AUSTRALIAN PASSIONFRUIT **Postharvest Best Practice Guide**

Hort Innovation
Strategic levy investment

PASSIONFRUIT FUND

Contents

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01. Introduction

Consistent retail quality is essential in order to satisfy consumers. However, maintaining quality of passionfruit after harvest can be challenging. Despite their sturdy appearance, passionfruit are fragile fruits that easily lose moisture, are susceptible to disease and rapidly deteriorate after harvest.

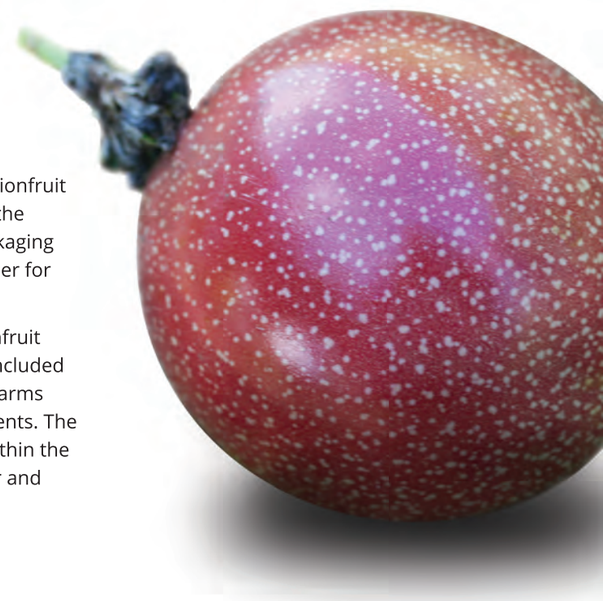
Passionfruit are produced from northern NSW right up into the far, wet tropics of northern Queensland. Most passionfruit farms are relatively small, family operations with basic packing facilities. Many do not have cold rooms, relying on centralized depots to cool fruit. However, trucks carrying mixed loads have limited capacity to adapt to the specific needs of passionfruit. Moreover, relatively long transport times are often required in order to reach consumers in southern markets.

Fruit which has not been grown, picked and packed well is therefore poorly equipped to face the challenges of extended transport and marketing.

The fruit faces other issues too. Volatility in supply and, therefore, prices, is an ongoing issue for growers and marketers alike. Managing harvest and extending storage could help flatten some of the peaks and troughs in the volumes of fruit arriving at wholesale markets. Increasing consistency of supply through improved postharvest management would help to market fruit better as well as improve returns for growers.

Maintaining passionfruit quality through the supply chain starts with growing a good quality product in the orchard. Well managed harvest, cooling and packing operations will ensure passionfruit stay in good condition right up until they reach the retail shelf. Postharvest treatments such as packaging and waxing can also help passionfruit stay fresher for longer.

This guide summarises best practice for passionfruit supply chains. Wherever possible, options are included to suit both larger operations and small family farms with limited capacity for postharvest improvements. The key issue is to understand what is happening within the fruit once it is detached from its source of water and nutrients and starts its journey to market.



02. **Pre-harvest**

*Postharvest handling can only deliver high quality fruit if it is grown well from the start. Only a healthy plant will produce quality fruit with maximum shelf life. Plant nutrition, variety and climate all influence the rate of fruit growth and maturation, as well as susceptibility to breakdown during storage and transport. Detailed information on passionfruit production is included in **The Passionfruit Growing Guide** by Peter Rigden (2011), copies of which are available from Passionfruit Australia Inc. This section therefore highlights just a few of the key areas where pre-harvest management affects postharvest fruit quality.*

VINE NUTRITION

Healthy soils and well-nourished plants produce the best quality fruit. Maintaining a biologically active soil helps suppress plant diseases as well as store and cycle water and nutrients. Fertilisers improve yield and quality. However, over-fertilising can increase fruit acidity.

BEST PRACTICE

- ✔ **Well-nourished, healthy plants produce the best fruit**
- ✔ **Leaf analysis can help determine whether the elements that are key to producing good quality fruit (nitrogen, potassium, calcium and boron) are within recommended ranges**
- ✔ **Soils should be somewhat acidic, with pH below 6.5, but above 3.5**
- ✔ **Optimise irrigation to prevent either too little or too much water**
- ✔ **Good pollination is essential to maximise yield and quality; the amount of pollen deposited on flowers directly relates to size and pulp content**
- ✔ **Encourage bees into the orchard and avoid using pesticides that could harm potential pollinators**
- ✔ **Implement a pre-harvest disease management program that includes products with different modes of action**
- ✔ **Practise good orchard hygiene, destroying rotting fruit and ensuring there is good air circulation around the vines**

Nitrogen

Nitrogen fuels vegetative growth. As flowers are produced in the leaf axils, plants with strong vegetative growth can also potentially produce the most fruit. However, nitrogen is very mobile in the soil and easily leached, especially if there is heavy rainfall. For this reason, it is best applied frequently in small quantities. For example, some agronomists recommend application through fertigation every 2 to 4 weeks.

The form of nitrogen may influence fruit quality. Japanese researchers have found that applying nitrogen as ammonia (e.g. sulphate of ammonia) rather than nitrate (e.g. calcium nitrate) resulted in sweeter fruit. Urea is usually the cheapest way to add nitrogen, but must be well watered in to avoid losing nitrogen to the air as ammonia gas.

Potassium

Like nitrogen, potassium is essential for passionfruit vine health and productivity. Potassium is a major component of fruit; Rigden (2011) estimates that 4.3kg of potassium is removed for every tonne of fruit production, compared to 3.3kg of nitrogen and 0.3kg of phosphorus. Providing adequate potassium is essential for good fruit production. Increasing levels of potassium increase fruit weight, rind thickness and Vitamin C content.

However, excess potassium inhibits the uptake of calcium, which is also essential for good fruit quality. It can also result in more acidic fruit.

Potassium is very mobile in both plant and soil, so easily leached under heavy rainfall. Like nitrogen, potassium is best applied in small amounts at 2 to 4 week intervals, with the most frequent applications during peaks in fruit development.

