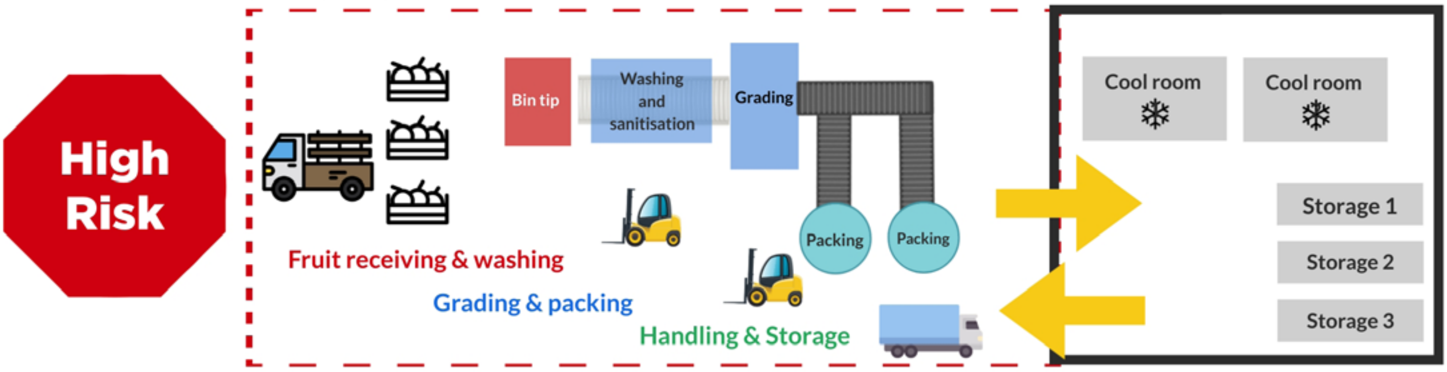
Fully enclosed packhouse; distinct separation between zones; one-way flow.



Partially-enclosed packhouse: fruit washing and sanitisation operation is exposed to the external environment.



Open packhouse; no distinct zones; postharvest operations are exposed to the external environment.



PACKHOUSE EQUIPMENT DESIGN

Best Practice

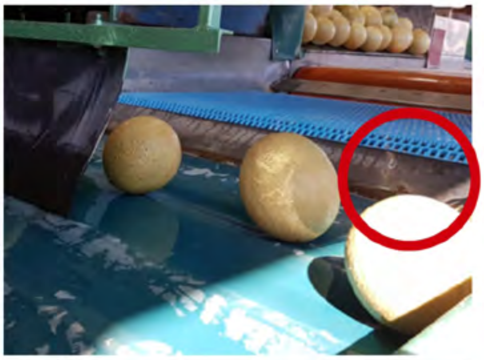
Equipment design should:

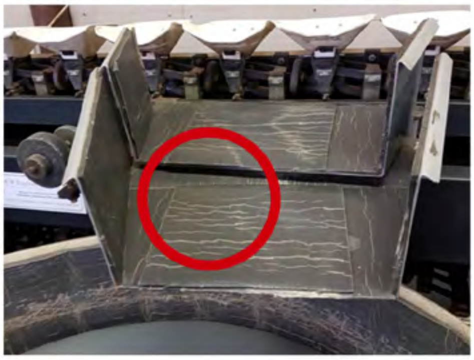
- be cleaning and sanitisation friendly
- be easy to disassemble and reassemble.
- be such as to have minimal areas for habouring bacterial growth
- consider sanitary materials and laminations

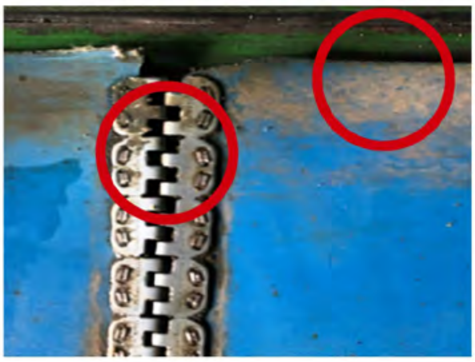
Equipment should:

- NOT have porous surfaces
- NOT have metal cracks
- NOT have sharp edges
- NOT have seams with metal or plastic lacing
- NOT have hollow rollers

Glimpses of bad equipment design







PACKHOUSE IDENTIFICATION ZONES

Zone 1: Fruit contact surfaces

Conveyor belts
Brushes - flatbed and overhead
Hollow conveyor rollers
Grading and sorting cups
Packing tables
Curtains in drying tunnels
Harvest bins





Zone 2: Near-fruit contact surfaces

Conveyor belts undersides
Hollow rollers
Weld seams
Electrical cords
Equipment stand/legs
Metal cracks
Bolt threads



Zone 3: Non-fruit contact surfaces

Cracks in flooring
Improper drains
Rubber mats
Plastic curtain strips
Entrance.exit roll-up doors
Drip pans under cooling units
Cool room floors and walls
Wash water/dump tanks
Fruit waste areas
Handwash stations






Zone 4: Outside packhouse area

Locker rooms
Cafeteria
Hallways
Loading dock
Maintenance areas
Offices


CLEANING AND SANITISATION SCHEDULE

DAILY

Fruit contact surfaces

- Harvest bins
- Dump tanks
- Wash tanks
- Brushes
- Rollers
- Conveyors
- Fungicide tanks
- Packing tables

