Quarantine Treatments

Postharvest Control of Insects & Other Pests

Mark Ritenour
Indian River Research and Education Center, Fort Pierce

Jeff Brecht
Horticultural Science Department, Gainesville
Quarantine Pests

“A quarantine pest is a plant pest of potential economic importance to an area that is not yet present there or that is present but not widely distributed and officially controlled.”

Follett & Neven, 2006
Overview

• World trade in agricultural commodities continues to increase

• Phytosanitary restrictions protect the agriculture in a region – Keeps bad bugs out
  – Should be based on a risk assessment, and not a zero risk
  – Should be based on scientific data, and not politics

• At times, phytosanitary regulations, without sound scientific support, are used as trade barriers
Overview

• If accepted disinfestation measures are not available, quarantine pests will prohibit marketing of fresh agricultural products
  – Between countries
  – Between geographical areas within countries (e.g., between Florida and other states)
Overview

- Quarantine or phytosanitary treatments eliminate, sterilize, or kill regulatory pests in exported commodities to prevent their introduction and establishment to new areas.
Treatments

- Treatment protocols are under the authority of the USDA Animal and Plant Health Inspection Service (APHIS)

- This includes overseeing treatment application
Treatments

• Phytosanitary restrictions
  – Often a very high degree of insect control is required before commodities are allowed in
  – “Probit 9 mortality” = the treatment kills or sterilizes 99.9968% of the insect pests
    • ~3 survivor in 100,000 insects, or no survivors in 93,613 insects

• See http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/treatment.pdf for a list of approved treatments
Treatments Protocol Strategy

1. Kill the most resistant life stage of the pest (insect, etc.)
2. Cause NO physiological injury to the host commodity

• That’s a TALL order! And it doesn’t always work...
Unfortunately for Fresh Produce

• The most important aspect of any treatment(s) is
  – Preventing pest introductions
  – NOT on the impacts of those treatments on product quality!

https://www.researchgate.net/publication/330945775_Citrus/figures?lo=1
Treatments

- Postharvest quarantine treatment factors are related to horticultural commodity differences
  - Maturity
  - Variety
  - Source
  - Handling procedures
  - Cost
Treatments

• Chemical
  – Fumigation
  – Detergent washes
  – Insecticides

• Physical
  – Temperature
    • Cold treatments
    • Heat treatments
  – Irradiation
  – Controlled Atmospheres
Fumigation

• **Most common** type of postharvest insect control
  – both for disinfestation & storage
• Often **easy to use and relatively inexpensive**
• Future availability of some fumigants is **questionable**
  – Human health issues
  – Environmental impacts
Methyl Bromide (MeBr)

- Most commonly used (general biocide)
- Under the Montreal Protocol (UN treaty):
  - 2005 phase out for developed countries
  - 2015 phase out for developing countries
  - Quarantine treatments & “critical uses” are exempt
- In general, there is a time temperature relationship
  - Higher temperatures require shorter exposure to the fumigant
Commodities approved for methyl bromide fumigation:

<table>
<thead>
<tr>
<th>grape</th>
<th>sweetpotato</th>
<th>yam</th>
</tr>
</thead>
<tbody>
<tr>
<td>avocado</td>
<td>cut flowers</td>
<td>root crops</td>
</tr>
<tr>
<td>citrus</td>
<td>ornamentals</td>
<td>beans/lentils</td>
</tr>
<tr>
<td>pome fruit</td>
<td>leafy vegetables</td>
<td>berries</td>
</tr>
<tr>
<td>stone fruit</td>
<td>okra</td>
<td>celery</td>
</tr>
<tr>
<td>tomato</td>
<td>asparagus</td>
<td>cucumber</td>
</tr>
<tr>
<td>garlic/onion</td>
<td>kiwifruit</td>
<td>melons</td>
</tr>
<tr>
<td>pineapple</td>
<td>squash</td>
<td>sweetcorn</td>
</tr>
<tr>
<td>nuts</td>
<td>banana/plantain</td>
<td>potato</td>
</tr>
</tbody>
</table>
Phosphine

• Used limited to dried fruit and nuts
  – Fresh commodities often injured
• Slower to act than MeBr and does not penetrate as well
• On dried products, its use is often alternated with MeBr
• Phosphine is a potential carcinogen & its future is in doubt
Hydrogen Cyanide (HCN)

- Many commodities are injured by HCN exposure
- HCN is also very hazardous to people
- Thus, HCN is not used very often
  - Has been used for citrus
Physical Treatments
Temperature

