NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Growing lemons in Australia- a production manual - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/lemon-manual

Updated versions of this document can also be found at the above web address.

16. Postharvest Handling

Photo by Greg Moulds
Lemons on the packing line

POSTHARVEST DISEASES

Green and Blue Mould

Green mould is the most serious postharvest disease of citrus and generally more common than blue mould. The moulds develop in damaged areas in the fruit rind. Initial symptoms are a softening of the tissue which turns into a water-soaked area. The infection progresses into a white fungal growth which turns blue or green, but retains a white margin. This margin is larger with green mould.

Photos by Brian Wild
Blue and green mould

Cause
Fungal pathogens of *Penicillium digitatum* (green mould) and P. *italicum* (blue mould). Green mould is more common than blue mould, but blue mould grows faster.

Symptoms
Both infections develop in damaged areas in the rind. Initial symptoms include a softening of the tissue followed by development of a water soaked area. The infection site then develops into a white fungal growth which turns blue or green as spores are produced. The white margin is larger (10-20mm) with green mould.

The optimum temperature for mould growth is 27°C. No growth occurs above 30°C and growth is slow below 10°C.

Control
Careful handling of fruit during and after harvesting is the key to reduce damage to the fruit rind. Ideally fruit should be washed prior to fungicide application. Fungicide should be applied within 24 hours of harvest.

In and around the packing shed all mouldy fruit should be removed to reduce the spread of mould spores.

Sour Rot

Photo by Brian Wild
Sour Rot

This fungal disease can occur in mature lemon fruit damaged during harvesting. It can also occur when fruit have been treated with a fungicide that controls green or blue mould but not sour rot.

A very soft watery decay develops around the injury site on the rind of fruit. It is very attractive to vinegar flies.

Cause
The fungus *Geotrichum candidum*.

Symptoms
A soft watery decay generally around an injured section in the rind. This decayed area has a well defined ridge around the margin and produces white slimy spores.

Sour rot is favoured by high temperatures and humidities with optimum growth at a temperature of 30°C.

Control
Careful handling of fruit to reduce rind damage. Fruit should be treated with a fungicide that controls sour rot.

Brown Rot

Brown rot

Cause
The fungus *Phytophthora citrophthora* or P. *parasitica.*

Symptoms
A soft leathery brown rot on the fruit rind with a pungent odour.

The *Phytophthora* fungus is present in the soil and the spores are carried onto the fruit in rain splash. The infection can spread upwards throughout the tree in the water during wet conditions.

Control
Control is undertaken in the field using copper fungicides usually applied to the lower parts of the tree. Skirting the tree reduces the chance of fruit and foliage coming into contact with spores in rain splash.

Oleocellosis

Oleocellosis (also known as oil spotting) is caused by the phytotoxic action of peel oil released onto the rind as a result of abrasion, rough handling, thorn punctures or other injuries. The rind of lemons is especially prone to oleocellosis. Foggy wet conditions exacerbate the disorder making the rind more turgid and subject to the rupturing of oil glands.

To reduce the incidence of oleocellosis do not harvest fruit which is wet or cold and use care in handling, transporting and grading fruit.

Cause
A burn like damage from the oil released from oil glands when the rind tissue is damaged.

Symptoms
Damaged tissue shows up 1-2 days after the oil is released. Superficial damage results in light yellow coloured patches. Severe damage results in dark brown patches and rind collapse.

Oleocellosis is more common when fruit have been harvested when cold, wet or turgid. During these conditions the oil glands are easily ruptured when the fruit is handled. The released oil spreads over the fruit surface burning the tissue.

Control
Don't harvest fruit in cold wet conditions. Pick only dry fruit. Lemon fruit when picked green for degreening or storage are more turgid than fruit fully coloured. Don't harvest green fruit in the early morning when they are at their most turgid. Careful handling of fruit during and after harvest to reduce damage to the rind.

Peteca

A postharvest disorder of lemons, the cause of which is not known. The fruit develops either large sunken areas in the rind or pitting of the surface soon after packing.

Fruit which have been sprayed with high concentration oil sprays and cold conditions prior to harvest increase the severity of peteca. Susceptible fruit should not be subject to excessive brushing. In Queensland Meyer lemons are not waxed to reduce the incidence of peteca.