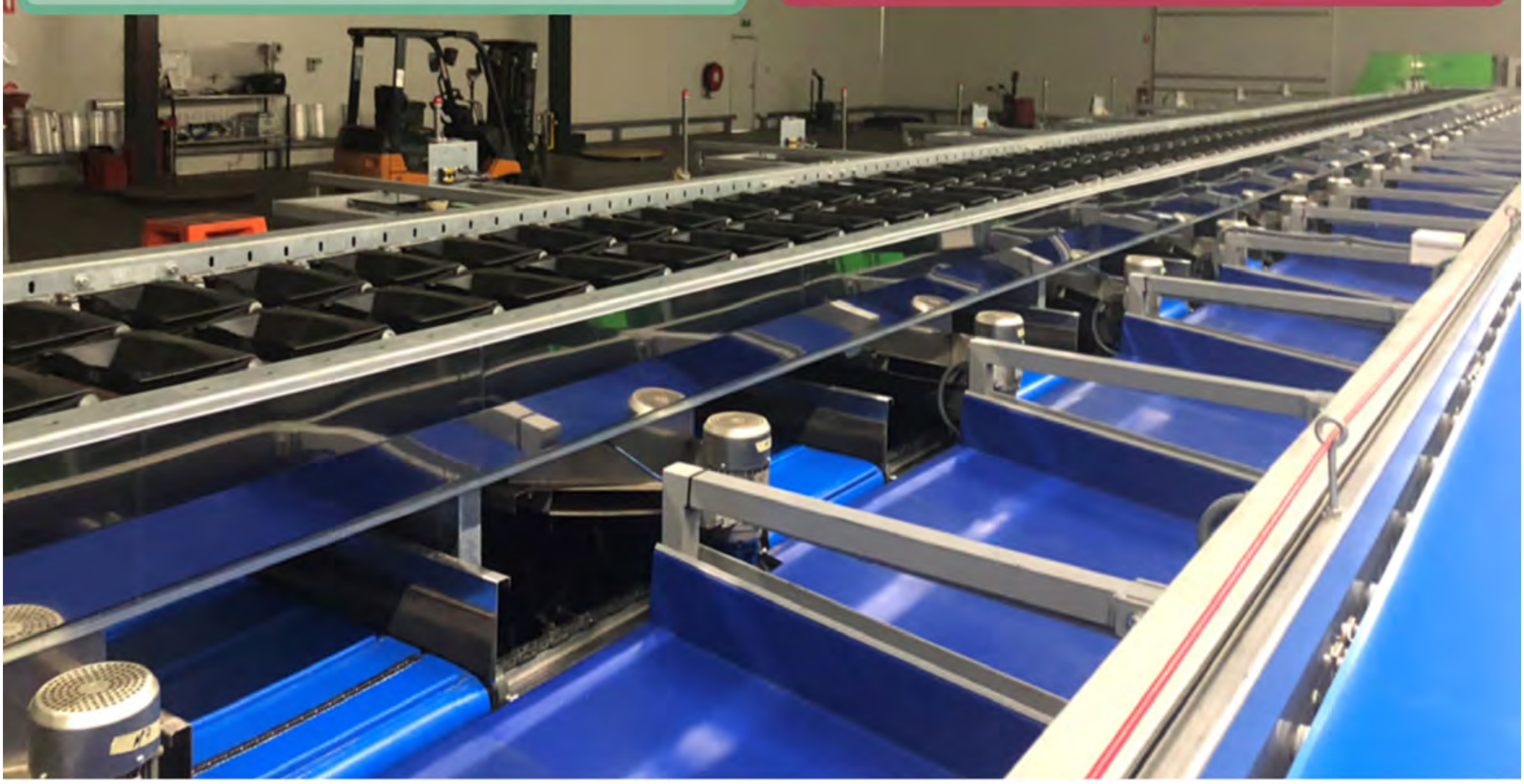
Non-fruit contact surfaces

- Drains and floors in fruit tipping, washing, sanitisation and packing areas
- Handwash stations and hygiene facilities, foot mats

Less than DAILY

Non-fruit contact surfaces

- Cool room floors and walls
- Floors and walls away from packing area
- Refrigeration units & drip pans
- Drains from refrigeration units and drip pans
- Cross beams & concrete beams
- Light fixtures
- Stairs, hand rails, guard rails and elevators
- Cooling tarps
- Doors and strip curtains
- Fork-lifts, pallet-jacks
- Carts, pallet racks, warehouses
- Loading docks



SEEK AND DESTROY THE BUGS

- **To prevent transient pathogens from becoming entrenched, forming biofilms and spreading**
- **To verify the effectiveness of cleaning and sanitation measures**
- **To determine and undertake corrective actions**

1 Target pathogens

- *Listeria monocytogenes*
- *Salmonella* species

2 How frequent?

- One size does not fit all. Consider processing volumes and packhouse risk history
- weekly testing for large operations (>20 tonnes/shift); bi-weekly for medium scale (3-20 tonnes/shift); and monthly for small packhouses (up to 3 tonnes/shift)
- Increase the frequency in the event of a positive detection and weather events (dust storms, flooding)

3 How many samples and from where?

- Determine on the basis of trends & risk history
- Minimum 5-7 swabs from each zone
- Minimum 5 processed fruit samples

4 When to sample?

- Immediately after packhouse sanitation and prior to processing
- During fruit processing, 2-4 hours from the start of the shift
- After packhouse cleaning, but prior to sanitation

5 How to sample ?

- Train QA staff in aseptic techniques. Follow the sampling schedule as per food safety plan
- Use sponge swabs for sampling larger areas and Q-tip swabs for hard to reach niches
- Avoid compositing samples when targeting harbourage sites.
- Accurate labelling and documentation
- Pack samples with frozen gel-ice packs to maintain 0-4°C during transportation

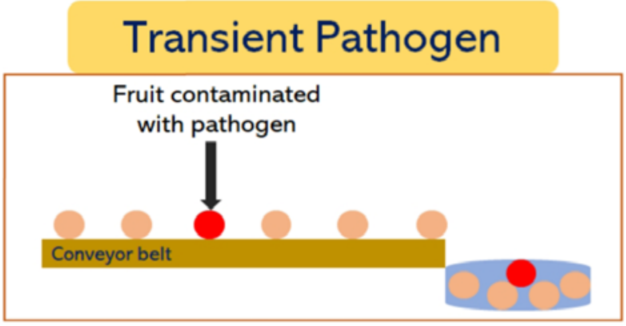
6 Microbiological testing

- Contact an accredited laboratory service provider to select sampling swabs and testing
- Test reports to be documented for analysing trends and record-keeping
- Corrective actions to be undertaken in response to a positive detection

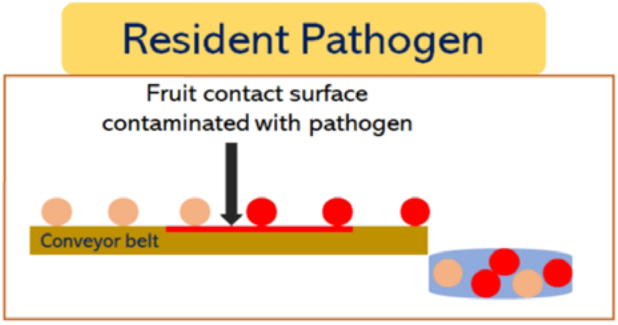
TRANSIENT VS RESIDENT PATHOGENS IN PACKING OPERATIONS

Transient vs Resident Pathogens

Transient isolate is a one off isolate which is not detected after repeated swabbing (a minimum of 3 negative results in a row). This detection indicates that cleaning and sanitisation are being implemented effectively. Pathogens such as *Listeria* may be introduced occasionally through incoming fruit and it is essential that best practices are followed to keep occasional presence under control. Once introduced and not controlled a transient pathogen can become a resident.



