Electronic Cold Pasteurization to Extend Produce Shelf Life

Dr. Francisco Diez-Gonzalez
Director and Professor, Center for Food Safety

Business Operations Conference
2018
Outline

1. Technology overview
2. Regulatory framework
3. Effectiveness
4. Market
5. Benefits and consumer concerns
Technology Overview: Definitions

• Electronic Cold Pasteurization

• Pasteurization: mild heat treatment of foods with the purpose of killing spoilage and pathogenic organisms (99.999% kill) while preserving its quality and nutritional value
Technology Overview: Definitions

• **Electronic Cold Pasteurization**

• **Cold Pasteurization**: treatment of foods with the purpose of killing spoilage and pathogenic organisms in which the thermal energy has been replaced by other type of energy to minimize changes caused by heating
Technology Overview: Definitions

• **Electronic Cold Pasteurization**

• **Pasteurization** that uses **electron beams** as the energy to kill spoilage and pathogenic organisms (99.999% kill) while preserving its quality and nutritional value at low temperature
Technology Overview: Electron Beam

- Electron beam
  - Ionizing radiation involving moving particles
  - Electrons accelerated as beta particles
  - Generated by electron guns or accelerators
  - First electron guns developed for TV – 1920’s
  - Cathode ray tubes
Technology Overview: Electron Beam

- **Electron beam technology**
  - Linear electron accelerators developed in 1950’s
  - Multiple applications:
    - Welding
    - Polymer-crosslinking
    - Microscopy
    - Semiconductor
    - Medical devices and drug sterilization
    - Food processing (pasteurization, disinfestation)
Technology Overview: Electronic Cold Pasteurization

- Electron beam technology

Cathode Ray Tube
- 20 kilovolts (keV)
- < 10 micro amps.

Electron Accelerator
- > 5,000 keV
- 10,000 - 100,000 micro amps.
Technology Overview: 
Electronic Cold Pasteurization

- Treatment parameters
  - Radiation dose in kiloGrays (kGy)
  - Process delivers > 10 kGy
  - Beam penetrates 14 inches
Technology Overview: Electronic Cold Pasteurization

- Lethal effects of ECP

1. Free radicals break DNA

Taken from Lung et al. 2015
Technology Overview: Electronic Cold Pasteurization

• Lethal effects of ECP

2. Production of free radicals from water

(b) E-Beam

\[ \text{OH}^\cdot, \text{H}^\cdot, \text{HO}_2^\cdot, \text{H}_2\text{O}_2 \]

Hydroxyl radical, Hydrogen radical, Superoxide radical, Peroxide

Taken from Lung et al. 2015
Regulatory Framework: USA

• Food, Drug and Cosmetic Act of 1958

The term “food additive” means any substance the intended use of which results or may reasonably be expected to result, directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food (including any substance intended for use in producing, manufacturing, packing, processing, preparing, treating, packaging, transporting, or holding food; and including any source of radiation intended for any such use), if such substance is not generally recognized, among experts qualified by scientific training and experience to evaluate its safety, as having been adequately shown through scientific procedures.
Regulatory Framework: USA

• Consequence: all irradiated foods are considered adulterated until proven otherwise

• Exemptions are granted through regulations
Regulatory Framework: USA

• Code of Federal Regulations, Title 21, Part 179 “Irradiation in the Production, Processing and Handling of Food”

179.26 “Ionizing radiation for the treatment of food”

(a) Energy sources. Ionizing radiation is limited to:

(1) Gamma rays from radionuclides Co-60 or Ce-137
(2) Electrons generated from machine sources < 10 meV
(3) X rays generated from machine sources < 7.5 meV
Regulatory Framework: USA

179.26 “Ionizing radiation for the treatment of food”

(b) Limitations:

<table>
<thead>
<tr>
<th>Food or application</th>
<th>Approval year</th>
<th>Limitation dose (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat disinfestation</td>
<td>1963</td>
<td>0.5</td>
</tr>
<tr>
<td>Sprouting inhibition potatoes</td>
<td>1964</td>
<td>0.15</td>
</tr>
<tr>
<td>NASA Food Sterilization</td>
<td>1960</td>
<td>Minimum 44</td>
</tr>
<tr>
<td><em>Trichinellae</em> in pork</td>
<td>1985</td>
<td>0.3 – 1.0</td>
</tr>
<tr>
<td>Herbs, seeds and spices</td>
<td>1986</td>
<td>30</td>
</tr>
<tr>
<td>Poultry</td>
<td>1990</td>
<td>4.5 fresh, 7.0 frozen</td>
</tr>
<tr>
<td>Beef</td>
<td>1997</td>
<td>4.5 fresh, 7.0 frozen</td>
</tr>
<tr>
<td>Fresh shell eggs</td>
<td>2000</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Regulatory Framework: USA

179.26 “Ionizing radiation for the treatment of food”

(b) Limitations:

<table>
<thead>
<tr>
<th>Food or application</th>
<th>Approval year</th>
<th>Limitation dose (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fruits and vegetables</td>
<td>1986</td>
<td>1.0</td>
</tr>
<tr>
<td>Seeds for sprouting</td>
<td>2000</td>
<td>0.5</td>
</tr>
<tr>
<td>Fresh iceberg lettuce and spinach</td>
<td>2008</td>
<td>4.0</td>
</tr>
</tbody>
</table>
Regulatory Framework: World

1961 – FAO/WHO started evaluating the technology
1964 – a joint FAO/IAEA/WHO Committee was formed
1969 – granted temporary approval to potato irradiation
1976 – approval of irradiation of potatoes, strawberries, papaya, wheat and chicken irradiation
1984 – 28 countries had approvals for one or more fruits and vegetables
## ECP Effectiveness on Shelf-Life: Scientific Evidence

<table>
<thead>
<tr>
<th>Fresh produce</th>
<th>Dose (kGy)</th>
<th>Shelf-life (SL) and quality results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberries</td>
<td>1.0, 2.0</td>
<td>Irradiated samples were softer</td>
<td>Yu et al. 1996</td>
</tr>
<tr>
<td>Broccoli</td>
<td>1.0, 2.0, 3.0</td>
<td>No difference, SL extended</td>
<td>Gomes et al. 2008</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>0.5, 1.0</td>
<td>SL extended one week, better flavor of treated samples</td>
<td>Boyton et al. 2006</td>
</tr>
<tr>
<td>Mango</td>
<td>1.0 – 3.1</td>
<td>Delayed ripening; no difference in phenolics; induced flesh pitting</td>
<td>Reyes &amp; Cisneros-Ceballos 2007</td>
</tr>
<tr>
<td>Blueberries</td>
<td>1.0 – 3.2</td>
<td>A 1.6 kGy dose was satisfactory to maintain sensory characteristics</td>
<td>Moreno et al. 2007</td>
</tr>
<tr>
<td>Baby spinach</td>
<td>0.7 – 1.4</td>
<td>SL extended; spoilage organisms reduced; sliminess reduced</td>
<td>Neal et al. 2010</td>
</tr>
<tr>
<td>Tomato, lettuce, cantaloupe seeds</td>
<td>7.0</td>
<td>No effect on germination rate</td>
<td>Trinetta et al. 2011</td>
</tr>
</tbody>
</table>
## ECP Effectiveness on Microorganisms: Scientific Evidence

<table>
<thead>
<tr>
<th>Fresh produce</th>
<th>Dose (kGy)</th>
<th>Microorganisms</th>
<th>Key findings, microbial reductions</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage</td>
<td>1.0, 2.3, 4.0</td>
<td>Total plate count <em>E. coli</em> K-12</td>
<td>Undetectable &gt; 7 Log CFU/g</td>
<td>Grasso et al. 2011</td>
</tr>
<tr>
<td>Baby spinach</td>
<td>0.2 – 1.25</td>
<td><em>Salmonella</em> and <em>Listeria</em> spp.</td>
<td>5 Log CFU/g</td>
<td>Gomes et al. 2011</td>
</tr>
<tr>
<td>Tom., let. &amp; cantal. Seeds</td>
<td>7.0</td>
<td><em>Salmonella</em></td>
<td>4.4 Log CFU/g</td>
<td>Trinetta et al. 2011</td>
</tr>
<tr>
<td>Lettuce and spinach</td>
<td>1.5 – 5.0</td>
<td>Poliovirus, Rotavirus</td>
<td>3 kGy reduce risk by 100 fold</td>
<td>Espinosa et al. 2012</td>
</tr>
<tr>
<td>Tom., let., cantal. &amp; spinach</td>
<td>0.2 - 0.9</td>
<td><em>Salmonella</em> LT-2, <em>E. coli</em> K-12</td>
<td>Dose uniformity affects killing rate</td>
<td>Moreira et al. 2012</td>
</tr>
<tr>
<td>Crushed garlic</td>
<td>1.0, 4.0, 7.0</td>
<td>Molds, yeasts and total plate count</td>
<td>Reduced TPC more than 99.9% at 4.0 kGy</td>
<td>Kim et al. 2014</td>
</tr>
</tbody>
</table>
ECP Effectiveness: Practical Evidence

Control

ECP™ Treated

< 1.0 kGy

Day 12

(Provided by ScanTech Sciences, Inc.)
ECP Effectiveness: Practical Evidence

Control vs. ECP™ Treated: < 0.5 kGy

Day 12

(Provided by ScanTech Sciences, Inc.)
ECP Effectiveness: Practical Evidence

Control

ECP™ Treated < 1.0 kGy

Day 14

(Provided by ScanTech Sciences, Inc.)
ECP Effectiveness: Practical Evidence

Control

ECP™ Treated < 0.15 kGy

Day 63

(Provided by ScanTech Sciences, Inc.)
Market for ECP Treated Produce

• Domestic – Hawaiian produce

• Imported
  • Rapidly growing
  • Driven by limitations of traditional phytosanitary methods (cold, hot water, methyl bromide)
Market: Irradiated Produce from Hawaii