• **Advantages:**
  – No residue left on the commodity
  – Relatively safe for workers

• **Disadvantages:**
  – Possible product injury
  – Higher energy costs
  – Treatment times potentially longer
Cold Treatments

• Approved for a variety of insects on many commodities

• Most effective on insects from subtropical and tropical environments
  – However, crops from these areas are chilling sensitive
  – Potential used of other conditioning treatments to help protect the crops from CI
Commodities approved for cold treatment:

- Plum
- Nectarine
- Peach
- Apricot
- Apple
- Pear
- Grape
- Citrus
- Pomegranate
- Persimmon
- Passionfruit
- Kiwifruit

Schedule varies with target pest
## Example Cold Treatment Protocol (Mediterranean Fruit Fly)

<table>
<thead>
<tr>
<th>Days</th>
<th>Temperature*</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0°C (32°F)</td>
</tr>
<tr>
<td>11</td>
<td>0.55°C (33°F)</td>
</tr>
<tr>
<td>12</td>
<td>1.11°C (34°F)</td>
</tr>
<tr>
<td>14</td>
<td>1.66°C (35°F)</td>
</tr>
<tr>
<td>16</td>
<td>2.22°C (36°F)</td>
</tr>
</tbody>
</table>

*Maximum allowable temperature*
Cold treatments can be applied during marine transport

However, if the temperature exceeds the maximum allowable, even by a fraction a degree at one reading, the treatment must be started over
## Conditioning Treatments
(for chilling sensitive commodities)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Duration</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapefruit</td>
<td>3-7 days</td>
<td>10-30</td>
</tr>
<tr>
<td>Mango</td>
<td>1-4 days</td>
<td>36-40</td>
</tr>
<tr>
<td>Tomato</td>
<td>&lt;60 minutes</td>
<td>40-55</td>
</tr>
<tr>
<td>Avocado</td>
<td>10 hours</td>
<td>38</td>
</tr>
</tbody>
</table>
Heat Treatments

• Hot water dips, vapor heat, and high-temperature forced air treatments
  – e.g., mango, lychee, papaya, citrus

• Vapor heat was one of the first postharvest insect control methods (1920’s)
Heat Treatments

• Often shorter treatments than cold treatments
  – Size of commodity will affect the rate of heating
  – Therefore, different protocols may exist for different varieties of the same commodity or the same variety produced in different countries.
Mango Hot Water Treatment

- Min. pulp temp. at start of tmnt. 21°C (70°F)
- Fruit must be submerged >4 inches
- Water must circulate constantly and be min. of 46.1°C (115°F)
- Duration 65 to 90 min. depending on fruit origin, size and shape (variety)
- Fruit may be hydocooled after hot water tmnt. in water that is max. of 21°C (70°F)
- If hydrocooled: a) wait 30 minutes, or b) hot water treatment must be extended 10 minutes
Mango Hot Water Treatment

1. Arrival
2. Inspection
3. Pre-sizing
4. Screened treatment area
5. Hot water treatment
6. Hydrocooling
Examples of Fruit Injury

- Hot water treatment of mangos (various fruit fly species)

Internal cavitation

Scald
Irradiation Treatments

• Gamma rays
  – Isotopic sources: cobalt-60 or cesium-137

• X-rays
  – Electrically driven machine source

• Electrons from E-beam
Irradiation Treatment

• Irradiation is approved for fruits and vegetables up to 1,000 Grays (Gy) (FDA 1986)

• APHIS requires generic minimum doses of 70-400 Gy for various Tephritid fruit flies and other arthropod plant pests
  – ‘Generic’ in that the required dose is not dependent on the commodity that is being treated, just the pest
Types of radiation

- Alpha rays
- Beta rays
- X-rays
- Gamma rays
- Neutron rays

PAPER
- Stops α-rays

ALUMINUM
- Stops β-rays

LEAD
- Stops X-rays and γ-rays
- Stops neutron rays

WATER
- Stops neutron rays
Irradiation Treatments

• Insect sterilization often requires doses < 300 Gy

• Decay control (esp. fungi) often requires doses > 1,000 Gy

• For required levels of irradiation to the center of pallets, outside product must receive 2-3X the minimum C60 or Cs137 dose

• E-beam requires treatment of individual cartons
Sterilizing Dose versus Lethal Dose

- Sterilization Dose
  - 150 Gy for fruit flies
  - 300 Gy for other insects
- Lethal Dose - varies with species
  - 750 - 1000 Gy
Irradiation Treatments