Resident isolate is an isolate that is repeatedly detected. This can indicate a failing implementing best practices in particular cleaning and sanitisation or an undiscovered niche where a pathogen has established a habourage site. There is a high chance that the site is continually re-contaminating the facility, increasing the potential for fruit to be contaminated. Processing should be stopped until repeated negative results can be produced. Aggressive corrective measures need to be implemented to seek out and eliminate resident isolates and assess the factors that allowed the site to be established.



First detection vs. second detection

Occasional isolates can be brought into the facility through incoming produce, however these must be prevented from continuing through the packhouse and taking up residence along the process. It can be expected that most detected isolates will be transient, from one location and not actually the source location. However, it is critical that this initial detection is not dismissed as a one off but is aggressively followed by testing to ensure it is not a resident isolate. If repeated detection occurs, an intensified response such as dismantling of equipment, deep cleaning and line shut downs are warranted. It is crucial that after first detection, the seek and destroy methodology is employed to identify niches and prevent habourage sites and future product contamination.

Current packing practices in Australia

Packaging is one of the most important processes in the long and complex journey from grower to consumer, playing a critical role in the postharvest handling and distribution of watermelons. It also protects the fruit from hazards including contamination during distribution, facilitates transport and storage as well as carries printed information.

In Australia, watermelons are packed using the bulk bin/carton system in fields straight after harvesting. These empty bulk bins are set up on pallets before harvest and brought into the field on trailers. After a quick wipe and grading, the watermelons are placed into bins, which are later palletised for storage and transport. This packing method is widespread in the industry and offers:

- protection of the fruit
- unitised handling, resulting in less labour needed for handling and unloading the watermelons
- less watermelon damage due to reduced manual handling
- better use of truck and dock space.

The USDA compared this bin system to a more traditional bulk system (where watermelons were bulk loaded into a trailer and transported to a packing site) and found that the bin system eliminated one step of manual handling, resulting in a 33% reduction in losses compared to watermelons bulk packed into trailers (Boyham et al. 2006).

What packing materials are used?

The most common material used in watermelon packing is corrugated fibreboard. It is extensively used for transporting and storing fresh produce in the horticultural industry (Pathare and Opara 2014). It is well known for its good stacking strength, low cost, versatility and easy availability.

The most common type of bulk bin used for watermelon packing is the double and triple wall octagonal bins. Certificates indicating strength characteristics and limits should be consulted when selecting and procuring bins. Bursting test and edge crush tests are important to determine the durability and stackability of these bins. The bursting test measures the force required to rupture or puncture the face of corrugated board. This force is indirectly related to a bin's ability to withstand external or internal forces and thus to contain and protect a product during shipment. The edge crush test strength, which is the better indicator of stacking strength compared to bursting strength, is a true performance test and is a measure of the edgewise compressive strength of corrugated board.

Being paper based, fibreboard strength is reduced by cold temperatures and high humidity. Absorbed moisture from surrounding air and contents has been shown to drastically reduce the stacking strength of the packaging (Dongmei et al. 2013; Patterson 2011). Over time, corrugated boxes become structurally weaker under load, especially with increased handling during storage and transport. They become 'fatigued' and lose strength when supporting weight. Thompson and Mitchell (2002) observed a box supporting weight for 10 days had only 65% of its original, laboratory determined strength and after 100 days, only 55% of its original strength was sustained.

Corrugated fibreboard bulk bins are shipped to growers and packers flat and are assembled at the packing site before use, usually by hand. Many cardboard and paper companies provide corrugated fibreboard bin options, the most commonly used in the Australian fresh produce industry are:

VISY – https://www.visy.com.au/product-view/#bulk-bins

Orora – https://www.ororagroup.com/what-we-do/products/boxes_cartons.

Packing, stacking and palletising

Bulk bin vertical strength comes from the corners and fibreboard strength should be considered when stacking. Over filling the bottom bin can result in damaged watermelons. Use pallets in good condition and the correct size to match the bins to prevent pallets from breaking due to top stacked bins causing damage to lower bins.

Fruit bruising can occur during handling, transport and storage. Most bruises are visible on the surface of most fruits, however, due to the thickness of watermelon rind, flesh bruising is difficult to detect. Using parallel plates to compress watermelons in longitudinal and transverse directions, Sadrnia et al. (2008) studied the internal bruising using non-linear finite element analysis (Figure 15). Force applied to watermelons was set to 10% of watermelon breaking force. Failure stress of red flesh was much lower than the rind. When force is applied, bruising will occur in the area where stresses are equal or more than failure stress. This indicates bruising of the red flesh is the primary form of mechanical damage under compression in both directions. Rough handling can cause internal bruising, even in the absence of rind injury because bruising occurs first to the internal flesh. Also, maximum stresses in longitudinal compression of watermelons are much higher than the maximum stresses in transverse compression, indicating that rind breaks occurring in longitudinal compression are more probable than transverse compression (Sadrnia et al. 2008).

Shahbazi et al. (2010) evaluated in-transit vibrational damage (frequency, acceleration and duration) and fruit position in the bin on watermelon. Damage was defined as the difference in the modulus of elasticity of the watermelon flesh and hull before and after the test. Results showed greater damage to watermelon flesh than watermelon hull. Watermelons positioned on the top of the bin showed more damage than those in the middle or lower positions in the bin (Shahbazi et al. 2010). This study shows that packaging, especially for fruit that has extended transport times such as when going interstate or to foreign countries, should be evaluated and improved.