Volume (metric Tonnes)

2007 2008 2009 2010 2011 2012 2013 2014

Mostly purple sweet potato. Other fruits include: longan, rambutan, sweet basil, dragon fruit, papaya, etc.

http://foodirradiation.org/Hawaii.html
Market: Imported Irradiated Produce

Preclearance Totals (in kg)

<table>
<thead>
<tr>
<th>Year</th>
<th>India</th>
<th>Mexico</th>
<th>South Africa</th>
<th>Thailand</th>
<th>Vietnam</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>195,000</td>
<td>0</td>
<td>195,000</td>
</tr>
<tr>
<td>2008</td>
<td>276,000</td>
<td>262,000</td>
<td>0</td>
<td>2,440,000</td>
<td>121,000</td>
<td>3,099,000</td>
</tr>
<tr>
<td>2009</td>
<td>132,000</td>
<td>3,559,000</td>
<td>0</td>
<td>2,247,000</td>
<td>117,000</td>
<td>6,055,000</td>
</tr>
<tr>
<td>2010</td>
<td>94,000</td>
<td>5,672,000</td>
<td>0</td>
<td>1,540,000</td>
<td>754,000</td>
<td>8,060,000</td>
</tr>
<tr>
<td>2011</td>
<td>80,000</td>
<td>5,539,000</td>
<td>16,500</td>
<td>743,000</td>
<td>1,445,000</td>
<td>7,807,000</td>
</tr>
<tr>
<td>2012</td>
<td>217,500</td>
<td>8,349,500</td>
<td>16,500</td>
<td>937,500</td>
<td>1,764,500</td>
<td>11,286,500</td>
</tr>
<tr>
<td>2013</td>
<td>283,000</td>
<td>9,526,000</td>
<td>16,500</td>
<td>1,060,500</td>
<td>1,967,500</td>
<td>12,853,500</td>
</tr>
</tbody>
</table>

http://foodirradiation.org/pages/produce_import_update.html
Market: Imported Irradiated Produce

Volume of Irradiated Fruits (metric tons)

- Guava
- Longan
- Rambutan

Market: Imported Irradiated Produce

- Imports of Mexican phytosanitary irradiated fruits (tons)

<table>
<thead>
<tr>
<th>Fruit</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guava</td>
<td>257</td>
<td>3,521</td>
<td>9,121</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>0</td>
<td>67</td>
<td>101</td>
</tr>
<tr>
<td>Mango</td>
<td>0</td>
<td>35</td>
<td>239</td>
</tr>
<tr>
<td>Sweet lime</td>
<td>0</td>
<td>0</td>
<td>600</td>
</tr>
<tr>
<td>Manzano pepper</td>
<td>0</td>
<td>0</td>
<td>257</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>257</td>
<td>3,623</td>
<td>10,318</td>
</tr>
</tbody>
</table>

Hallman, 2011
ECP Benefits for Fresh Produce

- Insect elimination
- Pathogen inactivation
- Shelf-life extension
- Replacement of methyl bromide
- Cold-chain integrity
- Quality characteristics preservation
- Lack of residues
- Reduction of food wasting
Consumer Perception of Food Irradiation
Consumer Concerns

- Food becomes radioactive (completely false)
- Nutrient loss
- Companies are encouraged to operate under filthy conditions
- Production of harmful chemicals
  - Negligible generation of alkyl-cyclobutanones
  - No cancer evidence in animal and human long term studies
# ECP or Electron Beam Commercial Operations in North America

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Type</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadex Corp.</td>
<td>Sioux City, IA</td>
<td>Operator</td>
<td>Food</td>
</tr>
<tr>
<td>Sterigenics International, LLC</td>
<td>San Diego, CA</td>
<td>Operator</td>
<td>Food, Medical</td>
</tr>
<tr>
<td>Mevex</td>
<td>Ottawa, Canada</td>
<td>Designer, Operator</td>
<td>Food</td>
</tr>
<tr>
<td>eFresh</td>
<td>Tijuana, Mexico</td>
<td>Operator</td>
<td>Food</td>
</tr>
<tr>
<td>ScanTech Sciences, Inc.</td>
<td>Norcross, GA</td>
<td>Designer, Manufacturer, Operator</td>
<td>Food</td>
</tr>
<tr>
<td>Steri-Tek</td>
<td>Fremont, CA</td>
<td>Designer, Operator</td>
<td>Medical</td>
</tr>
<tr>
<td>Iotron Industries</td>
<td>Columbia City, IA</td>
<td>Operator</td>
<td>Food</td>
</tr>
</tbody>
</table>
Summary

- ECP offers multiple benefits for fresh produce preservation
- ECP is a proven and safe technology with great potential for fresh produce
- ECP maintains the freshness characteristics of produce
- Not all produce is compatible with ECP
- Only effective alternative for pathogen control in leafy greens and similar produce


Questions?

Thanks!!!