Calcium

Calcium is critical to the strength of cell walls. High levels of calcium are widely associated with improved postharvest quality for many fruit. Increased calcium has been reported to slow ripening, inhibit disease and improve saleable life of fruit such as avocados, papaya and apples.

Calcium moves through the plant in the xylem (water holding) vessels. Movement is passive, depending on the rate at which transpiration is pulling water from the roots to the expanding leaves and fruit.

Calcium deficiency causes the disorder 'blossom end rot' in fruit such as tomatoes and capsicums. This is due to the collapse of rapidly dividing cells within the expanding fruit. Blossom end rot usually occurs because of high humidity, which reduces transpiration rates to the point where calcium cannot be transported to where it is needed. Calcium deficiency also occurs due to low calcium levels OR excess potassium and magnesium in the soil.

As passionfruit mature, transpiration rates decrease. It is therefore essential to have adequate levels of calcium available in the soil when fruit first form, as this is when they accumulate enough calcium to support later development. Foliar applications of calcium are often found to be ineffective at raising calcium levels in fruit. This is because calcium moves through the water stream; fruit are supplied with water by the roots, not the surrounding leaves.

Calcium can be applied as gypsum (calcium sulphate), lime (calcium carbonate), dolomite (calcium magnesium carbonate) or cal-nitrate (calcium nitrate/ calcium ammonium nitrate). Both lime and dolomite increase soil pH, whereas gypsum does not. Calcium is relatively immobile and insoluble, so is best applied during spring and/or at the end of the dry season, as rain helps incorporate it into the soil (Rigden, 2011).

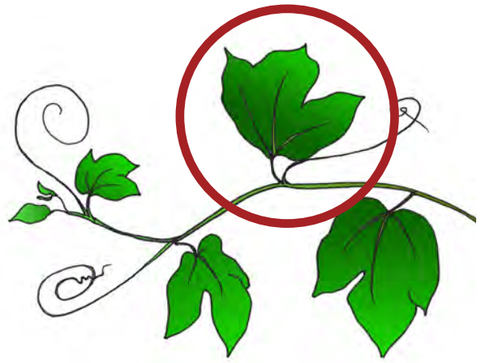
Leaf tissue analysis

Leaf sampling is generally conducted during cooler months, when development has slowed. Take leaf samples from representative vines spaced around the orchard. Select the last fully expanded leaves from healthy shoots. These are usually the fourth to eighth leaf from the growing tip. Keep cool until ready to send for analysis. Optimum leaf nutrient ranges for passionfruit are reproduced from Rigden (2011) in the table below.

Optimum leaf nutrient levels, using the youngest fully expanded leaf

	NUTRIENT		OPTIMUM RANGE	NOTES
MACRONUTRIENTS	N	Nitrogen	4.25 to 5.25%	Essential for growth but easily leached
	P	Phosphorus	0.25 to 0.35%	Passionfruit have low requirements for P
	K	Potassium	2.0 to 3.6%	May be low due to leaching, insufficient fertiliser or competition with Ca or Mg
	Ca	Calcium	1.0 to 2.5%	Uptake reduced if soils are acidic, lacking Ca or have excess Mg or K
	S	Sulphur	0.2 to 0.6%	Rarely deficient
	Mg	Magnesium	0.3 to 0.5%	Deficiencies most likely in leached, acidic, sandy soils
MICRONUTRIENTS	B	Boron	40 to 60mg/kg	Boron must be managed carefully to avoid both deficiency and toxicity
	Cu	Copper	5 to 20mg/kg	Copper sprays for disease control usually add sufficient Cu
	Fe	Iron	100 to 200mg/kg	Rarely deficient
	Mn	Manganese	50 to 350mg/kg	Rarely deficient
	Zn	Zinc	>50mg/kg	Low levels are common in sandy soils
	Na	Sodium	<0.15%	If high levels are detected, check irrigation water EC

MOST IMPORTANT FOR FRUIT QUALITY

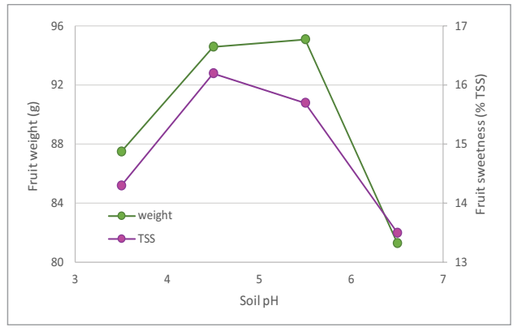


Test the youngest fully expanded leaf.

SOIL PH

Soil pH greatly influences the ability of the plant to take up essential nutrients. Strongly acidic or alkaline soils limit nutrient availability. For example, both N and P are most available if soil has a neutral pH (pH 6.5 to 7.5). Potassium is limited by pH below 5.5 whereas boron is equally available between pH 5 and 7.5.

Passionfruit prefer a somewhat acidic soil. Rigden (2011) recommends soil should have pH 5.5 to 6.5 (measured using a water based test). However, new research (Niwayama and Higuchi, 2019) suggests that even lower pH may be beneficial to fruit quality. Purple passionfruit growing in soils adjusted to pH 4.5 and 5.5 were larger, heavier, more strongly coloured and sweeter than fruit grown at pH 3.5 (strongly acidic) or pH 6.5 (very slightly acidic). Fruit grown under relatively neutral soil conditions tended to have more acidic juice and were relatively pale and thin skinned, increasing shrivel. Nitrogen fertilisers tend to reduce soil pH, whereas lime and dolomite applications increase pH.



Effect of soil pH on quality attributes of hybrid purple passionfruit cv. Summer queen. Data from Niwayama and Higuchi, 2019.

Irrigation

Passionfruit have a relatively high water requirement. While wilting is an obvious sign of water stress, fruit quality and yield are dramatically affected well before wilting occurs. However, too much water can also have negative impacts. It is important to get irrigation right, especially when fruit are forming. During this time, plants must be irrigated enough for calcium to be transported through the xylem vessels to the developing fruit.