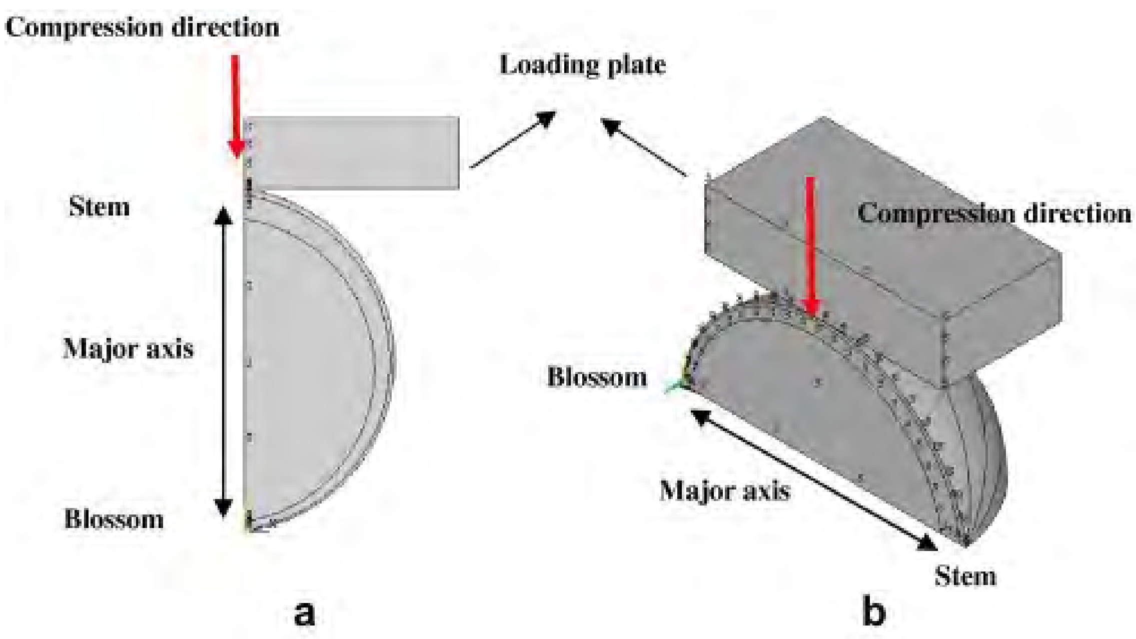


Figure 15. Compression model in (a) the longitudinal direction as a 2-D model and (b) the transverse direction as a 3-D model (Sadrnia et al. 2008).

Postharvest

Packing for export markets

Packaging standards vary between countries and industries. When preparing to supply watermelons to export markets, the market expectations should be known and understood. For example, Japanese markets are accustomed to watermelons being packed in 10–12 kg cartons with two watermelons separated by a cardboard divider (Figure 16). In American and European markets, watermelons are commonly found packaged in fibreboard boxes of 6, 10 and 12 fruit depending on fruit size (Figure 17). However, it is becoming more common to see watermelons packed into bulk bin cartons on pallets where around 50 watermelons can be packed and often displayed in the bulk bin.

Figure 16. Packaging practice in Japan. Photo: SP Singh.

Transport

Watermelons are transported by truck to the supermarkets and greengrocers. This is a critical step in the supply chain; however, it could expose the fruit to cross-contamination if the vehicles used are not clean. For example, the trucks could be contaminated with pathogens from pests or birds, or from other items that might be transported in the vehicles such as pesticides, fuel, oil, other chemicals and biological matter. The water used to clean the vehicles could contaminate them if the water source is not clean. Watermelons can also become damaged from physical hazards such as screws, glass or metal objects during transport.

To manage, minimise and eliminate the contamination risks, SOPs for packing and unpacking trucks, cleaning, sanitising and evaluating the vehicles should be used. Cleaning and sanitising schedules and records should be kept for when the vehicles were cleaned and what was used to clean them. Maintenance inspections need to be performed regularly, and records kept of what the findings were and of any actions taken.

Figure 17. Packaging practice in Italy. Photo: Fresh Plaza.

Retail

Display and labelling

Watermelons are displayed and sold either whole or cut up into quarters or halves. Whole watermelons are displayed at ambient temperatures and are usually in the cardboard crates in which they were transported. Half and most commonly quarter watermelon pieces are wrapped in plastic cling film and are displayed in ambient or refrigerated displays. Often the date and time the watermelons were cut is not displayed on them. The longer the watermelons are left on display, especially at ambient temperatures, the higher the bacteria load on the skin and flesh will be, which could be harmful to the consumer.

The key food safety risks associated with retail watermelons (Figure 18) include:

- no washing or sanitising steps before being cut for retail display
- cut watermelons being displayed at ambient temperatures
- refrigerated shelves holding the fruit can be inadequately cooled
- improper labelling without detailed information about the cutting time and date, or the best before date
- irregular cleaning and sanitising schedules for cutting implements and surfaces
- inconsistent retail policies and practices for the duration of cut melon displays and their disposal.

Figure 18. There are many food safety risks associated with retail watermelons.

Yellow Watermelon kg
2501018005770137417
DATE : 18.04.19
EXP DATE :
(RM) KG : 4.20
WEIGHT : 1.374kg
PLU : 1018
RM 5.77
VILLAGE GROCER (AK) SDN BHD
C-9 & C-10, Level Concourse, Avenue K,
156, Jalan Ampang, 50450 Kuala Lumpur.
Tel : 03 - 2181 8399 Fax : 03 - 2181 8699
Yellow Watermelon kg
RM 6.44
Red Seedless Watermelon kg
RM 7.77

Recommendations

Supermarkets, greengrocers and retailers have equal and shared responsibility with watermelon growers and packers to provide safe watermelons to consumers. How the watermelons are handled, packaged, stored and displayed can contribute to the 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.

1. Before being cut, all watermelons should be thoroughly washed in drinking quality water with sanitiser at the appropriate concentration (e.g. chlorine at 100 ppm). During washing, the watermelons should be completely immersed in the sanitiser and the surface should be scrubbed/brushed because simply putting them in sanitiser will not remove the bacteria from the waxy layer on the surface of the watermelon skin.
2. All cutting equipment (e.g. knives) and contact surfaces (e.g. cutting boards) should be cleaned and sanitised between cutting each batch of watermelons. The cleaning methods to be used, the sanitiser and its concentration, as well as the cleaning and sanitising frequency, should be outlined in SOPs. As cross-contamination between watermelons can easily occur when knives, cutting boards or contact surfaces become contaminated, the cleaning and sanitising time and frequency should be recorded.
3. Watermelons should be cut in small batches frequently so they are not stored for long on the shelves. The longer cut watermelons sit on display shelves, the longer the bacteria on the flesh have time to increase. All cut watermelon should be wrapped in cling/shrink wrap and marked with the date and time the watermelon was cut using stamps, stickers or other methods to keep track of how long the cut watermelons sit on the display shelves. Any watermelons sitting on display shelves for an extended period need to be removed and discarded. To help isolate the contamination source should an outbreak occur, records of when the watermelons were cut and the suppliers (e.g. grower's name, address, date of harvest and lot identification) should be kept.
4. All cut watermelon should be displayed in refrigerated cases that are kept at 5 °C. Watermelon display shelves should be cleaned and sanitised regularly because cut watermelons exude juices, which can accumulate on the display shelves and become a contamination source. Watermelon juice is an ideal medium for pathogenic bacteria to grow and survive, which can then be transferred to the watermelon surface, cling/shrink wrap or the consumers, causing cross-contamination. To minimise contamination for consumers, food safety information should be provided along with antibacterial hand wash. Employees should also ensure vigilant inspection of produce to determine if consumers touch the fruit and put it back on display, or when the fruit is exposed to sneezing and coughing.
5. Any cut watermelon that is not sold on the same day it is cut should be thrown away and not stored and sold the next day. Fruit showing any signs of decay, mould or bruising should also be discarded. This is recommended as foodborne pathogens can grow on the flesh of the watermelon when stored at both refrigerated and ambient temperatures.
6. All workers should be trained in food safety, especially in handling watermelons and personal hygiene. Only trained workers should be allowed to handle and cut watermelons and gloves should be worn when doing so. All workers should be washing their hands regularly with soap and water. Workers who do not wear gloves or have inappropriate personal hygiene might come in contact with contaminated produce and then handle watermelons, contaminating them. Untrained workers might also sneeze or cough on the watermelons or their hands and then handle watermelons without taking proper food safety measures, contaminating the watermelons. Food safety information should also be provided to consumers for safe handling and consumption of cut fruit.

