Phytosanitary Irradiation: Technology and Efficacy
Outline

• Irradiation Technology
• Insect Efficacy
• Phytosanitary Irradiation History
Background

Global trade of commodities
• New products for US consumers
• New export markets for US producers
• Exotic pests
Phytosanitary Treatment - Regulatory measure intended to prevent the introduction or spread of quarantine pests by killing or sterilizing pests with high efficacy.

Examples of Treatments:
- Irradiation
- Heat (44-48 °C)
- Cold (0-2 °C)
- Fumigation
Definitions & Concepts

Irradiation - The exposure of a substance to ionizing energy (radiation) for the purpose of achieving some desired technical benefit

- Food and agricultural products
  - phytosanitary treatment, shelf life extension, sprout inhibition, pathogen reduction
- Sterilization of medical products
- Materials modification
  - semiconducters, gemstone coloration, polymers
Irradiation (gamma, e-beam, X-ray) at typical energies for radiation processing WILL NOT cause any of the irradiated products to become radioactive or leave any radioactive residue.
Definitions & Concepts

Dose vs Absorbed Dose- Dose refers to the amount of ionizing radiation delivered; Absorbed dose refers to the quantity of radiating energy (in Gray) absorbed per unit of mass of a specified target.

Gray (Gy)- a unit of absorbed dose where 1 Gy is equivalent to the absorption of 1 joule per kilogram of the specified material (1 Gy = 1 J/kg)
## Typical Absorbed Dose Requirements

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Dose (Gray)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhibit Sprouting</td>
<td>50</td>
</tr>
<tr>
<td>Phytosanitary Irradiation</td>
<td>60-400</td>
</tr>
<tr>
<td>Pathogen Reduction (Meat and Poultry)</td>
<td>1,500</td>
</tr>
<tr>
<td>Spice Sanitation</td>
<td>6,500</td>
</tr>
<tr>
<td>Medical Device Sterilization</td>
<td>25,000</td>
</tr>
<tr>
<td>Food Sterilization (NASA)</td>
<td>46,000</td>
</tr>
</tbody>
</table>
Approved Irradiation Sources

**Gamma:** Cobalt 60 or Cesium 137 emits photons during decay

**E-beam:** High energy electrons propelled (particle beam) from an electron gun

**X-ray:** High energy electrons are converted to X-rays (photons)
Components of Irradiation Facilities

- Radiation source (gamma, x-ray, e-beam)
- Biological shield
- Product transport system
- Control and safety equipment
Gamma Irradiator (Cobalt 60)

Cherenkov radiation
E-beam Irradiator
X-Ray Irradiator
Dose Distribution - The spatial variation of absorbed dose throughout the process load, the dose having the extreme values $D_{\text{max}}$ and $D_{\text{min}}$.

Note: FDA limits fresh fruit and vegetable treatments to 1000 Gy

From www.teasystems.com/WhitePapers/WeirPW_DoseUniformity.htm
Insect Efficacy

The objective of using irradiation as a phytosanitary measure is to prevent the introduction and spread of plant pests. This can be realized by achieving certain responses in the target pest(s) such as:

- mortality
- preventing development
- sterility
- inactivation

Mortality is usually not the target response for phytosanitary irradiation treatments and live insects may remain after treatment.
Insect Efficacy

Effects of ionizing radiation on insect pests:
• Free radicals cause tissue damage
• Broken chemical bonds
• DNA damage can be fatal or prevent reproduction
Absorbed Doses Required for Sterility vs. Mortality

From Castro et al., 2004 and Hallman, 2003.
Phytosanitary Irradiation History

• 1986. US FDA approves irradiation of fruits and vegetables for insect disinfestation

• 1989. Approval of Hawaii papaya

• 1995. Hawaii produce exported with special permit

• 1996. USDA APHIS approves phytosanitary irradiation against fruit flies on any commodity
Phytosanitary Irradiation History

2002. Irradiation approved for all admissible fruits and vegetables from all countries to US

2004. Australian mangos to New Zealand

2006. USDA APHIS approves generic doses

2007. Thai mango to United States

2011. First Upon Arrival Irradiation Treatment

2015. First US exports of irradiated fruit
Generic vs. Specific Treatment

Generic
• Treatment covers multiple pests and commodities
• Subset of insects from group are tested

Specific
• Treatment applies to a single pest
• Often commodity-specific
• Single pest tested
APHIS Approved Irradiation Treatments, as of March 2017

<table>
<thead>
<tr>
<th>Pest</th>
<th>Dose (Gy)</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>Eggs and larvae of the family Tortricidae</td>
<td>290</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pest</th>
<th>Dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rhagoletis pomonella</strong></td>
<td>60</td>
</tr>
<tr>
<td><strong>Anastrepha ludens, Anastrepha obliqua, Anastrepha suspensa</strong></td>
<td>70</td>
</tr>
<tr>
<td><strong>Conotrachelus nenuphar</strong></td>
<td>92</td>
</tr>
<tr>
<td><strong>Anastrepha serpentina, Bactrocera jarvisi, Bactrocera tryoni, Ceratitis capitata, Copitarsia declora</strong></td>
<td>100</td>
</tr>
<tr>
<td><strong>Aspidiotus destructor, Cylas formicarius, Euscepes postfasciatus, Omphisa anastomosalis, Pseudaulacaspis pentagona, Bactrocera cucurbitae, Bactrocera dorsalis</strong></td>
<td>150</td>
</tr>
<tr>
<td><strong>Sternochetus frigidus</strong></td>
<td>165</td>
</tr>
<tr>
<td><strong>Cydia pomonella, Grapholita molest, Epiphyas postvittana</strong></td>
<td>200</td>
</tr>
<tr>
<td><strong>Cryptophlebia ombrodelta, Cryptophlebia illepida</strong></td>
<td>250</td>
</tr>
<tr>
<td><strong>Brevipalpus chilensis, Sternochetus mangiferae</strong></td>
<td>300</td>
</tr>
</tbody>
</table>
## Generic Treatments in Use

<table>
<thead>
<tr>
<th>Trading Partners</th>
<th>Commodity</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico to US</td>
<td>Citrus, manzano pepper, mango</td>
<td>150 Gy</td>
</tr>
<tr>
<td>India &amp; Pakistan to US</td>
<td>Mango</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Mexico to US</td>
<td>Guava</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Vietnam to US</td>
<td>Dragonfruit</td>
<td>400 Gy</td>
</tr>
<tr>
<td>Australia to New Zealand</td>
<td>Mango, papaya</td>
<td>250 Gy</td>
</tr>
<tr>
<td>Australia to New Zealand</td>
<td>Lychee</td>
<td>350 Gy</td>
</tr>
</tbody>
</table>

Concluding Thoughts

Benefits of PI

• Effective for many types of pests
• Minimal impact on commodity quality
• May be applied at diverse points post-harvest