Food Safety: General Principles for Edible Horticultural Crops

Linda J. Harris
Department of Food Science and Technology
Western Institute for Food Safety and Security
UC Davis

U.S. Foodborne Illness

- **CDC ESTIMATES** (Scallan et al., 2011)
  - Major foodborne pathogens (31 organisms)
  - 9.4 million cases/year (6.6 to 13 million)
  - 56,000 hospitalizations (40,000 to 76,000)
  - 1,200 deaths (710 to 2,300)
  - Unspecified illness
  - 20 to 61 million cases/year
  - Combined about 1 in 6 ill every year – most very mild but many severe

Costs of foodborne illness

- **Estimates**
  - 50 to 80 billion/year

- **Affected person**:
  - loss of earnings and productivity
  - cost of medical treatment
  - cost of death

- **National costs**:
  - cost of investigation
  - medical costs - insurance

Food Safety Hazards

- **Is a**:
  - biological,
  - chemical, or
  - physical property
  - that is *reasonably likely* to cause
  - cause injury or illness
  - in the absence of its control

Chemical Hazards

- **If not controlled will cause illness**
  - Chemicals
    - Pesticides
    - Sanitizers
  - Allergens
    - Undeclared ingredients
    - Cross contaminants
  - Unapproved additives
  - Mycotoxins
    - E.g., patulin
Chemical Hazards - Mycotoxins

- Toxins produced by fungi
  - Primarily Aspergillus spp., Penicillium spp., and Fusarium spp.
- Long-term chronic toxicity of concern
  - Can be carcinogenic
  - Influence immune response

Examples of major mycotoxins

- Aflatoxin (corn, peanuts, figs, tree nuts)
  - Aspergillus flavus, Aspergillus parasiticus
- Patulin (apple juice)
  - Penicillium expansum
- Fumonisin (corn)
  - Fusarium moniliforme
- Ochratoxin (corn, cereals, coffee beans)
  - Penicillium verrucosus, Aspergillus ochraceus

Preventing Aflatoxin Formation

- Pre-harvest
  - Resistant varieties (if practicable)
  - Crop rotation, irrigation
  - Insect management
  - Minimize damage during harvesting
- Post-harvest
  - Dry to <15% moisture
  - Facility with temperature-moisture control
  - Insect and pest management

Physical Hazards

- Foreign objects capable of injuring the consumer
  - Glass
  - Wood
  - Stones
  - Hard plastic
  - Metal

Food Allergy

- Key components of food allergies:
  - An immunologic response to a food protein
  - (food intolerances usually related to carbohydrates)
  - Extremely small amounts may cause a reaction
  - Reactions can be severe and even life-threatening

Metal Detection is a (the) Critical Control Point
Difficult to screen other types of physical hazards
Allergens
• The “big eight” (90% of allergies in U.S.)
  – cow’s milk, peanuts, tree nuts, shellfish, egg, soybean, crustacea, fish, wheat
• Less common
  – cottonseed, sesame seed, poppy seed, sunflower seed, other legumes, mollusks
• Biggest reason for “Class I” recalls
  – Non-declared allergens
• Control
  – Allergen management, labeling

Biological Hazards
• If not controlled will cause illness
  – Bacteria, e.g., *Salmonella*
    • Or their toxins
      (e.g., *Clostridium botulinum* toxin)
  – Viruses, e.g., hepatitis A
  – Parasites, e.g., protozoa
    • Cryptosporidium parvum

Produce Recognized as Important Vector of Foodborne Illness 1990s
• Proportion of reported outbreaks
• USA
  – 1970s: <1% (outbreaks) <1% (cases)
  – 1990s: 6% (outbreaks) 12% (cases)
• Australia
  – 4%: (2001-2005)
• Europe
  – Increases in past decade

Produce

Reported outbreaks linked to FDA-regulated foods by vehicle, 1996-2009 (N=532 outbreaks)

Reported illnesses linked to FDA-regulated foods, by vehicle, 1996-2009 (N=29,750 illnesses)

Types of produce associated with outbreaks, 1996-2009 (N=87)
Agents associated with produce outbreaks, 1996-2009 (N=87).