FOOD SAFETY RECOMMENDATIONS TO RETAILERS OF CUT-WATERMELONS

Watermelons are hand-picked, cleaned/wiped with cloths and packed in bulk bins for shipping to the markets. Retailers cut the fruit into halves and quarters for retail. In the absence of a washing and sanitisation step, the potential foodborne pathogens (e.g. *Salmonella*) present on the skin can be transferred to the flesh during cutting. The risk of cross-contamination also increases due to cutting equipment and contact surfaces. The display time and temperature for cut-watermelons are critical factors which influence the growth and multiplication of potential pathogens. We recommend the following to minimise the microbial food safety risks associated with retailing of cut-watermelons:

Wash and sanitise watermelons before cutting

- Watermelons should be thoroughly washed before cutting into halves or quarters for retail.
- Drinking quality water containing a sanitiser at appropriate concentrations (e.g. chlorine 100 ppm) should be used.
- Scrub/brush the entire fruit surface with water containing a sanitiser

Clean and sanitise cutting equipment and surfaces

- The cutting equipment (e.g. knives) and contact surface (e.g. cutting board) should be cleaned and sanitised as per a standard operating procedure (SOP).
- Frequency of cleaning and sanitisation should be mentioned in the SOP such as before and after cutting each lot of fruit.

Label cut-watermelons with date and time

- Watermelons should be cut in small batches and cutting time and frequency should be recorded.
- All cut watermelon should be cling/shrink-wrapped and labelled with **cutting time** and best before **date**.
- Advise the consumers for safe handling and consumption.

Refrigerate retail shelves

- All cut watermelon must be displayed in a refrigerated shelf at 5°C.
- The cut-watermelons may exude fruit juice during display where pathogenic bacteria can grow and multiply. Regularly clean and sanitise the display shelves.

Discard unsold cut-watermelons

- Cut watermelon that is not sold on the day of cutting should be thrown away.
- Fruit showing any signs of decay, mould or bruising should be discarded.

Train staff and consumers food safety

- Only staff trained in food safety should be allowed to handle and cut watermelons.
- Staff should wash hands with soap and water and wear gloves and other personal protective equipment.
- Food safety information should be provided to consumers for safe handling and consumption of cut-fruit.

Traceability

Product traceability is defined as the ability to identify and track the movements of a batch of produce throughout all stages of production, processing and distribution, i.e. from the farm to retailers and customers (FAO 2017). As the number of food safety crises has increased in recent years, product traceability has become more important. This has heightened public awareness of food safety and consumers are now more interested in where their food comes from and the processes involved in the supply chain (Jin and Zhou 2014). Consumers have also become more interested in where and how their food is produced, believing that food can directly affect their health (Chen and Huang 2013). Product traceability systems can reduce consumers' concern about food safety by giving them information about the products and can serve as a form of quality assurance (Jin and Zhou 2014).

Product traceability systems have already been introduced in many countries for many products. A study in Korea showed consumers were willing to pay more for products covered by the traceability system and bought large quantities (Chen and Huang 2013). Another study showed that once consumers were fully informed and understood the product traceability system, 68% were willing to pay more for their food covered by the system (Wu et al. 2011). Consumer reasons for unwillingness to buy products under the traceability system included lack of familiarity, doubts about the system, preference for quality food labels and concern about price (Wu et al. 2011).

In a good product traceability system, the whole supply chain should know where the fruit has come from and where the fruit is going in real time, not just a one step forward and one step back system. In the latter, if just one part does not correctly document their step in the supply chain, then tracing where the produce comes from can be difficult. In a system where every step in the supply chain is known, then if one part fails, the rest of the system can trace it. Although this type of traceability system would not prevent a food safety crisis, it would minimise the fallout by allowing businesses to quickly discover the cause and promptly activate the product recall. Thus the harmful consequences such as potential illness, loss of life and damage to the market can be mitigated (Chen and Huang 2013).

A good product traceability system also helps:

- efficiently track and manage inventory, saving time and reducing human error
- determine if there is an issue within the supply chain, such as if the product turns up damaged in one part, you can quickly find out where (FAO 2017)
- determine how long the product is being stored before being sold to consumers, which could affect the shelf life.

A product traceability system is an important element of a comprehensive food safety program and therefore should also be verified periodically for effectiveness. For an effective product traceability system, it is recommended that:

- you have accurate and detailed records including:
    - the contact information (e.g. names, addresses, phone numbers) for all parts of the supply chain
    - a list of the produce you provided
    - records of product delivered to recipients
    - batch or lot identification records
    - other relevant production and supply records that can assist in a food safety failure.
- you have an efficient inventory and management system where:
    - high-quality tracking software is in place
    - each watermelon should be labelled (Figure 19) with branding and provenance claims.
- you have a response plan in case of a recall
- all parts of the supply chain in the product traceability system are transparent and honest.

