Physiological effects of Phytosanitary Irradiation and impacts on fruit quality

NICSTAR 2018
March 5, 2018

Anuradha Prakash
Outline

• Goals of phytosanitary irradiation
• Effect on fruit quality and physiology
• Recent research findings on apples
• Functional benefits beyond phytosanitary impact
• Next steps and applications to other fruit
Phytosanitary Treatments

• Pest infestations on agricultural commodities
• Mitigation strategies include field measures, inspection, and phytosanitary treatments.
• Treatments:
  • Fumigation
  • Heat Treatment
  • Cold Treatment
  • Irradiation
International Standards

• International Plant Protection Convention (ISPM): ISPM 18 Guidelines for the Use of Irradiation as a Phytosanitary Measure

• ISPM Technical Panel on Phytosanitary Treatments (TPPT): Development of internationally recognized treatments.

• ASTM International: ASTM F1355 - 06 Standard Guide for Irradiation of Fresh Agricultural Produce as a Phytosanitary Treatment
Irradiation treatment endpoints

• Sterility

• Inability to emerge or Fly

• Inactivity or Devitalization

• Mortality
## Generic doses

<table>
<thead>
<tr>
<th>Pest group</th>
<th>Dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit flies</td>
<td>150</td>
</tr>
<tr>
<td>Insects*</td>
<td>400</td>
</tr>
<tr>
<td>Regulated pests*</td>
<td>400</td>
</tr>
<tr>
<td>A variety of insects**</td>
<td>250</td>
</tr>
<tr>
<td>Leafroller larvae, eggs</td>
<td>290</td>
</tr>
</tbody>
</table>

*some exceptions

**on lychee, mango, papaya
• Non-thermal treatment
• Phytosanitary doses are low!

Intrinsic factors:
• Fruit
• Variety
• Climacteric versus non-climacteric
• Maturity stage
• Composition
• Initial microbial load

Extrinsic factors:
• Dose
• Temperature
• Atmosphere/Packaging
• Handling
Fruit with high tolerance to phytosanitary doses

- Apples
- Blueberries
- Cherries
- Dragon fruit
- Figs
- Grapes
- Guava

- Longan
- Lychees
- Mangoes
- Papaya
- Peaches
- Pitaya
- Pomegranates
- Rambutan
Effect of irradiation on climacteric fruit

Delay in ripening
- Banana
- Papaya
- Mango
- Pear

• Treatment of immature fruit - greater delay of ripening
• Treatment of mature fruit - better quality

Acceleration of ripening
- Nectarines
- Peaches
California Apples

- Conventional phytosanitary treatments: fumigation (MeBr) and cold
- Market advantage of using irradiation
Gala apples

• Evaluate the impact of maturity stage at harvest on fruit quality and shelf-life

• Investigate the effect of irradiation at 250 Gy and 1000 Gy on *Gala* apples harvested at two maturity stages
Ethylene biosynthesis
Sensory: Difference test between control and 250 Gy

- Total number of panelists $\rightarrow$ 57
- Could correctly tell difference $\rightarrow$ 21
Gala versus Gala

California Gala apples 8 weeks

New Zealand Gala apples 400 Gy 10 weeks
Granny Smith

• Common Disorders
  • Storage scald
  • Internal browning
Superficial Scald

- Storage scald develops after 2-4 month cold storage and following 3 to 4 days of warming of the fruit
- Fumigation with MeBr induces scald
Role of diphenylamine (DPA)

• DPA reduces production of ethylene and hence, alpha-farnesene and conjugated trienes

• Issues with DPA
  • considered a health risk, EU has withdrawn authorization for DPA

• Role of irradiation
PI suppresses ethylene and elevates respiration rate

**Ethylene**

- Ethylene (µL kg\(^{-1}\) h\(^{-1}\))
- Storage days

**Respiration rate**

- CO\(_2\) (mL kg\(^{-1}\) h\(^{-1}\))
- Storage days

Graphs show the changes in ethylene and respiration rate over storage days for different treatments.
Alpha-farnesene

Storage days

Alpha-farnesene (nmol·1·Cm²)

CTRL-I  250 Gy  1000 Gy  CTRL-F  48-F

0  90 + 7
Fuji Apples
Results and Discussion

Ethylene Production

![Graph showing ethylene production over storage days for different radiation doses.](image)
ACC Oxidase

Results and Discussion

![ACC Oxidase Graph](image-url)
Results and Discussion

Electrolyte Leakage

Relative Electrolyte Leakage

Storage Time (Days)

Control
377 Gy
1148 Gy

0
7
14

0
2
4
6
8
10
12
14
16
18
20

Electrolyte Leakage Results and Discussion
Appearance: Fuji Apples

Control

1000 Gy
Firmness

Results and Discussion

<table>
<thead>
<tr>
<th>Storage Time (Days)</th>
<th>Area (N.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>377 Gy</td>
</tr>
<tr>
<td>1</td>
<td>1148 Gy</td>
</tr>
<tr>
<td>FUM</td>
<td></td>
</tr>
<tr>
<td>Ctrl-Fum</td>
<td>Cold</td>
</tr>
</tbody>
</table>

The graph shows the firmness measurements over different storage times and radiation treatments. The data points are marked with letters indicating significant differences among the treatments.
Irradiation

- Fuji Apple
- OH⁻
- O₂⁻
- Reactive Oxygen Species

Membrane Damage

Ethylene Production

- Malondialdehyde
- Electrolyte leakage
- Ethylene forming enzyme
- ACC Oxidase

Polygalacturonase

Pectin methyl esterase

Firmness

Cell wall radiolysis

Phenylalanine ammonia lyase

Polyphenol Oxidase

Browning

No Change

Respiration Rate

Sugar content

Organic acid

Sensory Quality

No Change

No Change
Explore in greater depth

• Longer storage studies to explore the impacts of lowered ethylene and increased respiration on surface scald and internal browning

• Effect on firmness
  • Enzyme production/activity
  • Pectin hydrolysis
  • Explore the variable response of different cultivars
Next Steps

• What causes the reduction in ethylene?
  • Gene expression of the enzyme or post-translational enzyme activity

• Can we predict fruit response?
• Can we use this data to identify cultivars most suited for treatment?
• Better yet, can we develop cultivars most suited for PI?
Thank you!

- USDA TASC
- California Apple Commission
- Prima Fruita
- Steritek

Anuradha Prakash
(714) 744-7826
prakash@chapman.edu
The Eighth Annual Chapman Phytosanitary Irradiation Forum 2018
June 13-15, 2018
Bangkok, Thailand

Register now:
www.chapman.edu/piforum

Thanks to our sponsors: