Food Irradiation

James S Dickson
Department of Animal Science
Iowa State University
Purposes of Food Irradiation

- Low doses (<1 kGy):
  - control of insects and parasites
  - delay of ripening

- Medium doses (1 - 7 kGy):
  - reduction of foodborne pathogens
  - extension of shelf life

- High dose (> 25 kGy):
  - sterilization

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History of Food Irradiation - United States

- 1958 - Amendment to the Food, Drug and Cosmetic Act classifies food irradiation as an additive
Sources of Ionizing Radiation
Sources of Ionizing Radiation

- gamma rays
  isotopes: Cobalt$^{60}$, Cesium$^{137}$
- electron beam
  linear accelerator
  Van de Graff generator
- X-rays
  collision of electron beam with metal target
Sources Approved for Food Irradiation

- Cobalt$^{60}$
- typically loaded to 250,000 curies

- Cesium$^{137}$ used less commonly
- slightly soluble in water
Electron Beam Source

- machine source
- generates and accelerates electrons under vacuum
- electrons accelerated to at least 5 million electron volts (5 MeV)
- maximum allowable energy is 10 MeV
X-ray Irradiation

- X-rays have penetration similar to gamma rays
- Low conversion of electrons to x-rays requires high power
- High penetration requires shielding similar to gamma ray facility
Isotope Source Facility
Doses Required to Inactivate Food Borne Disease Agents

- *Toxoplasma gondii* (0.25 kGy) likely similar to *Cyclospora* spp.
- *Trichinella spiralis* (0.3 kGy)
- *Cysticercus* spp. (0.4-0.6 kGy)
Decimal Reduction Values

D_{10} Value = dose (in kGy) required to reduce population by 90% (1 \log_{10} cycle)
# Doses Required to Inactivate Food Borne Bacteria

<table>
<thead>
<tr>
<th>Bacterium</th>
<th>$D_{10}$ Value (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeromonas</td>
<td>0.14 - 0.19</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>0.19</td>
</tr>
<tr>
<td>Escherichia coli O157:H7</td>
<td>0.25 - 0.3</td>
</tr>
</tbody>
</table>
## Doses Required to Inactivate Food Borne Bacteria

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<thead>
<tr>
<th>Bacterium</th>
<th>$D_{10}$ Value (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Listeria</td>
<td>0.27 - 0.77</td>
</tr>
<tr>
<td>Salmonella</td>
<td>0.38 – 0.77</td>
</tr>
<tr>
<td>Staphylococcus</td>
<td>0.36</td>
</tr>
</tbody>
</table>
### $D_{10}$ Values of selected Viruses

<table>
<thead>
<tr>
<th>Virus</th>
<th>$D_{10}$ Value (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot and Mouth</td>
<td>4.8 (aqueous) 6.3 (dry)</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>2</td>
</tr>
<tr>
<td>Rotavirus SA11</td>
<td>2.4</td>
</tr>
</tbody>
</table>

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# Doses Required to Inactivate Food Borne Bacteria

<table>
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<tr>
<th>Bacterium</th>
<th>D&lt;sub&gt;10&lt;/sub&gt; Value (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clostridium botulinum (spores)</td>
<td>3.56</td>
</tr>
</tbody>
</table>

[Iowa State University](http://www.innovations-report.de/html/berichte/biwissenschaften_chemie/bericht-49772.html)
Irradiation
Mode of Action

- Direct Effect
- Indirect Effect
Irradiation Modes of Action

- Direct ionization of nucleic acids
- Lesions produced in genetic material
- Single stranded breaks are repairable (may cause mutations)
- Double stranded breaks are lethal

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www.pnl.gov/berc/bg/fatal_lesion.html
Irradiation - Mode of Action

Indirect Effect

- Radiation interaction with other molecules in cell
- Cell cytoplasm is approximately 80% water
- Hydroxyl radical is a radiolytic product of water
- Hydroxyl radical very reactive with other cell components
Irradiation - Microbiological Effects