END-TO-END SUPPLY CHAIN TRACEABILITY

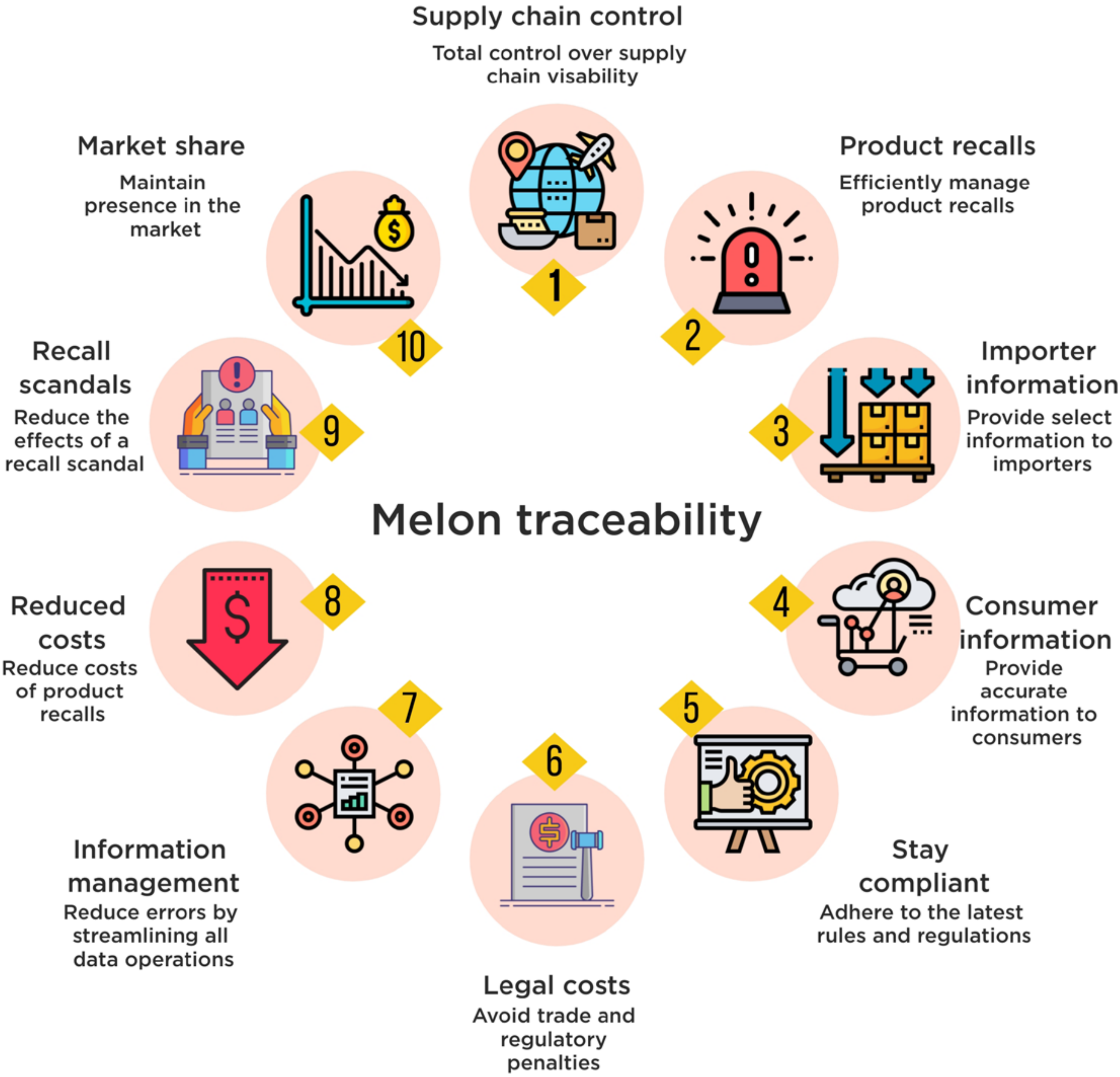


Figure 19. Labelled watermelons in Japan.

Product recalls

A product recall is a procedure involved in removing a product that is believed to be contaminated or faulty from the market at any stage of the supply chain, including when the product is possessed by consumers (FAO 2017). This process is vital to consumers and businesses and can be activated for multiple reasons such as cross-contamination, public health risks, inaccurate food preparation instructions, material tampering, inadequate shelf-life, inadequate food safety protocols and improper packaging or labelling.

To be prepared for food safety outbreaks, each farm should have a recall strategy containing:

- documented procedures to be implemented if a recall is required
- management plan with the contact details of a designated recall team who can be contacted at any time
- communication plan detailing who needs to be contacted in a recall with a contact list of key regulatory officials
- contingency plans for the unexpected
- plans to safely dispose of recalled products
- a list of commodity organisations and trade association experts that could be called upon to provide technical help if needed
- written public notifications to be issued depending on the severity and classification of the recall.

The recall strategy should be revised and practised at least once a year. If improperly managed, product recalls can lead to long-term damage to the brand and industry reputation with stakeholders, consumers, customers, shareholders and regulators. With a proper recall program in place, the size and effect of a recall can be minimised as the specific cause and the affected produce can be identified and located quickly. A proper recall program can be the difference between recalling a batch and needing to do an industry-wide recall.

TRACEABILITY IN MELON SUPPLY CHAIN

Traceability refers to the ability to follow the movement of any food through all stages of production, processing, transportation, distribution and retail. Currently it is required to be able to track any produce movement one step backward and one step forward at any point along the supply chain.

Improving traceability through the supply chain maintains and enhances consumer and government confidence, supporting industry's commitment to food safety. It limits the scope and cost of recalls to suspect product only, reducing impact and disruption on the industry's investment and allowing non-implicated product to remain in distribution. A robust traceability system also allows for more efficient investigations, expediting tracking while minimising business disruptions and costs.

Critical tracking events (CTE) are various points in the supply chain at which data capture is necessary to follow product movement. At each CTEs, key data elements (KDEs) must be captured to enable tracking and tracing of fruit movement throughout the supply chain.

Critical Tracking Events and Key Data Elements

Grower KDEs

- Grower name
- Farmer manager
- Melon type
- Melon variety
- Harvest date
- Harvest time
- Harvest method
- Field lot number
- Harvest lot quantity
- Harvest crew name
- Harvest crew manager
- Irrigation water source
- Irrigation water quality tested (Y/N)
- Agri-chemical spray water source
  - Drinking quality (Y/N)
  - Microbiological test results (Y/N)
- Soil amendments - raw animal manure (Y/N)
  - Type of animal manure
  - Application time and method
- Soil amendments - Compost use (Y/N)
  - Compost contain animal product (Y/N)
  - Compost source
  - Safety certification
  - Time of application