TOO LITTLE WATER

- Reduced uptake of calcium and boron
- Reduced flowering and fruit set
- Small fruit with low pulp content
- Premature fruit drop

TOO MUCH WATER

- Anaerobic soil, reducing vine health
- Increased root rots e.g. Phytophthora, which can infect fruit
- Leaching of nitrogen and potassium
- Increased susceptibility to disease

Monitoring soil moisture is the best way to determine how much irrigation is required and when. Tensiometers are relatively cheap, can be accurate in sands, and work well so long as soils remain relatively moist. More sophisticated tools such as the WildEye® (Time Domain Reflectometry - TDR) or EnviroScan® (capacitance) are used to monitor soil moisture in the root zone, with information provided via a web or app based interface.

Passionfruit are very sensitive to salinity, so it is also important that water is good quality. Mulching can help to reduce water use, as well as providing benefits in terms of weed control, reduction in root diseases and improved nutrient uptake.

Comprehensive information on irrigation for passionfruit is included in **The Passionfruit Growing Guide**. A range of fact sheets are also available through the Growcom website.

Flowering and pollination

Passionfruit are long day plants, meaning most flowers form when days are more than 11 hours duration. Flowering tends to concentrate in spring and autumn. Buds form between 15 and 30ºC, so high temperatures during summer can inhibit flowering.

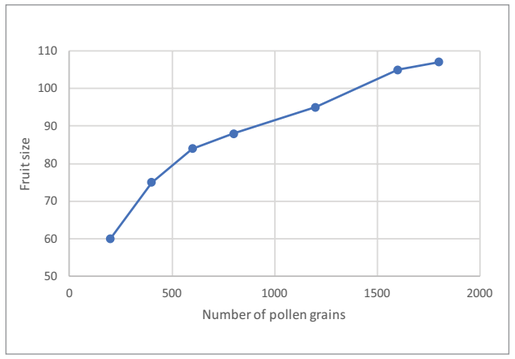
Both purple passionfruit and Panama varieties are self-compatible, meaning the flowers can be fertilized by their own pollen. However, the pollen sacs are positioned below the stigmas, meaning that pollen cannot naturally fall onto the receptive part of the flower. Cross pollination between different plants is likely to maximise fruit set and yield.

As passionfruit pollen is heavy and sticky, flowers are rarely fertilized by wind. Instead honeybees, native bees (e.g. carpenter bees), flies and other insects transfer pollen between flowers. Flowers are most receptive about an hour after they open, remaining receptive for only a few hours. If it rains within two hours of pollination the pollen is destroyed.

The amount of pollen deposited on the stigma directly affects fruit set, fruit weight and pulp content.

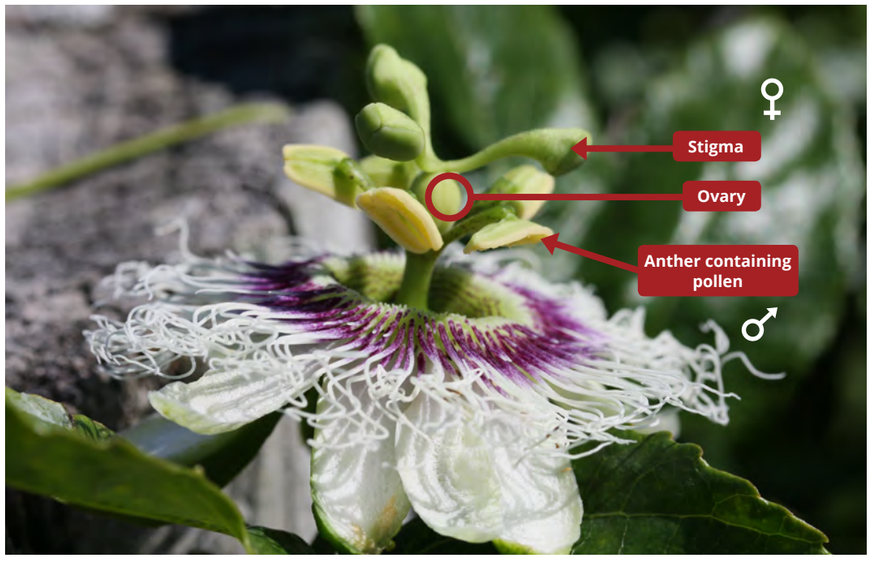
Hollow fruit are the results of poor pollination. Achieving thorough pollination is therefore essential to produce good quality, well-filled fruit.

- Encourage native bees, e.g. carpenter bees, into the orchard by providing nesting sites such as old logs
- If honeybee hives are available, locate them nearby to ensure a good bee population
- Avoid spraying insecticides that affect pollinators
- Plant windbreaks; wind not only physically damages vines and causes wind-rub blemishes on fruit, it discourages foraging by bees.



Relationship between the amount of pollen deposited on the flower and the size of the resulting fruit. Derived from Akamine and Girolami, 1959.

Fully pollinated and poorly pollinated fruit cv. Misty Gem



Structure of a passionfruit flower

DISEASE MANAGEMENT

Passionfruit are affected by numerous pre-harvest diseases that affect fruit quality. The most serious are alternata/brown spot *(Alternaria alternate and Alternaria passiflorae* respectively) which cause major fruit loss during the warm, wet periods from October to April; and anthracnose (*Colletotrichum gloeosporoides*), which is most severe in cool, wet periods.

Diseases occurring in the field directly affect fruit quality. Even if symptoms are minor at harvest, diseases continue developing during storage and transport. Weight loss is increased, and large, sunken lesions may form.

An effective disease management program is essential to producing high quality fruit. Fungicide programs involving products with different modes of action are most likely to be effective. A range of fungicides are registered for use on passionfruit, including azoxystrobin, pyraclostrobin, iprodione, mancozeb, phosphonic acid and a range of copper products. Check the APVMA or Infopest websites to confirm registration of specific products.

Strobilurin fungicides (e.g. azoxystrobin) are very effective and, unlike protective fungicides (e.g. copper based products), are partially mobile within the plant. However, the risk of resistance developing is high. To manage this risk:

- Start the cropping cycle with a different product
- Do not use more than twice consecutively
- Only use a strobilurin for (maximum) one in every three fungicide applications
- Do not apply more than five times annually.