Photos by Pat Barkley
Peteca of lemons

FRUIT HANDLING TO AVOID POSTHARVEST LOSSES

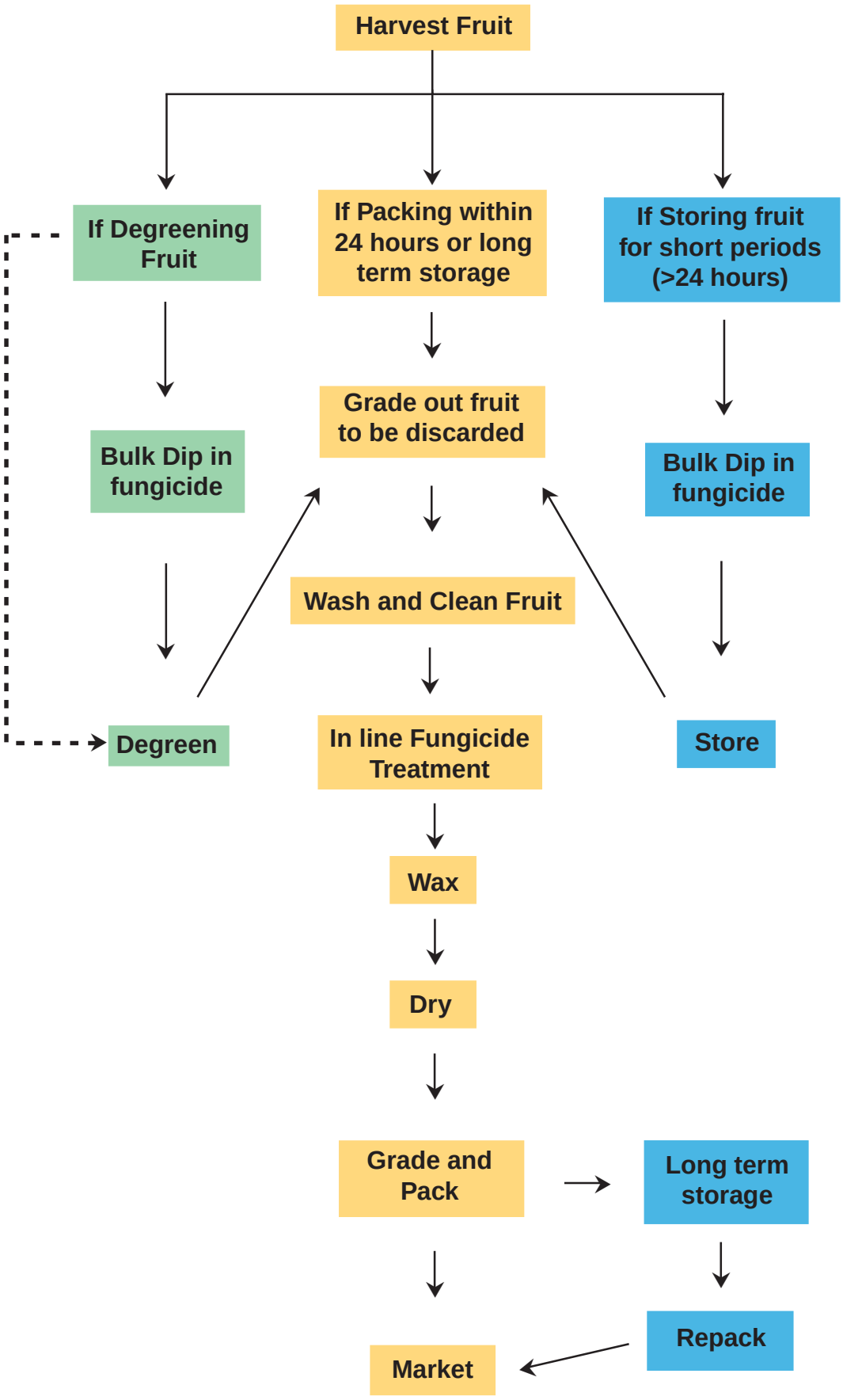
Green and blue moulds and sour rot usually develop on fruit where the rind has been physically damaged. Without this injury site the fungal spores do not grow and cannot penetrate the fruit surface.