Packer KDEs

- QA manager name
- Product identifier
- Produce size
- Product quantity
- Packing lot
- Precooling (Y/N)
  - Precooling method
  - Precooling time
  - Precooling location
  - Pre-cooling temperature
- Core temperature
- Dumping (Wet/dry)
- Dump tank water
  - Source
  - Sanitiser conc
- Washing (Y/N)
  - Wash water source
  - Water pre-treatment
  - Water temperature
  - Washing method (spraybar/flume)
  - Wash water pH
- Brushing (Y/N)
  - Brushing (OH/FB/Both)
- Sanitised (Y/N)
  - Sanitiser name
  - Sanitiser concentration
  - Sanitiser contact time
- Hot water treatment (Y/N)
  - Water temperature
  - Treatment time
- Fungicide (Y/N)
  - Fungicide name
  - Fungicide conc
  - Fungicide contact time
- Individual fruit labelling
  - Automatic or manual
    - Label material
    - Label adhesive
      - Food grade (Y/N)
- Packing date
- Packing time
- Packer name
- Packer facility
- Packing lot quantity
- Pallet tags
- Shipping manifest

Distributor KDEs

- Shipping manifest
- Driver details
- Transport mode
- Pallet tags/Case tags
- Melon type
- Melon variety
- Product identifier
- Product pack style
- Produce size
- Product quantity
- Detail pallet tags on shipment
- Packing date
- Packing time
- Packer name
- Packer location
- Packing lot quantity
- Core temperature
- Humidity
- Route taken
- Movement/shock
- Pick up number
- Customer name
- Customer purchase order number
- Bill of lading number
- Shipping quantity

Retailer KDEs

- Order number
- Receiving date
- Receiving time
- Quality control information
- Melon type
- Melon variety
- Product identifier
- Shipping manifest
- Pallet tags/Case tags
- Product pack style
- Produce size
- Product quantity
- Detail pallet tags on shipment
- Packing date
- Packing time
- Packer name
- Packer location
- Packing lot quantity
- PU number
- Customer name
- Customer purchase order number
- Bill of lading number
- Shipping quantity

Consumer KDEs

- Customer purchase order number
- Melon type
- Melon variety
- Product identifier
- Product pack style
- Produce size
- Product quantity
- Shipping date
- Shipping time
- Wholesale bill of lading

Note: The list of CTEs and KDEs is not exhaustive.

Appendix 1

Cut melon retail surveys

Food Authority cut melon survey results from 2015

From January to August 2015, NSW Food Authority surveyed the cutting and wrapping practices used with watermelon, rockmelon and honeydew melons, as these are the main types of melons that are produced and consumed in Australia. The survey also noted the display conditions and observed that most major supermarkets and greengrocers did not display cut watermelon under temperature control or refrigerated conditions (NSW Food Authority 2017).

Samples (n=191) were collected to test if there were any foodborne pathogens present on cut melons and papaya. One watermelon sample tested positive for *Escherichia coli* and neither *Listeria monocytogenes* nor *Salmonella typhimurium* were detected in any watermelon samples.

Standard plate counts (SPC) were also taken and only two watermelon samples had an SPC below detection levels. Most samples collected had an SPC between 1,000 and 100,000 cfu/g, with a few having the maximum SPC quantification levels of 30,000,000 cfu/g.

All melon samples were collected during summer, which would increase the ambient temperature of the watermelons displayed in areas with no temperature control. The survey noted that this would cause higher bacterial growth rates on the watermelon surface, whereas if the melons were tested during winter, lower bacterial growth rates would be expected.

It was difficult to determine how long before purchase the samples were cut and displayed. Only a few stores had a date marked on the fruit to show when they were cut but not the time. Most greengrocers stated the melons were cut on the same day they were sold, but there were a few who had stored unsold melons overnight in a cool room and sold them the next day. When asked how the greengrocers' employees determine if the product is still safe for sale, all indicated that a visual inspection was carried out. No major supermarket kept leftover fruit.

Many stores indicated the melons were only washed if they appeared dirty and none of those surveyed used detergent or sanitiser when washing the melons. If the melons were washed, they were then dried with a cloth or paper towel before being cut or displayed. The melons were cut with a knife, usually with a plastic handle and a plastic chopping board. The knife and chopping board were sanitised by most supermarkets and greengrocers but none were sure if they cleaned the knife and board between cutting each fruit, at the end of the cutting period or the end of the day. There were a few stores that did not use any detergent or sanitiser to clean the knife and chopping board and most stores did not know the distinction between detergent and sanitiser.

NSW DPI cut melon survey results from 2020

To understand the retail food safety practices we surveyed 41 supermarkets and greengrocers. Most watermelons were cut into halves or quarters and displayed at either ambient or cold conditions. The potential food safety issues during retail of cut watermelon included:

- no washing and sanitising step before cutting into halves or quarters
- irregular cleaning and sanitisation schedules for cutting equipment and surfaces
- improper labelling without detailed information on cutting date and time or best before date
- cut watermelons were displayed in ambient conditions
- refrigerated shelves were inadequately cooled

Some key observations from the survey included:

- most (94%) retailers did not wash or sanitise fruit before cutting
- most (88%) retailers claim to clean and sanitise cutting equipment and surfaces, however, do not have a regular sanitisation schedule
- 17% of retailers used some form of labelling on cut melons
- 56% of retailers displayed cut melons at ambient conditions
- 95% of retailers cut fruit in small batches to sell on the same day.

Retail conditions are critical to the food safety of cut melons. Displaying cut melons at ambient conditions is still a common practice. The cut melon pulp temperatures recorded at the retail outlets revealed that the fruit were either not properly cooled before cutting or retail shelves were not maintained at 5 °C. In the cut melon survey, 56% (251) of samples were collected from ambient fruit displays with 44% (197) collected from cold or refrigerated displays. Fruit pulp temperatures recorded at the retail displays showed a great variation across the stores. Even refrigerated shelves were not maintained at 5 °C. Higher total plate counts have been observed in samples collected from ambient display in retail stores.

To further investigate the potential food safety risks associated with the cut melons, we collected 448 samples (252 watermelons, 123 rockmelons, 65 honeydews and 8 specialty melons) from October to April 2020 from various supermarkets and retails stores. None of the samples tested positive for target pathogens such as *Listeria monocytogenes*, *Salmonella species* and *E. coli* O157:H7. The data suggested that microbiological quality of cut melons was good, but the growers and retailers should continue to manage food safety risks with a higher degree of precaution while producing and retailing the product.

Our laboratory experiments showed that retail display temperature and duration influence the survival and growth of foodborne bacterial pathogens on cut melon surfaces. The data suggest prolonged display of potentially contaminated cut melons can lead to growth and proliferation of bacterial pathogens (*Salmonella* spp. and *Listeria monocytogenes*) faster at ambient conditions compared to cold or refrigerated conditions.

