The Principles of Citrus Postharvest Handling

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Overview

• Citrus Postharvest Biology, Pathology and Disease Management

• CA Postharvest Handling Procedures
  - Oranges/Grapefruit
  - Lemons
  - Mandarins
Challenges for the Citrus Handler

- Causes of peel damage poorly understood
- Damage due to low temperature, high temperature, methyl bromide fumigation etc. are often similar
- Interaction of physical damage with other postharvest treatments often difficult to ascertain
- Preharvest environment plays a difficult to quantify but important role

Postharvest Biology, Plant Pathology and Disease Management
Citrus

- Non-climacteric
- Chilling sensitive
### Storage Temperature Requirements

- Varies with citrus type and variety
- Ranges from approximately 0°C to 15°C

<table>
<thead>
<tr>
<th>Most Cold Tolerant</th>
<th>Least Cold Tolerant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kumquats</td>
<td>Limes, Citrons</td>
</tr>
<tr>
<td>Mandarin</td>
<td>Lemons, Grapefruit</td>
</tr>
<tr>
<td>Oranges</td>
<td></td>
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</tbody>
</table>

Low temperature damage

Membrane Staining in lemons
**Peteca**

Lemon Disorder

Develops after harvest

Curing of lemons allows detection

Cause unknown

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### Initiation of Postharvest Citrus Diseases

**Preharvest Infection**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pathogen</th>
<th>Infection Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem-end Rot</td>
<td>Diplodia</td>
<td>Flower, young fruit</td>
</tr>
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<td>Phomopsis</td>
<td>Flower, young fruit</td>
</tr>
<tr>
<td>Stem-end Rot; black rot</td>
<td>Alternaria</td>
<td>Flower, young fruit, navel</td>
</tr>
<tr>
<td>Brown Rot</td>
<td>Phytophthora</td>
<td>Fruit surface</td>
</tr>
<tr>
<td>Botrytis Rot</td>
<td>Botrytis</td>
<td>Flower, young fruit</td>
</tr>
<tr>
<td>Anthracnose</td>
<td>Colletotrichum</td>
<td>Fruit surface</td>
</tr>
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</table>
Anthracnose (tear staining)

Botrytis

Phytophthora Fruit Rot or "Brown Rot"

Phomopsis Stem End Rot

Diplodia Stem End Rot
**Alternaria**

**Lemons**
occurs in storage
controlled by prestorage application of 2,4-D to control “button” abscission

**Navel Oranges**
occurs primarily on navel end
more severe in “freeze” years

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<tr>
<td>Blue Mold</td>
<td><em>Penicillium italicum</em></td>
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<tr>
<td>Sour Rot</td>
<td><em>Geotrichum</em></td>
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<tr>
<td>Trichoderma</td>
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</table>
Blue Mold  
*P. italicum*

Caused by wounding during harvesting and handling

Green Mold  
*P. digitatum*

Sporulation - direct loss and necessitates repacking

Sour rot  
*Geotrichum candidum*

Caused by fruit wounds  
Spreads from fruit to fruit  
May be a problem in long-term lemon storage
Trichoderma sp.
Trichoderma rot

Caused by fruit wounds
May be a problem in long-term lemon storage

Packinghouse practices and treatments reduce decay by:

- Destroying inoculum on fruit surface
- Inhibiting development of latent infections
- Preventing infection by wound-invading pathogens
- Protecting fruit surface from subsequent infection through wounding
- Inhibiting sporulation and spread from diseased to healthy fruit
Cold Storage and Packinghouse Cleaning Schedule
Fruit dump should be well ventilated and use sanitizer at point of dump

Discard decayed fruit downwind from packing house to minimize contamination

Maintain tank mixtures/fungicide applicators at optimal conditions
Minimize fruit drops and other points of fruit handling that can cause damage

Ambient spore sampling
Important for detection of resistant strains of Penicillium
Examples of Grade Defects

Puff and Crease

Split navel

Surface abrasions

Sunburn

Uneven coloring

Defects from the field that would be sent to processed products
Scarring due to insects, wind, limb rub

Fruit Shape

Freeze Damage
ice marking or internal damage
Postharvest Handling Practices

Fruit Handling and Quality
Care should be taken in the field during harvest to minimize damage to fruit since the consequences of mechanical injury are:

- increased decay
- enhanced water loss
- peel breakdown in subsequent handling

Impact of Handling Injuries on Postharvest Fruit Quality
“The most common type of injury was made by ... the clippers ... many were injured by stem punctures, while others showed scratches from thorns. Other common ... injury... were from gravel and twigs in the bottom of boxes and cuts by the finger nails of the pickers.”

