Postharvest Quarantine Treatments for Insect Control

The goal of phytosanitary regulations

- To prevent entry and establishment of exotic or non-indigenous organisms that pose a risk to plant life or health

- Entry or establishment must be prevented

- Systems approach may employ independent mitigation measure targeting both entry and establishment
APHIS
Animal & Plant Health Inspection Service

• A branch of the USDA

• Responsible for regulating the import/export and movement within the US of commodities that are subject to quarantine restrictions

Development of Phytosanitary Regulations

• Assessment of Risk
• Systems Approach
• Treatment Schedules
What is a “Systems Approach”?

- “[A] defined set of phytosanitary procedures, at least two of which have an independent effect in mitigating pest risk associated with the movement of commodities.” (Plant Protection Act)

- “The integration of different pest risk management measures, at least two of which act independently, and which cumulatively achieve the desired level of phytosanitary protection.” (UN, FAO 2001)

Steps in the development of “System Approach” Strategies

Step 1
- Pest Harm Identification
- Impact Analysis; Quarantine Pest Identification and Pest Risk Assessment

Step 2
- Selection of Risk Mitigation Measures
- Selection of Enforcement Instruments

Step 3
- Review, Evaluation and Adjustment
Strategies used in a Systems Approach

- Pest Free Zones
- Non-host Status
  - Harvest maturity
  - GA sprays - susceptibility to infestations
- Inspection/certification
- Physical Commodity Treatments

Packaging

Containment

Inspection and Certification
Physical commodity treatments

The Desired Level of Control

With the exception of Irradiation the goal of any phytosanitary treatment is to achieve Probit 9 Control

Probit 9:
Treatment should result in 99.9968% mortality of target pest

3 survivors per 100,000 treated
Treatment Schedules for Fruits and Vegetables

- Methyl Bromide Fumigation
- Water Treatment
- High Temperature Forced Air
- Pest Specific/Host Variable
- Irradiation

- Vapor Heat
- Cold Treatment
- Fumigation + Refrigeration of Fruits
- Cold Treatment + Fumigation of Fruits
- Quick Freeze

T101 - Methyl Bromide Fumigation
What is fumigation?

Fumigation is the act of releasing and dispersing a toxic chemical so it reaches the target organism in a gaseous state.

Chemicals applied as aerosols, smokes, mists, and fogs are suspensions of particulate matter in air and are not fumigants.

Methyl Bromide

- Widely used - primary quarantine fumigant
- General Biocide - Very effective
- Inexpensive
- Easy to use
Methyl bromide: the issue

Politics
Economics
Science

Fumigants

- Methyl Bromide – CH₃Br
- Phosphine (Cytec®) – PH₃
- Sulfuryl Fluoride (Dow®) – SO₂F₂

- Methyl Iodide – CH₃I
- Carbonyl Sulfide – COS
- Ozone – O₃
- Ethyl Formate
- Ethanedinitrile
- Ammonia
Current Ways to Use Methyl Bromide

• As a “Quarantine” treatment for commodities being imported/exported from foreign countries or inter-state within the U.S.
• As a condition of “Pre-shipment” - treated within 21 days of shipment.
• As granted by the Parties to the Montreal Protocol under the “Critical Use Exemption” (CUE) provisions of the Montreal Protocol - done on a yearly basis.

Methyl Bromide fumigation treatment dependent on:

• Host
• Pest
• Temperature
• Duration
• Aeration time
Selected commodities approved for Methyl Bromide Fumigation (T101)

- grape
- avocado
- citrus
- stone fruit
- pome fruit
- chestnut
- macadamia
- almond
- walnut
- cut flowers
- okra
- asparagus
- corn
- root crops
- ornamentals
- leafy veg.
- beans/lentils

Schedule varies with target pest

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T101-s-1

**Cherry**

Pest: *Rhagoletis indifferens* (Western cherry fruit fly) and *Cydia pomonella* (codling moth)

Treatment: **T101-s-1** MB at NAP—chamber only

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Dosage Rate (lb/1,000 ft³)</th>
<th>Exposure Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°F or above</td>
<td>2 lbs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>60-69°F</td>
<td>2.5 lbs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>50-59°F</td>
<td>3 lbs</td>
<td>2 hrs</td>
</tr>
<tr>
<td>40-49°F</td>
<td>4 lbs</td>
<td>2 hrs</td>
</tr>
</tbody>
</table>