By following these few tips you will reduce postharvest losses:

- do not leave harvested fruit out in the hot sun;
- do not pick cold, wet fruit. When wet turgid fruit is handled the oil glands can be ruptured. The released oil burns the fruit surface (oleocellosis) and also stimulates fungal spores to germinate. The burn marks can take 2-3 days to develop;
- wear cotton gloves when harvesting. This reduces puncture marks from fingernails and jewellery;
- use picking bags. This reduces damage as a result of abrasion on wooden or metal picking bins and allows fruit to be gently lowered into bulk harvesting bins;
- do not leave stems on fruit or damage buttons by “plugging”;
- use clean, smooth harvesting bins;
- make sure packing line equipment is cleaned regularly. This reduces dirt and wax buildup which can cause fruit abrasion;
- reduce packing line abrasion by using foam, rubber and smooth belts to cushion fruit;
- remove all old fruit regularly from the packing shed and surrounds;
- treat harvested fruit with a registered fungicide within 24hrs of harvest;
- don’t leave rejected/rotten fruit in or around the packing shed or orchard.

- ☑ Don’t pick cold wet fruit
- ☑ Don’t pick turgid fruit
- ☑ Wear gloves when picking
- ☑ Don’t plug fruit
- ☑ Take care when handling and transporting fruit around the orchard
- ☑ Treat fruit with a fungicide within 24 hours of harvest
- ☑ Remove old/ rejected fruit from around packing sheds
- ☑ Ensure bins and packing lines are regularly cleaned and free of abrasive surfaces

SIMPLE POSTHARVEST HANDLING SEQUENCE



WASHING AND CLEANING

Washing fruit removes soil and dirt particles, disease spores and field spray surface residues. Washing disturbs the natural wax layer of fruit. Water sprays at high pressure are sometimes used to clean pests (such as red scale) and diseases (such as sooty mould) from fruit.

The water used should be clean and free of disease spores. Water can be treated with a sanitiser (e.g. chlorine compounds) to kill the free floating spores. Recirculated water in particular is more likely to become contaminated with disease spores and should be treated with a sanitiser. Sanitisers do not kill spores or disease organisms that have already penetrated the fruit rind, only fungicides can kill these. The pH and temperature of the water can also affect the activity of sanitisers and fungicides and should be monitored regularly.

- ☑ removes soil, disease spores and surface spray residues.
- ☑ water should be clean and free of disease spores.
- ☑ use sanitisers to kill free floating spores.
- ☑ monitor pH and temperature of water.

FUNGICIDE TREATMENTS

Application times

The effectiveness of all postharvest fungicides depends on the prompt treatment of fruit. The maximum time between harvest and treatment varies with temperature but should not exceed 24 hours.

Application methods

Bulk dipping: Bulk dipping is the complete immersion of bulk bins of citrus in a fungicide. Bulk dipping provides a convenient method of fruit treatment within 24 hours of harvest when fruit are not packed or processed immediately. Fruit should be immersed in the fungicide solution for at least 30 seconds.

Shower or spray application: Effective mould control can also be obtained using a shower application as the fruit move through the packingline. These treatments are normally effective by themselves if applied within 24 hours of harvest. Generally, the shower should be applied over revolving brushes or rollers so that fruit are treated for about 30 seconds and are thoroughly coated with the fungicide.

Fungicide Stripping: As postharvest fungicides are applied to fruit either as a bulk dip or shower in the packing line the fungicide is gradually removed on the fruit. Accumulated dirt and organic matter also bind some fungicides and reduce their effectiveness. Because the fungicides are removed they must be replaced if an effective concentration is to be maintained.

The type of fungicide application equipment used and quality of water used can all influence the rate of loss of the fungicide. The concentration of fungicide in the dip tank and inline equipment should be monitored at regular intervals.

Maintaining the correct concentration of fungicide in the water can be achieved by changing fungicide tanks regularly or by topping up with more fungicide.