Maintaining good orchard hygiene is another way to reduce disease pressure on fruit:

- Ensure there is good air circulation, keeping the canopy open by training and pruning vines
- Do not allow ground covers to smother vine bases
- Regularly clean any cutting tools used to trim plants with an appropriate disinfectant, such as bleach (100ppm chlorine)
- Control insects such as fruit spotting bug and fruit flies, as damage provides entry points for rots
- Healthy plants are more disease resistant; practices that improve vine health will help reduce the impact of diseases.

Small spots of disease observed in the field (left) can continue to develop after harvest, having major negative effects on fruit quality (right).

03. Harvest

Purple passionfruit are usually harvested after natural fruit drop. This ensures they have reached optimum maturity, developing the best possible colour and flavour. However, this creates challenges for the supply chain, as it can be difficult to predict precisely when this will occur. Once fruit drop, they must be picked up immediately to avoid sunburn and reduce the risk of shrivelling and disease. Panama passionfruit are picked directly from the vine when heavy and fully coloured. Purple passionfruit can also be harvested directly from the vine, especially if allowed to complete ripening under controlled conditions.

HOW AND WHEN TO HARVEST

Passionfruit are classified as a climacteric fruit. That is, ripening occurs in response to ethylene gas, and is accompanied by a large increase in respiration rate. Ripening can be triggered by ethylene in the external environment as well as through production by the fruit itself. Fruit start to produce ethylene once they are physiologically mature, while still attached to the vine.

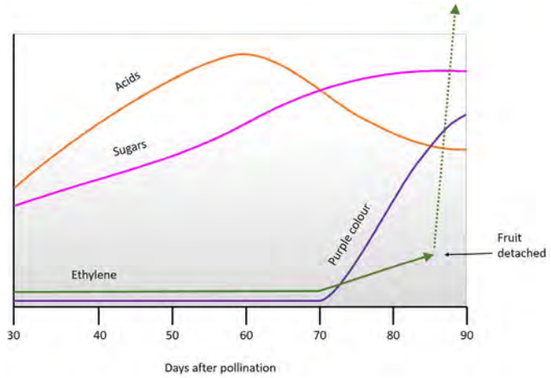
Ethylene stimulates changes in colour and flavour, as well as eventually causing fruit to detach from the vine. Passionfruit can be picked once ¾ coloured, without affecting flavour or colour. The stem should break easily at the natural joint above the fruit, or fruit can be snipped from the vine with a piece of stem attached.

Never pull fruit directly from the vine, as this creates an open wound. Wounds not only allow rots to develop, but increase moisture loss and shrivelling.

Under some circumstances, picking directly from the vine rather than allowing fruit drop, may optimise fruit quality. However, both methods have advantages and disadvantages. Combinations of picking up dropped fruit and harvesting mature fruit directly from vines may provide the best results.

BEST PRACTICE

- ✔ **For purple varieties, both picking up dropped fruit and harvesting directly from vines have advantages and disadvantages; either method may be used depending on circumstances**
  - **If picking up dropped fruit, maintain good ground cover to provide cushioning and avoid contamination**
  - **Pick up regularly to reduce the risk of sunburn and decay**
- ✔ **Panama varieties must be harvested directly from the vine**
- ✔ **Never pull fruit directly from vines, but either clip or snap at the natural joint in the fruit stem**
- ✔ **Harvested fruit should be picked while cool, kept shaded at all times and transferred to the packing facility as soon as possible**



Changes in sugars, acids, colour and ethylene production during maturation of passionfruit. Initiation of ethylene production triggers changes in colour and flavour. Ethylene production increases more than 20x once fruit detach from the vine. Derived from Shiomi et al., 1996.

If picking up dropped fruit:

- Maintain good groundcover – don't let fruit fall onto dirt
- While moving through the orchard, shake the trellis to release fruit caught up in the vines or about to naturally detach
- Aim to pick up while temperatures are cool, such as during the early morning
- Pick up daily, or even twice daily, during hot weather to avoid sunburn; do not leave dropped fruit in the sun during the middle of the day
- Note that fruit will roll into the row centres if plants are mounded, increasing sunburn risk

Overhead pergola systems and A-frames provide shade for dropped fruit.

Purple passionfruit can be harvested once 3/4 to fully coloured (top left). Fruit picked while half coloured (top right) will fail to develop maximum colour and flavour.

Purple passionfruit with mature vines growing on vertical trellis systems can be allowed to drop naturally then picked up from the ground (left) whereas Panama types grown on overhead trellises need to be harvested directly from the vines (right)

Advantages and disadvantages of different harvesting methods for purple passionfruit

	ADVANTAGES	DISADVANTAGES	WHEN TO USE
PICK UP DROPPED FRUIT	Fruit are fully ripe and ready to eat at harvest Quick and easy Can start before dawn (when the weather is cool) No damage to vines	Fruit may have reduced quality and storage life due to damage, disease or sunburn Reduces ability to plan transport and marketing	Mature vines Cool or overcast weather Overhead pergolas and A-frames where there is cushioning, groundcover
HARVEST DIRECTLY FROM VINES	Maximises storage life Avoids damage Avoids contamination from the ground Prevents fruit sunburn Can be scheduled, allowing more efficient transport and marketing	Fruit may not be fully ripe at harvest Searching for fruit can damage vines, especially the growing tips Harvest workers must be trained Needs to be done during daylight	Panama types e.g.. Pandora, McGuffies red Young vines If sunburn is likely (e.g. single wire systems during hot weather) If there is bare soil under vines

MANAGING HARVEST

Once passionfruit have detached from the vine, ethylene production increases by 10 to 20 times. There is some evidence this burst of ethylene can trigger other maturing fruit to drop, also. This may explain why, at times, fruit drop all at once.

Remember that passionfruit are alive and respiring. This means they are consuming oxygen and releasing carbon dioxide, fueling their ripening processes. However, once fruit have detached from the vine they are reliant on stored energy reserves to stay in good condition.