Powell, 1908 Riverside, California
Rind oil spotting of desert lemons
Related to fruit turgor pressure at harvest - more turgid; more damage

Lemons picked at different times of day then subjected to heat treatment

Obenland and Neipp, HortScience, 2005
The importance of peel turgidity on peel damage.

Susceptibility to Hot Water Treatment

Ethylene Degreening

- Early season navel oranges
- Re-greened valencia oranges
- Lemons
- Mandarins

- Ethylene: 1-5 ppm
- Temperature: 20 C in CA; 25 C in FL
- Humidity: 90-95%
- Ventilation: 1 air exchange/hour
- Carbon Dioxide: reports varies, <1%
Degreening depends on:

- Peel color
- Temperature
- Preharvest conditions such as GA

Button discoloration following degreening
Assessing Minimum Maturity

For all citrus (except lemon) maturity standard based on Soluble Solids Content and Titratable Acidity

Orange Harvesting

- 40 to 60 lb picking bag
- Gloves to prevent damage
- Fruit Clipped
- Bulk ~1000 lb bin
- No fruit from ground
- Fruit transported to PH on day of harvest
Care is taken in the field during harvest to minimize damage to fruit since the consequences of mechanical injury are:
- increased decay
- enhanced water loss
- may result in peel breakdown in handling

Source: J. Smilanick
Degreening
-early season navels
-late season valencias
1 - 5 ppm ethylene
68 - 70 F; 90 - 95% RH
<1% CO₂

Soak tank
1 to 4 min residence

Box or carton packing

Source: J. Smilanick
100 - 200 ppm chlorine spray

Pregrading for Processed Products and Cull Removal
Fruit for Processed Products

Cull Fruit for Land Fill or Feed

Flume system for rot removal

Tank Treatments
- optional
- solutions vary

Optional heating
Fruit submersion
Tank Treatments

- **Options for tank mixtures**
  - Sodium Carbonate (3%) @ ~105 F, pH 10.5
  - Sodium Bicarbonate (3%) w/ chlorine (200 ppm) @ 68 - 80F, pH 8.0
  - Borax/Boric Acid (4%/2%) @ 105 F, pH 10 - 11
  - Lime Sulfur (3%) @ 105 F, pH 10 (registered in 1998)

- Avg. duration 1.5 - 2 minutes (4 min. max.)
- Generally heated at night to ~140F; changed ~ 2 wks,
- ~30% orange houses; <20% grapefruit houses
California Red Scale

Controlled in field by
- biological control
- chemical control

High Pressure Washer augments field control measures and has allowed for increasing of field “economic threshold”

Scale Removal

Pre Wash

Post Wash

HPW Damage
High Pressure Washer

• 80 - 300 psi depending on level of scale infestation over brush bed
• Water Chlorinated (200 ppm) - may add sodium bicarbonate
• Re-circulating water system; water filtered to remove particulate matter
• Water replenished continuously; completely replaced every 24 hours
• Followed by water rinse (chlorinated)
Grading area to remove rots

Water Elimination

Grading for Rots and Processed Products
**Electronic Sorting**

Many orange houses use some sort of electronic grading; trend is increasing

Useful for sorting fruit by defect, color, weight, freeze damage

Used in conjunction with manual grading

Fruit separated electronically as First, Choice, Processed Products

Reduces manual handling of fruit and potential for damage to fruit

Electronically graded fruit that is "too green" or "Processed Products Grade" diverted to bins
Fruit Waxing

- Replacement of natural wax
- Reduce Water Loss
- Carry Fungicide
- Cosmetic

Fruit Waxing
pH 8-9
Based on Shellac, Carnuaba or Wood-Rosin or Combination

Dryer
Duration: 3 to 5 minutes
90 to 140 F
Post-wax Operations

Final grading for First, Choice, Processed Products and Culls

Electronic Sizing
Stickering of First Grade
Sent to Bulk Accumulation Bins

Pattern Packing
Packing by Hand
Box Sealer and Conveyor

Short-term Storage

Loading Area isolated from rest of Pack House

Palletization

Other Packing Options

Bulk bin for Choice
Poly or Net Bags
**Shipment to Market**
A substantial proportion of CA citrus (lemons and oranges) is exported; primarily to Pacific Rim countries.