Registered fungicides

Disease	Active Constituent	Example Trade Names®
Blue/Green mould	carbendazim	Bavistin, Spin Flo, Carbendazim
Blue mould	guazatine* imazalil } imazalil sulfate } SOPP thiabendazole*	Panoctine Imazagard; Magnate, Fungozil, Fungaflor Prevental, Brycote Tecto
Green mould	guazatine* imazalil } imazalil sulfate } thiabendazole*	Panoctine Imazagard, Fungaflor, Magnate, Fungazil Tecto
Sour rot	guazatine*	Panoctine
* Not registered in all states. See Pest and Disease Control Products section of this manual.		

Mould resistance

Cases of mould resistance have been reported to the benzimidazole fungicides such as Tecto ®, Benlate®, Spin®, Bavistin® and Topsin®. It is suspected that the resistance has developed because of the use of benzimidazole fungicides in the field, which can cause resistant strains to be selected and proliferate in the packinghouse. If resistance is suspected these fungicides should not be used.

Hygiene

Do not let decayed or mouldy fruit get into washing and fungicide treatment tanks. Unless a sterilising agent is present in the tank, spores will be released and infection of other fruit is likely.

- ☑ thoroughly clean bulk bins used to carry and store fruit if they contained mouldy fruit.
- ☑ sort out mouldy fruit before it starts along the packing line. This reduces spore contamination along the line.

WAXING

Waxing is used to improve the appearance of fruit, protect the fruit surface, slow down the development of some rind disorders and most importantly reduce water loss from the fruit. Waxes used on fruit should be suitable for human consumption.

Types

There are several different wax formulations used including: Carnauba (a natural wax extracted from palm leaves); shellac based waxes; polyethylene based waxes and resin based waxes.

Application

Wax needs to be applied evenly (at low pressure) to the fruit surface and should not be diluted with water. Fruit should be damp prior to application. Wax is normally sprayed or dripped onto fruit whilst they are being rotated on a bed of brushes. The revolving brushes help to spread the wax evenly over the fruit surface.

Combing wax with other chemicals

2,4-D

2,4-D (as amine) can be mixed with wax to improve colour retention (keep buttons green) and control stem-end and centre rot in citrus.

Fungicides

Some fungicides can be mixed with wax, however, decay control is reduced if applied in this way. Mixing fungicides with the wax is not recommended.

DRYING

After waxing, fruit are dried by running high velocities of air across the fruit. It takes between $2^{1}/_{2}$-3 minutes to dry the wax. Cool or warm air is used to dry fruit depending on conditions. Fruit should not be rolled during drying but should be turned once. There are several types of dryers including open line or closed recirculating tunnel dryers.

SORTING

☑ Provide good lighting

Fruit are sorted on the packing line to remove blemished or damaged fruit and to grade fruit according to market specifications. Any fruit that will not be packed should be sorted and removed from the line prior to fungicide application and waxing.

☑ Provide photographic examples of blemish types and extent to be allowed.

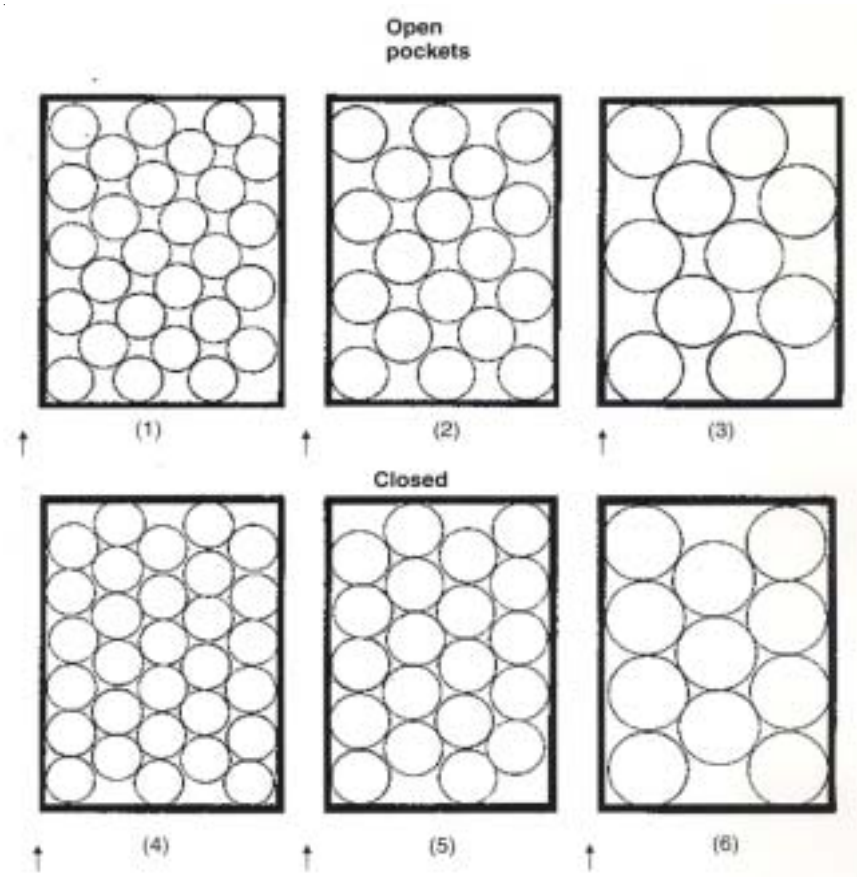
Sorting can be done by hand or by using electronic sorting equipment in the packing line. When hand sorting, good lighting is essential. Sorters also need to be provided with good information on which fruit need to be removed/culled. Photographic charts/posters showing the type and degree of blemish allowed on fruit are one of the best methods used.