Keeping harvested fruit as cool as possible is essential to slow down the inevitable processes of deterioration, shrivelling and decay.

- Pick passionfruit in the coolest part of the day
- Keep harvested fruit shaded at all times
- Transfer harvested fruit to the packing shed as soon as possible.

Covers can be installed on bins to help keep fruit cool during harvest.

04. Postharvest handling and treatments

BEST PRACTICE

- ✔ Ideally, fruit should be packed and cooled on the same day it is harvested
- ✔ If fruit is to be packed at a later date, then measure pulp temperature:
  - If fruit is hot (>30ºC) then immediately cool below 15ºC, preferably using a forced air systemy
  - If fruit is warm (20 to 30ºC) then place in a cold room
  - If fruit is already **cool** (<20ºC), keep shaded and protected
- ✔ Forced air systems cool passionfruit rapidly, avoid condensation and reduce total moisture loss compared to room cooling
  - Simple forced air systems can be constructed for bins placed in a standard cold room
- ✔ As passionfruit are one of the highest ethylene producers of all fruit, attempting to reduce ethylene levels during storage is difficult and unlikely to increase storage life
- ✔ Wash water must be clean, with a sanitiser added if water is recirculated instead of run to waste
- ✔ Any remains of the flower must be removed and fruit dried before packing
- ✔ Waxes can add a glossy appearance to fruit and delay weight loss and shriveling, but the effects will depend on the variety and growing conditions
- ✔ Cooling is the best way to reduce moisture loss

Once climacteric fruit such as passionfruit start to ripen, the process can be slowed, but not stopped. Attempting to prevent ripening once it has started can reduce the quality of the ripe fruit, as it interrupts normal changes that occur. Slowing ripening is particularly difficult for passionfruit as they are one of the highest ethylene emitters of all fruit. They are also susceptible to rots and lose water easily. Passionfruit must, therefore, be handled carefully to maintain postharvest quality.

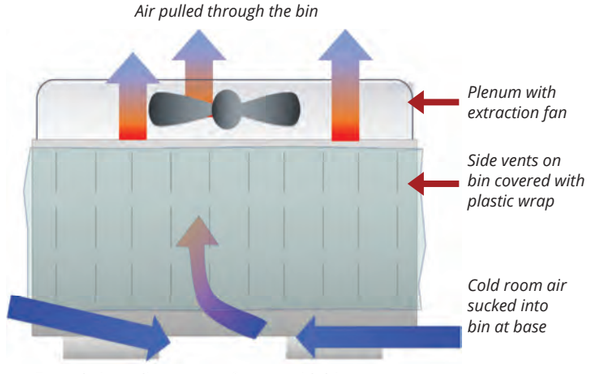
PACKHOUSE RECEIVAL

Whenever possible, fruit should be packed and cooled on the same day it is harvested.

If fruit is to be packed immediately, then it can be cooled after packing.

If fruit is going to be packed later, then actions depend on fruit temperature:

- If fruit is **hot** (>30ºC pulp temperature), then immediately cool below 15ºC, preferably using a forced air system, and pack within 2 days
- If fruit is **warm** (20 to 30ºC pulp temperature), then place in a cold room and pack within 2 days
- If fruit is already **cool** (<20ºC pulp temperature), and overnight temperatures are below 25ºC, then keep shaded and protected from wind and pack the next day



Forced air cooling system for use with bins

If cool room facilities are unavailable, placing damp hessian sacking on top of bins can help keep fruit cool and increase humidity inside the bin.

Cooling fruit

Simply placing a bin (or pallet) of fruit in a cool room does not make it cold. Cooling rates of full bins can be very slow, even if there is good air circulation within the room. Bins have a small surface area compared to their volume, and it is only at the surface that heat can move out of the fruit and into the surrounding air.

Though the top layer cools, fruit in the centre may take hours or even days to cool to room temperature. Cooling rates are even slower if fruit is in unvented wooden bins rather than vented plastic bins.

One way to increase the effective surface area is by using a forced air cooling system. If only 1–3 bins are to be cooled at a time, this can be done easily within an existing cold room. A fan (such as an old cold room fan or industrial fan) needs to be mounted onto a plenum which covers the top of the bin. Blocking the side vents of the bin will increase the efficiency of the system. The cold room air can be pulled through the harvested fruit. This method can cool fruit up to 10x faster than simply placing the bin in the cold room.

Slowing ripening

Ripening is triggered by ethylene gas. Ethylene is active at very low concentrations, usually expressed as parts per million (ppm). Only 0.1 to 1ppm (0.00001 to 0.0001%) can trigger ripening in many fruit. Ethylene can come from the external environment (other fruit, decaying vegetation, petrol engines) or be produced by the fruit itself.

Passionfruit have extremely high rates of ethylene production. The majority is produced by the seeds and pulp inside passionfruit rather than the outer rind. As a result, the fruit can accumulate very high internal levels of ethylene during ripening. For example, whereas rockmelons may accumulate up to 8ppm ethylene in the internal seed cavity and tomatoes up to 30ppm, passionfruit have recorded internal concentrations of over 500ppm!

There is a range of devices that can remove ethylene from the storage environment. These generally involve oxidizing ethylene using potassium permanganate contained inside air filters, trapping ethylene with materials incorporated into plastic films or reacting the ethylene with ozone. Such devices have been shown to be effective for a range of other types of fruit during cold storage.

However, keeping ethylene below physiologically active levels during passionfruit storage is extremely difficult. It may also have little effect on passionfruit storage life and quality, as significant ethylene concentrations are still likely to accumulate inside the fruit.

Installation of ethylene removal devices in cold rooms and/or use of ethylene absorbing packaging materials therefore seems unlikely to provide value for money.

The best way to slow ripening is by managing temperature

Threshold concentrations of ethylene, and maximum rates of ethylene production during ripening, for various fruits. Data from Reid, 2002, and other sources.