Note the temperature x dosage relationship

Source: APHIS Treatment Manual
Stippling on surface of stone fruits

Lenticel damage on avocado and enhanced chilling susceptibility

Physical Treatments

Water Treatments (T102)
Heat
- Hot Water Immersion (T102)
- Vapor Heat (T106)
- Forced Hot Air (T103)
Cold Treatment (T107)
Irradiation (T105)
Water Treatments (T102)
Non-heated

Soapy Water and Wax
- Cherimoya, Limes,
- Passionfruit from Chile
- Chilean false spider mite of grapes

Warm Soapy Water and brushing
- Durian and other large fruits such as breadfruit for external feeders

Heat Treatments

Generally based on maintaining the plant material at a specific temperature for a specified time; designed to kill plant pests without destroying or appreciably devaluing the infested commodity
Fruit Heat Tolerance

Goal:
Heat fruit fast without damaging quality yet controlling target pest

Considerations:
Heating Method
Treatment Temperature

What is the fastest way to heat a commodity?

<table>
<thead>
<tr>
<th>Heating</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water immersion</td>
<td>*****</td>
</tr>
<tr>
<td>Forced Vapor (wet surface)</td>
<td>*****</td>
</tr>
<tr>
<td>Forced Moist Air (surface dry)</td>
<td>***</td>
</tr>
</tbody>
</table>
Hot Water Treatments

**Principle**

Uses heated water to raise the temperature of the commodity to the required temperature for a specified period of time. Primarily used for fruit fly hosts.

**Schedules**

The time-temp relationship varies with commodity and the pest. Typically, pulp temp is raised to between 115 - 118F (46.1 - 47.8C) for a specified period of time.
**Water Treatments (T102)**

*Heated*

**Hot Water Immersion**
- 49°C (120.2°F) for 20”
- Litchi/Longan from HI - MFF, OFF
- Limes for mealybugs

**Hot Water Dip**
- Mango for MFF and MexFF; Anastrepha spp.

All require product to be submersed at least 4” below water surface.

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**Hot Water Treatment - Mango**

Duration of treatment dependent on:
- country of origin; target pest species; fruit variety and fruit size
- Pulp temperature must be at least 21°C (70°F) at start of treatment
- Fruit must be submerged at least 4” below water surface
- Water must circulate constantly
- Water must be kept at least at 46.1°C (115°F)

**TABLE 5-2-2: Determine Dip Time Based on Origin of Fruit**

<table>
<thead>
<tr>
<th>If the origin of the fruit is:</th>
<th>And the shape of the fruit is:</th>
<th>And the weight is (grams):</th>
<th>Then dip:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico or Central America (north of and including Costa Rica)</td>
<td>Flat, elongated varieties²</td>
<td>Up to 375 grams</td>
<td>65 minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>376 to 570 grams</td>
<td>75 minutes</td>
</tr>
<tr>
<td></td>
<td>Rounded varieties¹</td>
<td>Up to 500 grams</td>
<td>75 minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>501 to 700 grams</td>
<td>90 minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>701 to 900 grams</td>
<td>110 minutes</td>
</tr>
</tbody>
</table>

Source: APHIS Treatment Manual
Vapor Heat (T106)

**Principle**

Uses air saturated with water vapor to raise the temperature to a required point and hold the temperature for a specified period.

The latent heat released by the condensation of the vapor raises the pulp temperature quickly and thus prevents damage.

In application, a fine mist and air under forced circulation is present with saturated vapor.

Primarily used for fruit fly hosts.

**Schedules**

The time-temp relationship varies with commodity and the pest.

Typically, pulp temp is raised to 43.3–44.4°C (110–112°F) during a period of 6 - 8 hours and then holding for a specified amount of time.