Watermelon retail food safety practices

A total of **41** retailers were surveyed including

28 supermarkets (68.3%)

13 green grocers (31.7%)

94% of retailers **DO NOT** wash fruit prior to cutting

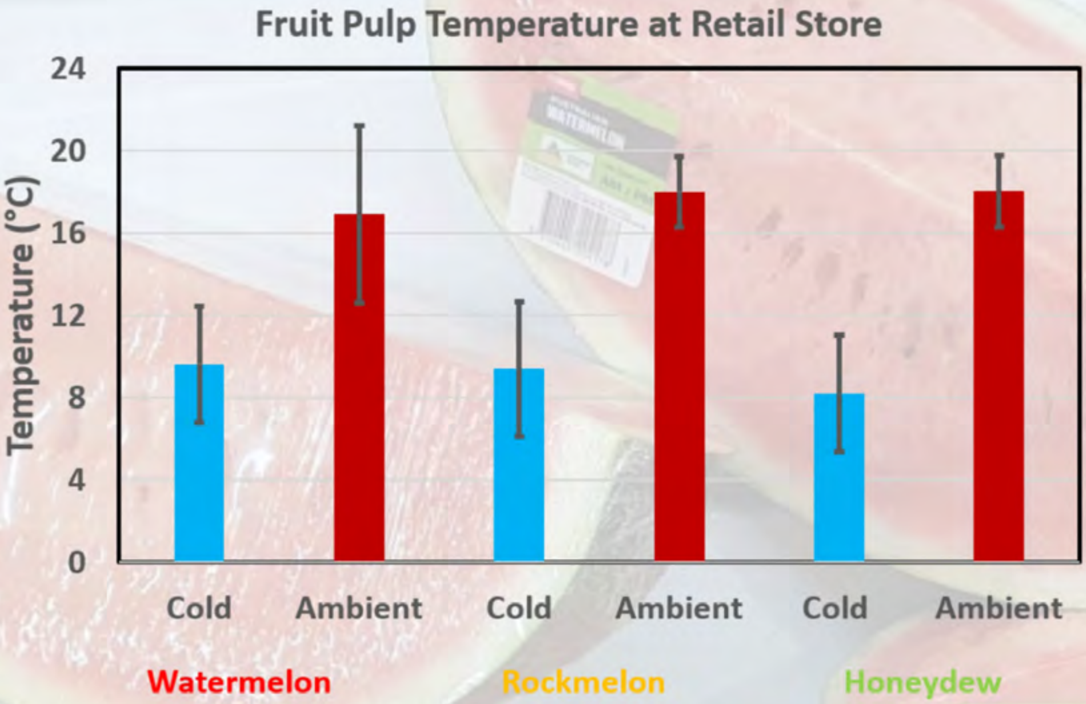
88% of retailers clean/sanitise cutting utensils before use

17% of retailers are using date marking to monitor the sales of cut melons

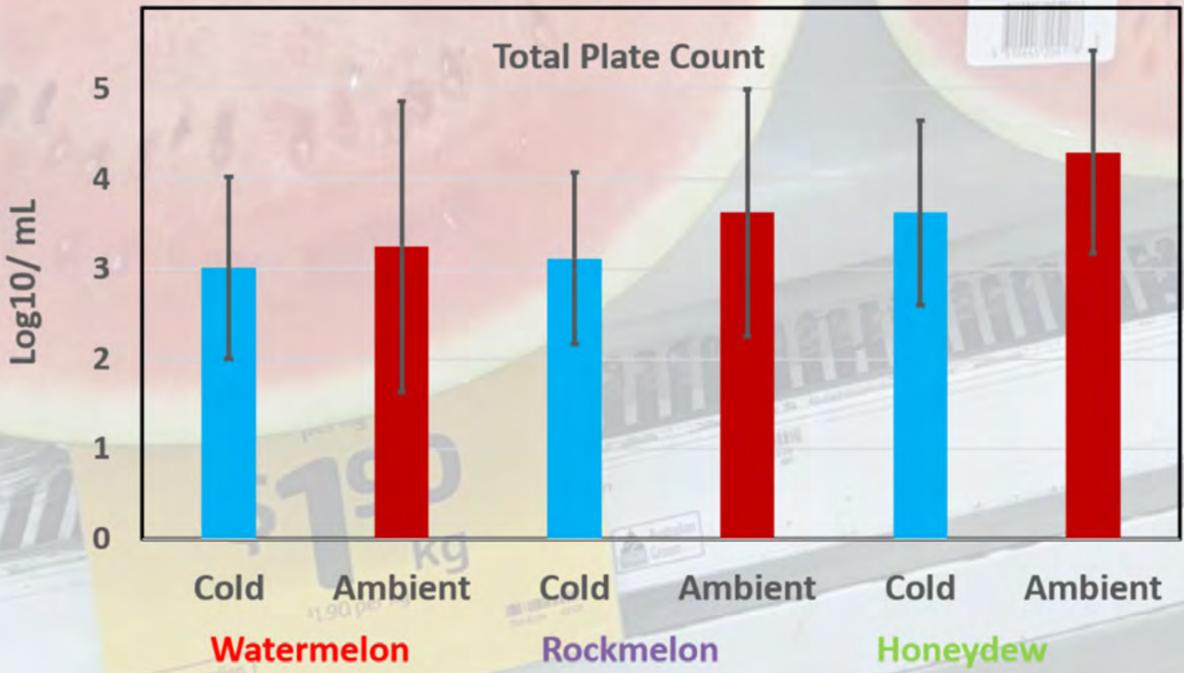
95% of retailers sell cut melons on the same day as they are cut

A snapshot of current retail conditions of cut melons

Retail conditions are critical to the food safety of cut melons. Displaying cut melons at ambient conditions is still a common practice as evident from the data. In our cut melon survey, 56% (251) of samples were collected from ambient fruit displays with 44% (197) collected from cold/refrigerated displays. Fruit pulp temperatures recorded at the retail displays showed a great variation across the stores. Even refrigerated shelves were not maintained at 5°C as shown in the figure below:



Higher total plate counts have been observed in samples collected from ambient display in retail stores as shown in the figure below:



Cut-melon food safety surveillance

A total of **448** samples collected

56% of samples collected from **ambient** displays (251)

44% of samples collected from **cold/refrigerated** displays (197)

Zero samples tested positive for all target pathogens :

- *Salmonella* species
- *Listeria monocytogenes*
- *Escherichia coli* O157:H7

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Watermelon food safety guide

Department of Primary Industries

Hort Innovation
Strategic levy investment

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