	Threshold concentration for ripening/decay (ppm)	Maximum ethylene production during ripening (µl C_2H_4/kg.h)
AVOCADO	0.1	100 – 350
BANANA	0.1 – 1.0	8 – 12
CITRUS	0.1	0.1
MANGO	0.1 – 0.4	5 – 10
PASSIONFRUIT	**Unknown**	**370 – 1,000**
ROCKMELON	0.1 – 1.0	80 – 150
TOMATO	0.5	5 – 20

WASHING

Fruit must be washed if they have been contaminated by dust in the growing environment or soil adhering after ground harvesting.

It is essential that wash water is clean. Dirty water can not only result in human pathogens contaminating the fruit, it can also spread diseases, increasing postharvest rots.

- Single use wash water does not need to contain a sanitiser, but should be clean i.e. drinking water quality
- If wash water is recirculated, it must contain a sanitiser such as 50-100ppm chlorine (0.01% active ingredient). Note that chlorine is ineffective at pH>7.5 and is rapidly de-activated if the water is dirty.

MANAGING DISEASE

The best way to control disease postharvest is by avoiding pre-harvest infection.

There are no registered postharvest fungicides for passionfruit. There is some evidence of hot water dips reducing disease (e.g. 4 minutes in 47°C water), but these have not been tested in the Australian environment.

To reduce risk of disease:

- **Always ensure that any dried remains of the flower are removed before packing**
- Use fans during packing or storage to help dry fruit that have been harvested while wet due to rain or dew
- Avoid packing wet fruit
- Do not store under saturated humidity e.g. in sealed plastic packages, as this encourages growth of surface mould.

WAXES AND COATINGS

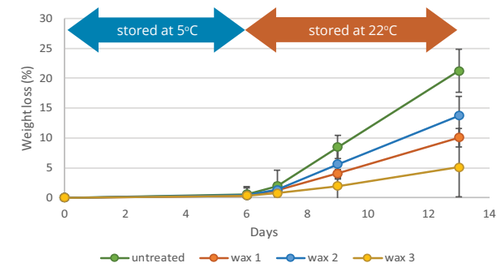
Waxes can add an attractive gloss to fruit as well as delay shriveling. However, it is important that waxes are correctly applied; thick waxes can inhibit gas exchange between the inside and outside of the fruit, resulting in development of off flavours.

Recent research indicates that waxes may be more effective at preventing weight loss and shrivel for cv. Misty Gem than for cv. Sweetheart. An example is shown below for cv. Misty Gem fruit; although effects of waxing were similar, cv. Sweetheart fruit lost relatively more weight in all cases. It can be seen that very little weight loss occurred during cold storage. However, once fruit were transferred to simulated retail display, weight loss and shrivel rapidly accelerated.

In this trial, waxes 1 and 2 both provided acceptable results. The wax gave the fruit an attractive appearance and shrivel was both delayed and less severe. In contrast, although wax 3 was the most effective at preventing weight loss, it resulted in off flavours. Large, sunken lesions appeared on some fruit, possibly due to ammonia content in the wax.

In summary, waxes can delay shrivel and extend acceptable life of passionfruit. However, effectiveness is likely to vary between varieties and possibly between regions. It is strongly recommended to test wax suitability on a batch of typical fruit before applying more widely.

It should also be noted that **controlling temperature is a highly effective way to reduce moisture loss and shrivel.**



Effect of waxing on weight loss of passionfruit cv. Misty Gem during cold storage followed by ambient display. Bars indicate standard deviations. AHR data.

Condition of untreated (left) and waxed (right, wax 1 from trial) passionfruit cv. Misty Gem after 6 days cold storage plus 3 days at ambient conditions.

05. Packing and storage

Good, consistent grading and packing ensures that fruit present well at wholesale markets, getting the best possible price. Cooling fruit properly also retains fresh appearance and is essential to maximise storage life; think of cooling as adding value with electricity. Because cooling can greatly extend storage life, it can also increase marketing flexibility. Fruit that has been handled correctly and kept at optimum temperature can potentially be stored for several weeks, thereby obtaining better prices.

GRADING AND PACKING

Passionfruit are usually size graded by count per carton. For purple passionfruit these generally range from Size 90 (90 fruit per carton) to Size 140 (140 fruit per carton). The standard industry carton is the T35; 375mm (L) x 280mm (W) x 188mm (H), which carries around 5-9kg of fruit. Twelve cartons fit in a single layer on a standard pallet.

Cartons should have vents which cover at least 5% of their surface area to allow effective cooling. For standard cartons this suggests total vents should be approximately 124cm^2. This could be achieved by, for example, eight vents measuring 80mm x 20mm. Note that many carton designs do not have this amount of venting; choose the one that is closest.

Large sizes of fruit (e.g. 90, 100) can be pattern packed; this takes longer than simply filling cartons, but greatly improves presentation at market. The larger, Panama types are more often sold pattern packed than purple varieties.

Passionfruit are usually graded into Class 1 and Class 2 based on external appearance. Fruit should not be packed if they are diseased, deformed, physically damaged or potentially contain fruit fly larvae. Slight sunburn (<25% of fruit affected), scratches, scuffs and blemishes affecting <1cm^2 downgrade quality but do not make fruit unsaleable.

A packing line should comprise a number of different components:

- Bin tipper (if harvesting into bins)
- Fruit hopper with moving floor
- Wash step (optional).