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**Example of Vapor Heat Treatment**

**T106-a**

Various Commodities from Mexico: Clementine (T106-a-1), Grapefruit (T106-a-2), Mango (Manilla variety only; T106-a-3), Orange (T106-a-4)

**Pest:** Anastrepha spp. (includes Mexican fruit fly, A. ludens)

**Treatment:** T106-a Vapor heat

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Up Time</td>
<td>8 hours</td>
</tr>
<tr>
<td>Heat Up Recording Interval</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Minimum Air Temperature</td>
<td>N/A</td>
</tr>
<tr>
<td>Minimum Pulp Temperature at End of Heat Up</td>
<td>43.3 °C/110.0 °F</td>
</tr>
<tr>
<td>Dwell Time</td>
<td>6 hours</td>
</tr>
<tr>
<td>Dwell Recording Interval</td>
<td>5 minutes</td>
</tr>
<tr>
<td>Cooling Method</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: APHIS Treatment Manual
High Temperature Forced Air (T103)

Principle
Really a modification of Vapor Heat
Maintain dew point temp of chamber 2C cooler than fruit surface temp to avoid condensation.
Based solely upon center pulp temperature of the fruit.
Primarily used for fruit fly hosts

Schedules
The time-temp relationship varies with commodity and the pest.
Can have rapid or slow ramping
Fruit should be sized
Typically, pulp temp is raised to 44-48°C (111.2–118°F) then held for a specified dwell time
Cooling after treatment – Forced air or hydrocooling

Example of High Temperature Forced Air

T103-c-1
Mango from Mexico
Pest: Anastrepha ludens (Mexican fruit fly), Anastrepha obliqua (West Indian fruit fly), and Anastrepha serpentina (black fruit fly)
Treatment: T103-c-1 High temperature forced air

<table>
<thead>
<tr>
<th>Heat Up Time:</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Up Recording Interval:</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Minimum Air Temperature:</td>
<td>90.0 °C/194.0°F</td>
</tr>
<tr>
<td>Minimum Pulp Temperature at End of Heat Up:</td>
<td>48.0 °C/118.0°F</td>
</tr>
<tr>
<td>Dwell Time:</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Dwell Recording Interval:</td>
<td>2 minutes</td>
</tr>
<tr>
<td>Cooling Method:</td>
<td>Forced air or Hydrocooling</td>
</tr>
<tr>
<td>Size Restrictions:</td>
<td>Fruit weight must not exceed 1 1/2 lbs. (700 grams)</td>
</tr>
</tbody>
</table>

Source: APHIS Treatment Manual
Cold Treatment (T107)

- Treatments vary: -1 to 8 °C for days to months
- Tropical and subtropical pests are easier to kill
- Many commodities are chilling sensitive and will not tolerate treatment

- Preconditioning fruit
  - May increase tolerance
  - Conditioning temperature varies; difficult to predict
  - Conditioning period appears to be time and temperature linked

Can commodities be conditioned to tolerate cold treatment?
Can you successfully cold-treat avocado?

The fruit will respond positively to intermediate low temperature conditioning.

Work published by Hofman et al (2003) PBT and Woolf et al (2003) PBT demonstrated that following several days at 6-8°C will provide protection against peel damage during subsequent low temperature storage.

Success of conditioning is dependent on temperature (don’t want softening) and duration.

Temperature Range: 5-10°C
Duration: 3-5 days

Examples of Cold Treatment

**T107-a**

*Ceratitis capitata* and *C. rosa*
(Med FF, Natal FF)

Apple, Apricot*, Avocado, Blueberry, Cape Gooseberry, Cherry, Etnrog, Grape, Grapefruit, Kiwi, Lemon, Loquat, Litchi (Lychee), Nectarine, Orange, Ortanique, Peach, Pear, Persimmon, Plum*, Plumcot, Pomegranate, Pummelo, Quince, Sand Pear, Tangerine (includes Clementine)

Pest: *Ceratitis capitata* (Mediterranean fruit fly) and *Ceratitis rosa* (Natal fruit fly)

Treatment: T107-a Cold treatment

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Exposure Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>34°F (1.1°C) or below</td>
<td>14 days</td>
</tr>
<tr>
<td>35°F (1.6°C) or below</td>
<td>16 days</td>
</tr>
<tr>
<td>36°F (2.2°C) or below</td>
<td>18 days</td>
</tr>
</tbody>
</table>

**T107-b**

*Anastrepha ludens*
(Mex, FF)

