IRRADIATION TREATMENT OPTIONS: SIZE MATTERS

Peter Follett
Research Entomologist
USDA-ARS
U.S. Pacific Basin Agricultural Research Center
Hilo, Hawaii
Overview

• Source of radiation
  • Isotope
  • E-beam
  • X-ray

• Size of irradiator
  • Large, medium, small
  • Technical objectives
  • Throughput requirements
  • Cost
Irradiation - The exposure of a substance to ionizing energy (radiation) for the purpose of achieving some desired technical benefit.

**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).

**Dose uniformity ratio (DUR)** – the ratio of the maximum to the minimum dose applied to the material
There are three approved radiation sources for phytosanitary treatment:

- **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)
Irradiation technology
Gamma, e-beam, or x-ray

- Ionizing radiation breaks chemical bonds within DNA and other molecules, disrupting normal cellular function.
- Insect response varies with species and life stage.
Dose Uniformity Ratio
Irradiation treatment efficiency

• US FDA approved irradiation doses up to 1000 Gy (1 kGy) for preservation and disinfestation.
• Maximum / minimum dose typically 1.5-3.0
• 400 Gy (generic dose) x 2.5 = 1000 Gy
• Advantageous to lower the dose:
  • Avoid problem of 1 kGy limit
  • Cost
  • Capacity
  • Quality
**Commercial irradiator - Requirements**

- Good penetration
  - Fruit boxes or pallets
  - Single layer of fruit
- Good dose uniformity ratio
  - Especially if 400 Gy, then $\leq 1$ kGy maximum
- Sufficient throughput
- Acceptable cost
- Reliable during continuous use
## Irradiator Size Matters

<table>
<thead>
<tr>
<th>Size</th>
<th>Boxes</th>
<th>DUR</th>
<th>Throughput</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Small</strong></td>
<td>Boxes</td>
<td>1.5</td>
<td>100s lbs/hr</td>
<td>$1 million</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td>Carrier</td>
<td>1.5-2.0</td>
<td>1000s lbs/hr</td>
<td>$3-10 million</td>
</tr>
<tr>
<td><strong>Large</strong></td>
<td>Pallet</td>
<td>2.5-3.0</td>
<td>10,000s lbs/hr</td>
<td>$10-30 million</td>
</tr>
</tbody>
</table>
Large multipurpose irradiator
Why might you be interested?

- Isotope, e-beam, x-ray
- Existing facilities can provide service
- High dose rate and throughput
- Versatile, larger products e.g. pallets
- Sterilization capability

But...
- Transportation
- Availability
- Dose uniformity issues
- If building your own:
  - High initial cost
  - Slow start up
Large multi-purpose pallet irradiator
Synergy Health (Thailand) Ltd.

Disposable medical devices – 70%
Food, fruit – 5%
If they treated only fruit: potential throughput of 17,500 lbs/hour
Medium scale irradiator
Why might you be interested?

- Isotope, e-beam, x-ray
- Lower initial cost
- Lower operating cost
- Smaller footprint
- Dedicated to one or a few products
- For fruit with no other treatment or sensitive to other treatments

But...
- Lower throughput

Hawaii examples:
- Hawaii Pride (x-ray)
- Pa’ina Hawaii (cobalt)
Hawaii’s commercial irradiators

< Hawaii Pride
- E-beam/X-ray source
- Started 2000
- Designed for fresh produce
- Expensive
- DUR = 1.4

Pa’ina Hawaii >
- Underwater cobalt source
- Started 2013
- Designed for fresh produce
- Relatively inexpensive
- DUR = 2.5, 1200 lbs/h
Medium-size x-ray irradiator for fruit

Hawaii Pride (Hawaii)
Medium-size cobalt Irradiator

Pa’ina Hawaii
Small cabinet x-ray irradiators
Why might growers be interested?

- Costs a fraction of a stand alone facility (<$1 million)
- Treat fruit the same day it’s packed – no transportation
- Moveable - ready-made for domestic quarantines
- Under grower’s control

- Methyl bromide alter.
- Can treat fruit cold
- Simple solution

Potential application:
- Sweet cherries to Australia and Mexico (80 Gy for SWD)
Small-scale cabinet x-ray irradiator

Sweet cherries

Designer: Randy Kirk
Applied Energy Devices

4-pi X-ray tube
Sweet cherry quality after x-ray

Demonstration tests

- Rad Source (Atlanta)
- Nutek (Hayward)
- Unique 4-Pi x-ray tube
- California ‘Bing’
- Oregon ‘Skeena’

Irradiation at:
- 0 (control)
- 150 Gy
- 400 Gy
Taste Test – Sambado’s

- 15 panelists
- ‘Skeena’
- 1-day after treatment
- Could not detect treatment differences
- 1 week later – same result

![Graph showing Degree of Liking vs Irradiation Dose (Gy)]
In-line irradiation

E-beam option

Cherry irradiation

Prima Frutta, Linden, Calif.

- High volume
  - 15,000 boxes per day
  - 1 box per 4 sec
- Keep fruit cold
- Short harvest
  - 2 months
  - Continuous use

Customize for packing line
Small-scale cabinet x-ray irradiator

**Papayas**

Comet AG
Flamatt,
Switzerland

X-ray emitter
At 180kV, 4.5kW and 10cm/min conveyor speed:
Min. dose: **78Gy**, max. dose: **109Gy**
DUR: **1.4**

- at **5cm/min**: Min. dose: **156Gy**, max. dose: **218Gy**
- at **1.95cm/min**: Min. dose: **400Gy**, max. dose: **559Gy**
- ➔ at **1.09cm/min**: Min. dose: **716Gy**, max. dose: **1000Gy**
Questions?
## Irradiator Size Matters

<table>
<thead>
<tr>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Boxes</td>
<td>• Carrier</td>
<td>• Pallet</td>
</tr>
<tr>
<td>• DUR 1.5</td>
<td>• DUR 1.5-2.0</td>
<td>• DUR 2.5-3.0</td>
</tr>
<tr>
<td>• Throughput 100s lbs/hr</td>
<td>• Throughput 1000s lbs/hr</td>
<td>• Throughput 10,000s lbs/hr</td>
</tr>
<tr>
<td>• Cost $1 million</td>
<td>• Cost $3-10 million</td>
<td>• Cost $10-30 million</td>
</tr>
</tbody>
</table>