SIZING

Fruit is normally sized mechanically (using belts or rollers), electronically or by weight. If mechanically sizing lemons use slow belt speeds. Weight sizers are not recommended when pattern packing fruit as there is too much variation leading to poor packout presentation.

PACKING

Fruit can be packed either as "loose fill " or pattern packed depending on the market being targeted. Pattern packing can be either "open pocket" or "closed pocket". Fruit are normally packed in either a 30 or 15 litre cardboard cartons. Each package of fruit should be graded to have a similar size, shape, colour and condition (blemish level).



Pack	Row Count	Fruit per layer
(1) 3 x 3	5 x 4	27
(2) 3 x 2	4 x 3	18 and 17
(3) 2 x 2	3 x 2	10
(4) 3 x 2	6 x 6	30
(5) 2 x 2	5 x 5	20
(6) 2 x 1	4 x 3	11 and 10

Row count refers to vertical fruit numbers.

Pack refers to horizontal fruit numbers.

Extracted from Citrus Handling Guide, 1999. Edited by B. Tugwell.

Packing Patterns for Lemons

Count	Pattern*	Size (mm)
30L carton (415 x 270 x 260mm)		
234	7 x 6 x 6 x 6	51
216	6 x 6 x 6 x 6	54
198	6 x 5 x 6 x 6	56
180	5 x 5 x 6 x 6	58
162	5 x 4 x 6 x 6	59
150	6 x 6 x 5 x 5	60
138	6 x 5 x 5 x 5	61
125	5 x 5 x 5 x 5	64
113	5 x 4 x 5 x 5	67
100	4 x 4 x 5 x 5	70
88	4 x 3 x 5 x 5	73
75	3 x 3 x 4 x 4	76
15L carton (370 x 230 x 175mm)		
120	4 x 4 x 6 x 5	51
110	6 x 5 x 5 x 4	54
100	5 x 5 x 5 x 4	56
90	5 x 4 x 5 x 4	57
80	4 x 4 x 5 x 4	59
70	4 x 3 x 5 x 4	61
60	5 x 5 x 4 x 3	64
56	5 x 4 x 4 x 3	67
48	4 x 4 x 4 x 3	70
42	4 x 3 x 4 x 3	73
36	3 x 3 x 4 x 3	76

* The first two numbers refer to the fruit in the rows, the third figure refers to the number of rows on the bottom layer and the last figure the number of layers in the pack.

Extracted from Citrus Handling Guide, 1999. Edited by B. Tugwell.

DEGREENING LEMONS

Photo by Greg Moulds
Degreening rooms

Mature lemons that may lack full colour development can be degreened by treating with ethylene gas (a natural product of fruit ripening). This gas causes the breakdown of the green pigment in the fruit rind and the fruit develops a far more saleable yellow colour. Ethylene does not ripen fruit, the sugar, acid and flavour are not affected. The greener the fruit the longer it takes to degreen. Fruit sprayed with giberrellic acid also takes longer to degreen.