BEST PRACTICE

- ✔ Accurate grading for both size and quality, and pattern packing of larger fruit, greatly improves market presentation
- ✔ If applying wax, use a spray applicator and brushes to distribute the coating and polish fruit
- ✔ Packing lines should include an air dryer if fruit are washed or waxed
- ✔ Plastic packaging materials (e.g. plasticised overwraps on punnets) are an effective way to reduce moisture loss and shrivel and extend storage life, but currently have very limited commercial acceptance
- ✔ Purple varieties should ideally be stored at **5 to 9°C** and Panama types at **10 to 12°C**
- ✔ Forced air cooling is the fastest and most efficient way to cool packed fruit
- ✔ If forced air systems are not available, room cooling may be optimised by ensuring the room is functioning well, there is good air circulation around cartons and RH is >70%
- ✔ **Trucks don't cool fruit**; fruit should be pre-cooled before loading
- ✔ Temperature is the most important factor affecting storage life and quality of fresh passionfruit

Pattern packing large fruit takes time but greatly improves presentation at market

- Grading table with good lighting and comfortable standing area for staff
- Waxing unit, with soft brushes to disperse and polish coating (optional)
- Air dryer if washing /waxing
- Sizer unit with diverging belts or rollers
- Accumulators for each size band
- Carton packing stands

A well-lit inspection table with rollers to rotate fruit is essential for effective grading

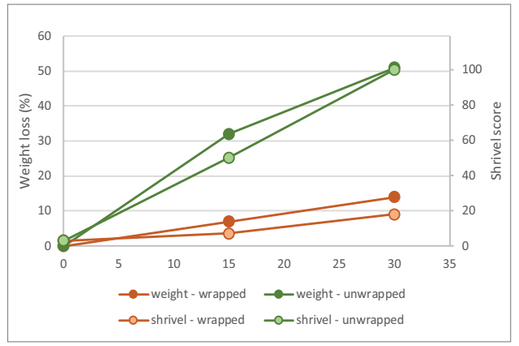
Waxing fruit requires a spray applicator as well as a series of brushes to disperse and polish the coating

Components of a small but well-designed packing line

PACKAGING

Passionfruit are normally packed straight into unlined cardboard cartons. While this maximises air movement around the fruit, cardboard can absorb significant amounts of moisture. Cartons therefore contribute to moisture loss from the fruit. Well-perforated liners could potentially reduce fruit shriveling during storage and transport. However, carton liners also increase costs and are not generally commercially used.

Overwrapping with a food grade plasticised film greatly increases storage life. Passionfruit may be placed in punnets or on small trays for overwrapping. plasticised films do not excessively modify the atmosphere inside the package (in terms of CO^2 or O^2), but do increase relative humidity. Although this may result in superficial mould developing after extended storage, life is still increased compared to unwrapped fruit. Unfortunately, although this type of packaging reduces food waste, it (potentially) increases plastic waste. Commercial acceptance of this type of presentation is limited.



Differences in weight loss and shrivel score of passionfruit packed into punnets overwrapped with plasticised PVC film compared to those left unwrapped. Derived from Arjona et al., 1994.

It is not recommended to package passionfruit in sealed plastic films that are designed to modify the atmosphere (increase CO^2 and reduce O^2) around the fruit. Passionfruit continue to respire at a very high rate after harvest, especially if they are warm. Unless the film is extremely permeable to gases, O^2 levels are likely to fall very low, resulting in off flavours in the fruit. Such packages are also likely to accumulate ethylene, further increasing senescence.

COOLING

What temperature?

Temperature management is key to extending storage life and retaining quality of passionfruit. However, the fruit are chilling sensitive, so it is also important not to drop temperatures too low. Chilling damage is a factor of time as well as temperature. Even temperatures close to 0°C are unlikely to cause significant damage if the exposure time is short. More than four weeks storage at 2 to 3°C can induce chilling damage in purple passionfruit. Chilling symptoms such as development of sunken patches and increased mould may only appear once fruit return to ambient conditions.

In contrast, only a few days at high temperatures will dramatically increase breakdown and shriveling.

Storage recommendations for passionfruit are:

Purple varieties: 5 to 8°C and >85% RH
Panama types: 10 to 12°C and >85% RH

Condition of passionfruit cv. Sweetheart (left) and cv. Misty Gem (right) following one month of storage at 2, 5 or 8°C then 3 days at ambient. Slight chilling damage, appearing as sunken patches on cv. Sweetheart and mould on cv. Misty Gem, occurred at the lowest temperature.

05.PACKING AND STORAGE

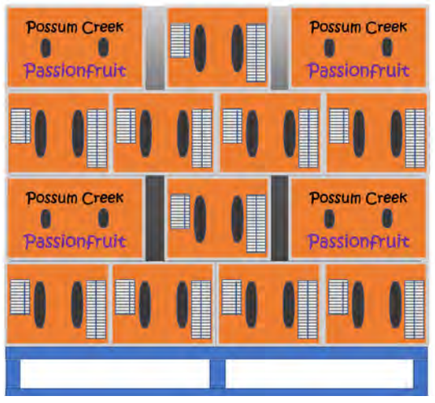
Cooling after packing

While fruit is warm it will lose moisture, even if it has been placed inside a cold room. As stated in the section on packhouse receival, it is essential to cool fruit as soon as possible, especially if the pulp temperature is 30°C or more. Forced air cooling is the best way to achieve this.

Forced air systems for packed fruit involve placing the pallet against a plenum containing a fan. The top and rear of the pallet are covered with a tarpaulin. Air is then pulled evenly through the cartons via the side vents. Forced air systems avoid condensation on the fruit and reduce moisture loss.