- Lethal effect of electron beam irradiation on bacteria equivalent to lethal effect of gamma rays
- A dose of 2 kGy has the same effect on *Escherichia coli* O157:H7 in beef whether it is applied with gamma rays or electron beam
Irradiation -
Microbiological Effects

- Irradiation effects are predictable, based on the biological hazard, type of food and the state (refrigerated vs. frozen) of the food
- As with any process, the final quality of the product is profoundly influenced by the initial quality
The Study Group concluded that food irradiated to any dose appropriate to achieve the intended technological objective is both safe to consume and nutritionally adequate.
Technical Objectives - Microbiology

- Improve safety
- Reduce Initial Population
- Extend Shelf Life
Technical Objectives - Improve Safety

- Examples of Food Safety Objectives

- 4 D (log_{10}) reduction - Listeria

- 5 D (log_{10}) reduction - E. coli O157:H7
Food Safety Objectives

Microbial Reductions of a Food Borne Pathogen (4 and 5 log\(_{10}\) reductions)

Margin of Safety

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Listeria monocytogenes in Ready-to-Eat Processed Meats

- Food Safety Objective:
  “The concentration of L. monocytogenes in frankfurters should not exceed 100 cfu g\(^{-1}\) at the time of consumption.”

- Example from “Microorganisms in Food 7”; ICMSF 2002
Listeria monocytogenes in Ready-to-Eat Processed Meats

Control Measures

- Control initial levels in raw materials
- Reduce levels during cooking
- Prevent recontamination between cooking and packaging
- Reduce levels in cooked product after packaging
- Prevent increase in levels between packaging and preparation
- Reduce levels prior to consumption
Listeria monocytogenes in Ready-to-Eat Processed Meats

Potential role of irradiation

- Control initial levels in raw materials
- Reduce levels in cooked product after packaging
Food and Drug Administration
Food Additive Petition

- FAP 9M4697
- USE OF IONIZING RADIATION ON CERTAIN REFRIGERATED, FROZEN OR DRIED MEAT, POULTRY, FRUIT OR VEGETABLE PRODUCTS
- Submitted August 1999
- Accepted for Review January 2000
- Still under review

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Consumer Concerns

- induced radioactivity in foods
- transportation of radioactive materials
- “re-processing” to salvage foods
- process associated nutrient losses
Will I Glow in the Dark?

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Nutrient Losses?

“food irradiation offers negligible loss of nutrients or sensory qualities in food”

American Dietetic Association – Position Statement on Food Irradiation
Toxicity of Irradiated Foods

- is the food safe to eat?
- presence of unique radiolytic products (URP’s)
- chemical changes in foods
Is irradiated food safe?

Yes. The Food and Drug Administration has evaluated the safety of this technology over the last 40 years and has found irradiation to be safe under a variety of conditions and has approved its use for many foods.
New Issues?

- 2-dodecylcyclobutanone?
- Furans?
Organizations Which Have Expressed Favorable Views of Food Irradiation

- World Health Organization
- American Medical Association
- American Dietetic Association
- U.S. Food and Drug Administration
“The Centers for Disease Control and Prevention, along with the World Health Organization and many other health organizations, welcomes the use of food irradiation as an important technology that can protect the public against foodborne diseases.”
Consumer Concerns

- Consumers prefer to make informed choices
- Labeling is an important issue
Label & Material Regulations

Labeling

- **Retail**
  - Radura, plus “Treated by Irradiation”
  - “Irradiated for food safety” most popular
  - If treated product used as an ingredient, identify in Ingredient Statement

- **Foodservice**
  - On case to establishment
  - No requirement to inform consumer

Packaging

- Few modern films are approved
- New approvals have temperature or oxygen restrictions
A new technology called thermal radiation has been developed that improves both the texture and taste of some foods. The process also kills many known pathogens and extends the shelf life of some foods. Unfortunately, thermal radiation also reduces the vitamin content of some vegetables, produces some benzene in eggs, and causes a charcoal-like carcinogen on the surface of meat. Therefore this process, also known as cooking, has been banned pending further studies.

Anonymous

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