In order to obtain satisfactory results from the degreening process, the following points should be followed:

- ☑ lemons should have a juice content of at least 25%;
- ☑ select fruit that shows some sign of colour development;
- ☑ pick fruit carefully and not during wet or cold weather. Rind damage to green fruit becomes very noticeable after degreening. Released rind oil from the damaged area burns the rind and produces oleocellosis;
- ☑ only use internally mature fruit;
- ☒ don't wax fruit prior to degreening as full colour will not develop;
- ! fruit sprayed with oil in the weeks prior to harvest will not develop full colour;
- ☑ control fruit temperature, 20-30^{0}C is recommended for lemons. The higher the temperature the more rapid the degreening process. Higher temperatures can also result in poor pigment development and a more rapid deterioration of fruit quality and increased fruit shrinkage;
- ☑ treat fruit with a registered fungicide in a bulk dip before degreening in order to control decay during the operation;
- ☑ dipping fruit in a 500ppm 2,4-D solution prior to gas colouring will help keep buttons green. The 2,4-D can be mixed with the fungicide in the bulk dip tank. Be careful using 2,4-D on very green fruit as the wet contact points between the fruit may not colour;
- ☑ provide high humidities (up to 90%) in the degreening room. It will reduce fruit weight loss and shrivelling during storage. It will also help reduce button death and abscission which occurs during and after degreening;
- ☑ measure ethylene gas quantities carefully. The recommended rate for degreening lemons in a closed room (batch or shot system is 50 ppm or 1 part in 20,000). If a trickle system is used, i.e. where air is removed from the room at one air change per hour and fresh air and ethylene are added continually, 20 ppm need only be maintained. This latter method is better because degreening times are reduced and fruit are not subject to as much stress. High ethylene concentrations cause excessive fruit button loss and aging of the fruit;

! take care! High concentrations of ethylene between 3 and 30% form an explosive mixture which only requires a spark from a fan or a switch to set if off;

☑ vent rooms used in the batch system every 8-12 hours. This removes carbon dioxide which builds up in the chamber, and which if not removed, will retard colour development;

☑ stack fruit so there is good air movement between them. This allows rapid heating of the fruit and more uniform degreening.

An alternative degreening process is also available that involves dipping the fruit in a solution containing the compound ethephon (sold as Ethrel®). This treatment produces a distinct colour change in the fruit rind, however, from experiments conducted at Gosford this colour development is not as good as the gas treatment and it takes longer. Additionally, fruit have to be stored for up to two weeks, without them being waxed while the colour development occurs. The fruit cannot be waxed until fruit has reached the desired colour.

STORING LEMONS

Introduction

Lemons are nonclimacteric fruit and have low respiration rates. They are therefore able to be stored for long periods of time. In contrast to other citrus varieties there are significant changes in the internal quality of lemon fruit during storage. During storage the percentage of juice increases (by up to16%) primarily due to the water stored in the peel. The acid content of fruit also increases (by up to 24%) during storage and the peel colour changes from green to yellow.

Lemons are sensitive to cold temperatures and should not be stored at temperatures below 10^{o}C as they develop chilling injury.

The length of time lemons can be stored depends on the stage that they are picked. Fruit harvested with a yellow tinge can be stored for a few weeks, silver-green fruit 6 weeks, light green fruit 2 months and dark green fruit 5-6 months. In Australia long term storage is not common practice. However, in California they store fruit for long periods of time and harvest fruit using four colour grades (refer to the Harvesting section of this manual).

Photo by Brian Wild
Chilling injury

Photo by Greg Moulds
Pitting of fruit in storage

Advantages

- possibility of achieving higher market prices when local fruit is in short supply;
- better quality main crop lemons. The main winter crop if stored is usually smaller with thinner skins;
- stored fruit have been shown to have a higher juice content.

Disadvantages

- high risk with the possibility of losing money;
- possible decay losses caused by blue and green moulds and sour rot;
- possibility of fungicide resistant strains of moulds and rots developing in stored fruit;
- moisture loss from stored fruit. Unwaxed fruit can lose about 5% of their weight/month. Applying wax should reduce this by 30-40%;
- overstored fruit can develop a deep yellow colour that makes them appear old;
- high capital costs if a storage facility has to be specially built;
- shortage of bulk bins "on farm" since they are being used to store fruit;
- additional costs of running the coolroom;
- competition on the market from other stored fruit and from imported fruit.