• When irradiation is used to sterilize insects, the receiving country must trust the exporters that the live insects they see are really harmless

• Social considerations:
  – US consumers are accepting more. Acceptance by other countries (not Japan, limitations for EU)?
  – Acceptance of irradiation facilities?
Irradiation Effects on Ripening and Senescence

- Inhibits ripening of subtropicals and tropicauls at 250-350 Gy
- Accelerates lemon degreening at >500 Gy
- May see uneven ripening and accelerated deterioration after treatment
Relative tolerance of selected commodities to doses <1000 Gy

<table>
<thead>
<tr>
<th>Minimal damage</th>
<th>Inconsistent results</th>
<th>Significant damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Apricot</td>
<td>Avocado</td>
</tr>
<tr>
<td>Cherry</td>
<td>Banana</td>
<td>Cucumber</td>
</tr>
<tr>
<td>Guava</td>
<td>Citrus</td>
<td>Grape</td>
</tr>
<tr>
<td>Longan/rambutan</td>
<td>Fig</td>
<td>Green bean</td>
</tr>
<tr>
<td>Mango</td>
<td>Litchi</td>
<td>Olive</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>Pear</td>
<td>Pepper</td>
</tr>
<tr>
<td>Papaya</td>
<td>Pineapple</td>
<td>Sapodilla</td>
</tr>
<tr>
<td>Peach/nectarine</td>
<td>Plum</td>
<td>Squash</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Loquat</td>
<td>Soursop</td>
</tr>
<tr>
<td>tomato</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Examples of injury (<1000 Gy) which may occur with storage

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Type of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>Internal browning; skin discoloration</td>
</tr>
<tr>
<td>Lemon / Limes</td>
<td>Formation of cavities along segment walls</td>
</tr>
<tr>
<td>Oranges / Grapefruit</td>
<td>Peel damage, including pitting</td>
</tr>
<tr>
<td>Table Grapes</td>
<td>Stem darkening</td>
</tr>
<tr>
<td>Peppers</td>
<td>Calyx discoloration; accelerated discoloration</td>
</tr>
</tbody>
</table>
Considerations pertaining to adoption of irradiation

- Some hosts are injured at <1000 Gy
- Sterilization dose vs. lethal dose
- Dosimetry
- Not a substitute for good handling
- Cost and Logistics
- Social Issues
Controlled Atmospheres

• CA quarantine treatments involve raising the level of CO$_2$ and/or lowering the level of O$_2$ in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality
Controlled Atmospheres

- Insects vary in susceptibility to CA
- Commodities tend to tolerate low $O_2$ better than high $CO_2$
  - $>60\% CO_2$ and/or $<0.5\% O_2$ appear to be the best treatments
- Treatment duration is temperature dependent (higher temps = shorter duration)
- May be used in combination with heat or cold to reduce the duration of the lethal treatment and help maintain commodity quality
- Could be applied during marine transport
Waxes and Other Coatings

- Presence of coatings can have dramatic effects on responses to quarantine treatments
- Probably due to internal tissue modified atmosphere effects
Alternative Methods

• **Systems Approach**
  – Integration of numerous biological & physical factors with operational procedures to provide overall quarantine security
    • Can be time-consuming & costly to develop
  – Developed so that if one of the mitigating measures fail, built in safeguards keep the overall risk to negligible levels

• **Eradication**
  – Removal of all target pests from a geographical area, with little chance of normal re-infestation
Alternative Methods

- Declaration as a **Nonhost** for all or part of its growth cycle
  - E.g., Unblemished, mature green ‘Cavendish’ bananas from Hawaii can be harvested and shipped to the mainland as a nonhost commodity even though ripe bananas are a preferred host for fruit flies
    - Fruit flies will not lay eggs on mature green bananas
  - This can be difficult because the physiological basis for host non-preference or non-suitability by a pest is often not understood
Alternative Methods

• Establishment of Pest Free Areas (PFAs)
  – Officially identified or established areas in which a target pest does not occur and is maintained as such
  – The identity of the commodity must be maintained throughout to prevent mixing with non-certified product
  – Enhanced by geographic (e.g., mountains or large bodies of water) or temporal (i.e., developmental period of susceptibility) barriers
Experimental Treatments

• New fumigants
  – E.g. methyle iodide, carbonyl sulfide, sulfuryl fluoride, & ozone

• New temperature treatments
  – E.g. used of radio frequency (RF) & conditioning treatments

• Hyperbaric pressure & Vacuum