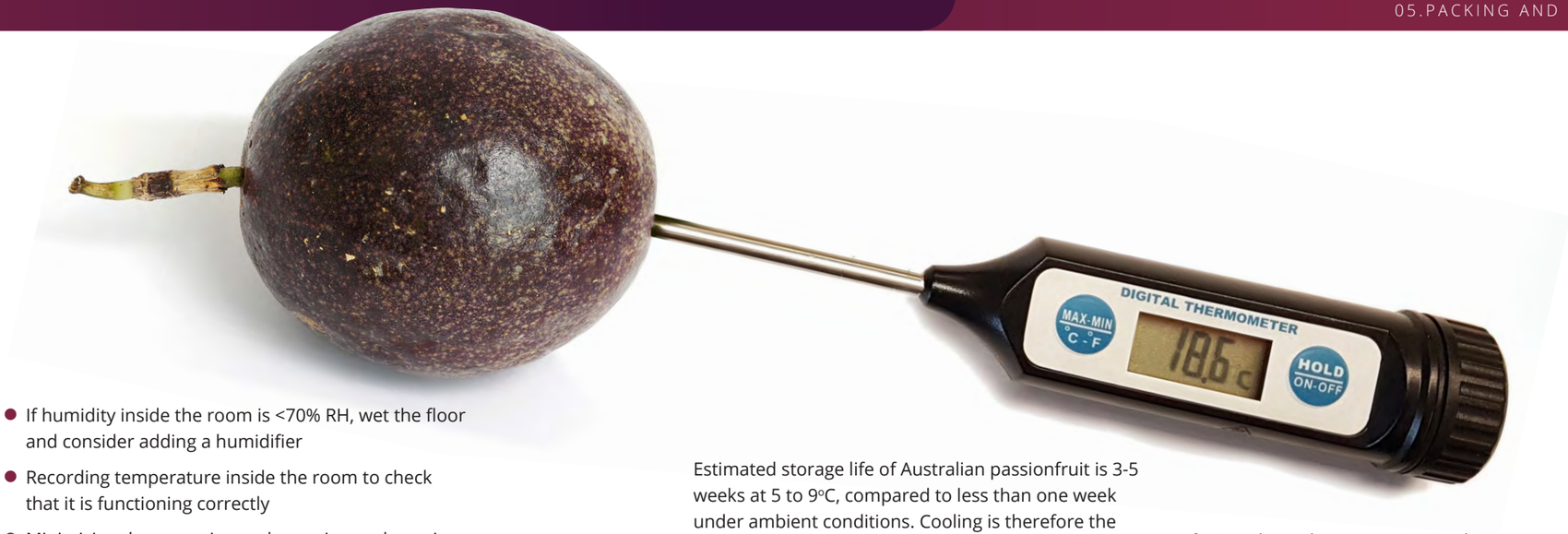
Many passionfruit packhouses have limited capacity to install forced air systems, and rely instead on room cooling. This reduces cost and is easy to do. However, full pallets of packed fruit can take a long time to cool. The efficient operation of cold rooms can be maximised by:

- Air stacking pallets, alternating between 12 and 11 cartons per layer
  - Ensure the gaps between cartons align with the pallet fork spaces, as this will maximise air circulation
  - Use corner protectors to stabilise the pallet



Air stacked pallet. Alternating between 11 and 12 cartons per layer allows air to circulate through gaps in the load.

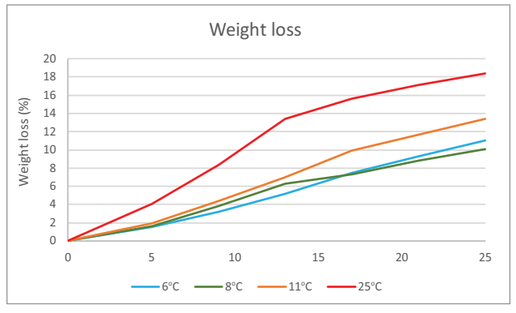
- Not overloading the cold room
- Spacing pallets as widely as possible
- Ensuring there is good air circulation within the room
- Adjusting the thermostat settings so as to minimise the temperature fluctuations allowed before the compressor turns on / off

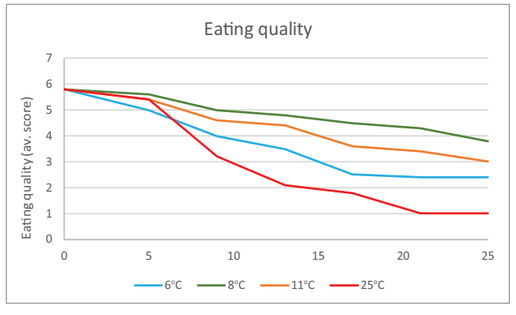


- If humidity inside the room is <70% RH, wet the floor and consider adding a humidifier
- Recording temperature inside the room to check that it is functioning correctly
- Minimising door opening and ensuring seals are in good condition
- Ensuring cold room panelling is well sealed and internally dry
- Ensuring the cold room floor is as thick as possible and waterproofed (NB. Along with doors, floors are a common source of heat infiltration)

Testing pulp temperature using a probe thermometer is the only way to know if fruit are cooling.

Cooling fruit reduces moisture loss and shrivel, inhibits development of disease and slows ripening and senescence processes such as the loss of flavour.





Effect of temperature on weight loss (top) and eating quality (bottom) of purple passionfruit stored at approx. 70%RH. Derived from Kishore et al., 2011.

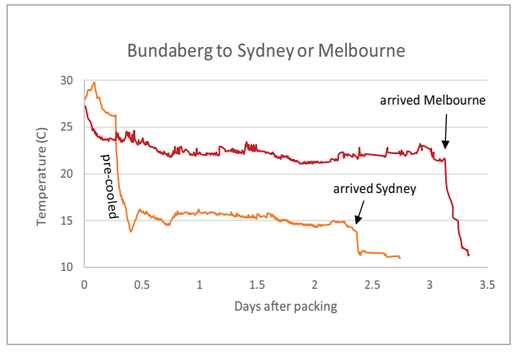
Estimated storage life of Australian passionfruit is 3-5 weeks at 5 to 9°C, compared to less than one week under ambient conditions. Cooling is therefore the easiest and most effective way to increase storage life of passionfruit. Cooling adds value for wholesalers, retailers and consumers and is the first step to increasing consumption of passionfruit.

Cooling for transport

Trucks don't cool fruit.

If fruit is loaded onto the truck while warm, it is very likely to arrive at the destination still warm. Truck cooling systems cannot create enough air movement around pallets to around pallets to effectively cool the fruit. At best, they can maintain the temperature that fruit were at when loaded.

This is particularly an issue for passionfruit, as they are likely to be shipped with mixed loads. For example, if passionfruit are transported with sweetpotato, the truck thermostat may be set at around 15°C, or not turned on at all.



Typical transport temperatures for passionfruit that were not pre-cooled before transport to Melbourne, and fruit that was pre-cooled for 6 hours before transport to Sydney. In both cases minimal cooling occurred inside the truck. Although 15°C is not optimum, this fruit would be expected to be significantly better quality than fruit at 22.5°C. AHR data.

TEMPERATURE is the most important factor affecting storage life and quality of fresh passionfruit

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■ For more information on growing, packing and marketing passionfruit:

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