Apple, Apricot*, Cherry, Etnrog, Grapefruit, Litchi, Longan, Orange, Peach, Persimmon, Plum*, Pomegranate, Tangerine (includes Clementine), White Zapote

Pest: *Anastrepha ludens* (Mexican fruit fly)

Treatment: T107-b Cold treatment

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Exposure Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>32°F (0.6°C) or below</td>
<td>18 days</td>
</tr>
<tr>
<td>34°F (1.1°C) or below</td>
<td>20 days</td>
</tr>
<tr>
<td>36°F (1.6°C) or below</td>
<td>22 days</td>
</tr>
</tbody>
</table>
Combination Treatments

- MB fumigation plus refrigeration
- Refrigeration plus MB fumigation
- Schedules Varies
- Limited number of commodities approved

Treatments for *Austrotortix* spp. and *Epiphyas* spp. (light brown apple complex), *Bactrocera tyroni* (QLD FF), *Ceratitis capitata* (Med FF) and other fruit flies

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Dosage Rate (lb/y,000 ft³)</th>
<th>Minimum Concentration Readings (xpages) At:</th>
</tr>
</thead>
<tbody>
<tr>
<td>50°F (10°C) or above</td>
<td>1.5 lbs</td>
<td>23</td>
</tr>
<tr>
<td>40.4°F (4.44 to 9.44°C)</td>
<td>2 lbs</td>
<td>30</td>
</tr>
<tr>
<td>Followed by cold treatment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Exposure Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>33°F (0.5°C) or below</td>
<td>21 days</td>
</tr>
</tbody>
</table>

TI08-b MB followed by cold treatment for Apple, Grape and Pear

TI09-d-1 Cold treatment followed by MB for Apple, Grape and Pear

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Dosage Rate (lb/y,000 ft³)</th>
<th>Minimum Concentration Readings (xpages) At:</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°F (21.1°C) or above</td>
<td>2 lbs</td>
<td>30</td>
</tr>
<tr>
<td>60 to 69°F (15.55 to 20.55°C)</td>
<td>2.5 lbs</td>
<td>36</td>
</tr>
<tr>
<td>40 to 59°F (4.44 to 25.0°C)</td>
<td>3 lbs</td>
<td>44</td>
</tr>
<tr>
<td>Followed by MB at MAP—Sapwood or clementine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Exposure Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>33°F (0.5°C) or below</td>
<td>25 days</td>
</tr>
</tbody>
</table>
Controlled Atmosphere Temperature Treatment Systems (CATTS)

- Approved for inclusion in APHIS Treatment Manual - January 2008
- Currently approved for commodities destined for EXPORT from US
- Other uses pending

Controlled Atmosphere Temperature Treatment Systems (CATTS)

- Combines forced moist or vapor hot air with controlled atmosphere
- Conducted in a chamber similar to a vapor heat or forced hot air chamber
- Atmosphere established first, then temperature
Controlled Atmosphere Temperature Treatment Systems (CATTS)

- Requires the following
  - Product at room temperature before treatment begins
  - Air speed equivalent to 1.3 - 2 m/s
  - Controlled atmosphere equivalent to 1% $O_2$ and 15% $CO_2$
  - Relative Humidity $\geq$ to 90%

Currently limited approval
- Nectarines/peaches, Apple, Sweet Cherry

Target Pests
- Codling moth, Oriental fruit moth, W. Cherry FF

Ramp Temperature
- Ranges from none to 24°C (75.2°F) per hour

Final Chamber Temperature
- Ranges from 45°C (113°F) to ranges 47°C (116.6°F)

Total Treatment Time
- Ranges from 25 minutes to 3 hours

Core Temperature
- Ranges from 42°C (107.6°F) to 44.6°C (112.3°F)

Time at Core Temperature
- 15 to 30 minutes
A methyl bromide alternative that may work for some commodities

USDA-APHIS facilitating the use of Irradiation (TASC meeting, 2012)

Treatment must be conducted at approved facilities.

Dose mapping required for each commodity and/or size. Different configurations, packaging and/or mixed commodities should also be mapped.