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**Oranges**

- **Storage:** 3 – 8°C (37 – 46°F)
- **Maturity:** normally SSC/TA ratio but for CA navels the California Standard
- **Storage Duration:** up to 3 months under ideal conditions
**Background of California Navel Maturity Standards**

1915 – California adopted the 8:1 ratio as the minimum maturity standard
1925 – Florida followed California by adopting an 8:1 ratio standard
1949 – Florida raised the minimum orange maturity standard to a 9:1 ratio
1983-1985 – CCM sponsored a consumer study of navel oranges. The study recommended that the ratio should be raise to 9:1.
2003 – California drops B color from the maturity standard
2003-2006 – At CCM’s request CRB conducted a three year taste study with University of California researchers. The study concluded that sugar to acid ratios were not the best method of measuring flavor. Brix minus Acid was proven to be a much better predictor of flavor.
2008 – CCM received a Specialty Crop Grant to fund a consumer study at Tragon consumer labs in Chicago. This study, using 400 actual consumers, confirmed that Brix minus Acid was a much better predictor of consumer acceptance than a simple ratio.
2010 – CCM Board agrees to pursue moving to a Brix minus Acid standard for navel oranges and decided to call it the California Standard.
2012 – California Standard adopted for navel oranges

**How is the California Standard calculated?**

The California Standard is easily converted to a table format, similar to the SSC/TA tables currently in use

It is a slight modification of the BrimA calculation proposed by Jordan et al: BrimA = Brix – (TA * k)

Steps involved in determining the California Standard

- Juice sample using Boswell Press
- Determine Brix using standard protocols
- Determine Titratable Acidity using standard protocols
- Calculate California Standard

**Formula for California Standard:**

California Standard = (Brix – (TA * 4)) * 16.5
Comparing SSC/TA ratio to California Standard 2012

Comparing 2010 – 2012 % Passing

SSC/TA Ratio

CA Standard

2010: 417 samples; 2011: 3,241 samples; 2012: 636 samples
Grapefruit

- Handled similarly to oranges except NO degreening
- Clipped; single harvest
- Maturity: Color (>2/3 fruit surface showing yellow) and SSC/TA ratio of 5.5 or 6 (depending on production area)
- Storage: 6-8 weeks at 12 - 14 C (54 - 57F)

Mandarins/Clementines

- More easily damaged than oranges; requires “soft handling”
- Clipped; may size pick
- Maturity: Color (yellow, orange, and/or red) on 75% of fruit surface and SS/TA 6.5 or higher
- Storage: 3-6 weeks at 5 - 8 C (41 - 46 F)
Clementines

SOPP Damage
Skin Burns  Skin Wounds  No Stem end

Puffines  Olleocellosis
Peel Damage – Various Causes

Rind Breakdown

• Related to long transit times
• Associated with high temperatures during shipping?
• Lot to lot variability
• Pale fruit shows more incidence than dark orange fruit
Lemons

- A minimum juice content by volume of 28 or 30% depending on grade
- Clipped
- Multiple harvests based on color and size
- May be stored prior to packing up to 150 days at 10 - 13 C (50 - 56 F)
- After packing and colored may be shipped and stored at 3 - 5 C (37 - 41 F)

Source: J. Smilanick
The influence of button condition and % incidence of Alternaria Stem End Rot

The influence of postharvest 2,4-D on button condition

Harvesting care is important. Damaged buttons are more prone to develop Alternaria
Post-Storage

Dump after storage
Eliminate rots

Washer

Imazalil
Thiabendazole
SOPP

Fungicides
In WAX

Box or carton packing

Water rinse

Dryer

Labeling and Sizing

Source: J. Smilanick

Color Sorting

Volume Fill

Storage Up to 150 days

Source: J. Smilanick
How preharvest factors may influence fruit quality

- Development and maturation
- Physical effects on quality and packout
- Susceptibility to physiological and pathological breakdown
Peteca, Maturity and Rainfall

Undurraga M., Olaeta C., Retamales A., Brito P., 2006

Rootstock/Scion Effects:

- **Production**
  - number of fruit
  - fruit size

- **Fruit composition**
  - SSC, TA
  - Rind thickness
  - Rind Oil content

- **Postharvest Disorders**
  - Rindstain
The influence of rootstock on juice content (M. Roose)

Planting design and pruning
**Irrigation**

- Frequency and amount may influence fruit number and size
- Good irrigation practices especially important during bloom and Stage 1 growth
- May play a role in navel end splitting
- May influence SSC and juice content
- Fruit turgidity (internal water pressure) is important in oleocellosis

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**Rind oil spotting of desert lemons**

Related to fruit turgor pressure at harvest - more turgid; more damage
Plant Nutrition

- Nitrogen (N) fertilization (rate and timing) likely has the greatest impact on citrus quality
- Adequate P and K are required for high fruit quality particularly the rind

High Nitrogen

- Delayed coloring
- Thicker rind
- Coarser rind
- Increased staining of navel orange
- Increased valencia re-greening
Potassium can influence peel thickness and juice content

*Embelton and Jones, HortScience, 1966*

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**Effects of phosphorus on valencia orange fruit quality**

*Aquatibia ranch, 1962*

>0.18%  0.13 - 0.14%  0.11 - 0.12%

*Leaf analysis*
Effects of nitrogen and phosphorus on navel orange fruit quality

Embelton and Jones, 1956 - Yr 6 of 10 yr study