Storage recommendations

Your first attempt at lemon storage should be on a small-scale to ensure all parts of the procedure are correct.

Growth regulators: Gibberellic acid (GA) has the ability to reduce ageing of the fruit rind and rind colour development in stored fruit. It can be applied as a tree spray at 10 ml (of 100 g/L product)/100 L water about four to six weeks before harvest when fruit are silver-green.

Fungicide treatment: The fungicides that control both green and blue moulds and sour rot, should be applied within 24 hours of harvest otherwise mould infection develops beyond the point of control. Fungicides can be applied either as a bulk dip or using a shower application.

2,4-D: The most effective way of preventing button death and subsequent stem end rot development, is by the application of 2,4-D. It can be applied in the bulk dip with the fungicide. Research has shown that residues of this compound decrease during storage and are virtually undetectable after eight weeks storage.

Storage temperature and humidity: The recommended temperature for lemon storage is 10-12°C. At temperatures below this point, chilling injury can develop if the fruit are stored for long periods. Temperatures above 10°C accelerate ageing and mould development. High humidities in storage are recommended to reduce weight loss. A relative humidity of between 90 and 95% is ideal.

Ethylene removal: One compound that can cause problems in long-term storage is the gas ethylene. It is produced from stressed or decaying fruit and in

an enclosed environment can accumulate and accelerate the colouring and ageing process in the fruit. This contributes to the stale yellow colour of stored fruit and causes the death of fruit buttons, which permits the development of organisms that cause stem end rot and black centre rot.

If you are considering long-term storage and fruit ageing becomes a problem removal of ethylene should be considered. It can be achieved on a small-scale by ethylene absorbers made from porous material carrying potassium permanganate (condy's crystals). Bags of this material can be left in the storage rooms or suspended from the ceilings and the ethylene will be absorbed.

Larger scale removal of ethylene can be obtained by the use of ultra violet tubes which release ozone and atomic oxygen which breaks down the ethylene. Commercial scrubbing units based on this system are available.

In California, where lemons are stored on a routine basis, the ethylene problem is overcome by continuous venting of storage rooms. This is a viable solution to the problem but it does mean that the new air has to be refrigerated to the storage temperature and this can be expensive, particularly during summer months.

Controlled atmosphere storage – an alternative: Research has shown that lemons can be stored for up to six months and still remain in a fresh condition when they are stored in an atmosphere of 5% oxygen with both the carbon dioxide and ethylene removed from the atmosphere. The success of this treatment depends very much on successful decay control and the economics of the process.

Step-by-step guide to lemon storage

- carefully examine the economic consequences, risk and potential benefits of the storage process;
- apply sprays of gibberellic acid to trees four to six weeks before harvest to help keep fruit green in storage;
- when harvesting select good, disease free fruit, in silver green condition. Disease control will NOT improve in storage;
- harvest fruit carefully, avoiding "plugging" of fruit at the stem end;
- apply appropriate fungicide and 2,4-D treatments within 24 hours of harvest;
- store fruit in clean storage bins or boxes. Only fill storage bins to $^{2}/_{3}$rds normal depth to avoid compression damage;
- place fruit in a storage room operating at 10°-12°C with a relative humidity of 90-95%;
- inspect lemons at least once a week to check fruit and storage conditions;
- during storage take appropriate measures to remove ethylene gas that is produced by mouldy fruit. The presence of ethylene will accelerate fruit ageing;
- do not over store the fruit hoping for a higher return. Once decay levels reach 5% it is time to sell the fruit;
- when removing fruit from storage, take care to remove mouldy or rotten fruit carefully and dispose of them without spreading spores to the remaining sound fruit;

- before packing fruit re-apply a fungicide to the fruit and treat with wax to reduce weight loss and improve fruit appearance.

Key References

- **Citrus Handling Guide**, 1999. Edited by B. Tugwell.
- **A Guide to the Common Postharvest Diseases and Disorders of Navel Oranges and Mandarins Grown in Inland Australia**. Taverner, P., Tugwell, B., and Wild, B. Advisory Brochure. Published by SARDI and HRDC.