**Standards**

- Intl. Plant Protection Convention (ISPM 18) established guidelines
- ISPM Technical Panel on Phyto-sanitary Treatments: development of intl. recognized treatments
- ASTM International: ASTM F1355 - 06: Std. guide for Irradiation as treatment

**Regulations**

- 10/23/2002: Establishment of requirements for irradiation (Closely followed ISPM 18)
- 1/27/2006: Est. generic doses for all insects (400 GY) and for fruit flies (150 GY)
- 2007 – present
  - Approved for importation from several countries
  - Establish pest specific doses
## Regulations: Required Doses (Gy)

<table>
<thead>
<tr>
<th>Generic Dose</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>All fruit flies of the family Tephritidae</td>
<td>150</td>
</tr>
<tr>
<td>All insects except adults and pupae of the order Lepidoptera</td>
<td>400</td>
</tr>
<tr>
<td>Rhagoletis pomonella</td>
<td>60</td>
</tr>
<tr>
<td>Anastrepha ludens, Anastrepha obliqua, Anastrepha suspensa</td>
<td>70</td>
</tr>
<tr>
<td>Conotrachelus nemaphar</td>
<td>92</td>
</tr>
<tr>
<td>Anastrepha serpenite, Bactrocera jarvisi, Bactrocera tryoni, Ceratitis capitata, Copitania declora</td>
<td>100</td>
</tr>
<tr>
<td>Bactrocera cucurbitae, Aspidiotus destructor, Bactrocera dorsalis, Cylas formicarius, Euscepes postfasciatus, Omyphasana anastomolalis, Pseudaulacaspis pentagona</td>
<td>150</td>
</tr>
<tr>
<td>Cydia pomonella, Grapholita molesta</td>
<td>200</td>
</tr>
<tr>
<td>Cryptophlebia ombrodelta, Cryptophlebia illapida</td>
<td>250</td>
</tr>
<tr>
<td>Brevipalpus chilensis, Sternocheta mangiflorae</td>
<td>300</td>
</tr>
</tbody>
</table>

## Regulations: Eligible Commodities

<table>
<thead>
<tr>
<th>Country</th>
<th>Eligible Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>Eggplant, Okra, Pepper</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Abiu, Atemoya, Banana, Breadfruit, Capsicum spp., Carambola, Cucurbita spp., Dragon fruit, Eggplant, Jackfruit, Litchi, Longan, Mango, Mangosteen, Melon, Mirangga pods (Drumstick), Papaya, Pineapple, Rambutan, Sapodilla, Sweet Potato, Tomato, banana, star fruit, curry leaves</td>
</tr>
<tr>
<td>India</td>
<td>Mango</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Rambutan</td>
</tr>
<tr>
<td>Mexico</td>
<td>Carambola, Clementine, Grapefruit, Guava, Mango, Chile Manzano, Sweet Lime, Sweet Orange, Tangelo</td>
</tr>
<tr>
<td>Pakistan</td>
<td>Mango</td>
</tr>
<tr>
<td>South Africa</td>
<td>Grapes, Stone Fruit, Pears, Persimmons</td>
</tr>
<tr>
<td>Thailand</td>
<td>Litchi, Longan, Mango, Mangosteen, Pineapple, Rambutan, Dragon Fruit</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>Dragon fruit, Rambutan</td>
</tr>
</tbody>
</table>
Considerations pertaining to irradiation

- Many hosts are injured at <1000 Gy
- Sterilization dose vs. lethal dose
- Dosimetry
- Not a substitute for good handling
- Cost/Logistics
- Social Issues
Approaches for the future

- **Chemically-Based Alternatives**
  - New Fumigants/New Techniques
  - Volatile Identification/Mating Disruption
  - Emissions Control
- **Non-Chemical/Physical Alternatives**
  - Irradiation
  - Heat/Cold
  - Physical Control – Compression/Vacuum
  - RF Energy

Resource Information


- APHIS Treatment Manual and updates
  - Fruit and Vegetables Manual
  - Cut Flowers and Greenery
  - Export Program Manual
FAVIR Database

Fruits and Vegetables Import Requirements (FAVIR)

This online reference allows easy access to regulations and information pertaining to the importation of fruits and vegetables into the United States, its territories, and possessions.


Electronic Index of PPQ Trmts

Allows for searching by treatment schedule including commodity

https://manuals.cphst.org/Tindex/treatmentSearch.cfm