**Bacterial**
- E. coli O157:H7: 26 (40%)
- Salmonella: 37 (57%)
- Shigella: 2 (3%)
- Salmonella: 2 (3%)
- Salmonella: 3 (5%)

**Parasitic**
- Cyclospora: 18 (100%)
- Hepatitis A: 3 (100%)
- Salmonella: 3 (5%)

**Viral**
- Norovirus A: 3 (100%)
- Norovirus B: 4 (100%)

**Toxin**
- Cucurbitacin toxin: 1 (100%)

### Multinational Outbreaks

<table>
<thead>
<tr>
<th>Year</th>
<th>Pathogen</th>
<th>Cases</th>
<th>Regions</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Salmonella</td>
<td>1442</td>
<td>North America</td>
<td>Fresh peppers</td>
</tr>
<tr>
<td>2007</td>
<td>Salmonella</td>
<td>51</td>
<td>Europe, North America</td>
<td>Fresh basil</td>
</tr>
<tr>
<td>2007</td>
<td>Shigella</td>
<td>175</td>
<td>Australia, Europe</td>
<td>Alfalfa sprouts</td>
</tr>
<tr>
<td>2006</td>
<td>E. coli O157:H7</td>
<td>206</td>
<td>North America</td>
<td>Fresh spinach</td>
</tr>
<tr>
<td>2006</td>
<td>Salmonella</td>
<td>20+</td>
<td>Europe</td>
<td>Arugula</td>
</tr>
</tbody>
</table>

### 2011 E. coli O104:H4
- Outbreak centered in Northern Germany
  - Cases May 1 – June 9
  - As of June 14, 2011
    - 4,321 cases, >50 deaths (including otherwise healthy adults)
      - HUS = hemolytic uremic syndrome
    - 70% women
    - 14 European countries, U.S., Canada
    - Linked to organic sprouts (imported fenugreek seed)
  - Rare hybrid pathotype: EAggEC enteroaggregative verocytotoxin-producing

### Listeriosis in Cantaloupe 2011
- Cantaloupe – whole melon
  - First outbreak with this vehicle
- Official report filed December 8, 2011
  - 146 people- 99% hospitalized
    - Ages <1 (3 newborns) to 96 years, most over 60, median 77 years
  - 30+ deaths
  - 30 in the report (48 to 96 years, median 82.5)
  - 6 additional deaths since
  - 1 miscarriage

### Listeria monocytogenes
- Matching isolates from
  - Melons, packing line, cold storage area, cantaloupes in the home
- Introduction of organism
  - Field, cull trucks
- Spread of organism
  - Facility had pooled water, floors difficult to clean, equipment difficult to clean, equipment previously used for another raw commodity
- Growth of organism
  - No pre-cooling step, wet melons placed into cold storage
Recurring Pathogen and Commodity Combinations

- **Salmonella Poona** and **Salmonella Anatum**
  - cantaloupes
- **E. coli O157:H7** (other EHECs?)
  - lettuce and leafy greens, sprouts
- **Salmonella**
  - mangoes, tomatoes, almonds (nuts), sprouts
- **Hepatitis A**
  - green onions
- **Shigella sonnei**
  - parsley, cilantro, and culantro

<table>
<thead>
<tr>
<th>Pathogen Multiply in Foods?</th>
<th>Enteric Source</th>
<th>Infectious Dose</th>
<th>Sequelae</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BACTERIA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salmonella spp. YES</td>
<td>human animals</td>
<td>10-100,000</td>
<td>Reactive arthritis</td>
</tr>
<tr>
<td>E. coli O157:H7 (EHEC) YES</td>
<td>human animals</td>
<td>10 - 1,000</td>
<td>HUS</td>
</tr>
<tr>
<td>Shigella YES</td>
<td>Human</td>
<td>10 - 100</td>
<td>Dysentery</td>
</tr>
<tr>
<td><strong>PROTOZOA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cryptosporidium NO</td>
<td>human animals</td>
<td>&lt;20</td>
<td>Severe diarrhea</td>
</tr>
<tr>
<td><strong>VIRUS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatitis A NO</td>
<td>human</td>
<td>10 - 100</td>
<td>Jaundice</td>
</tr>
</tbody>
</table>

Enteric (Fecal) Pathogens (partial list)

What are the sources of contamination?

Routes of Contamination

Contamination/Handling Errors

- Have occurred at:
  - Production
  - Packing
  - Processing
  - Final preparation

- Contamination MOST important factor
- Temperature abuse SOMETIMES contributes
  - Most critical in low-acid fruits and vegetables
  - Pathogens can multiply when fruit or vegetable cut
  - Only critical with bacteria

Survival/Growth of Pathogens in Produce

- Intact fruit/vegetable
  - Survival variable, growth rare

- Cut/wounded fruit/vegetable
  - Survival increases and growth possible

- Temperature
  - Growth slowed at lower temperatures
  - SURVIVAL sometimes increases at lower temperatures

- Humidity
  - Growth and survival enhanced with higher humidity
Growth of Pathogens in (cut) Produce

- High pH/low acid products:
  - Growth can be rapid at room temperature
  - Examples: sprouts, cut melons, chopped parsley, chopped lettuce
- Low pH/high acid products
  - Tomatoes: Under some conditions, chopped tomatoes will support the growth of Salmonella
  - Apples: Wound will support the growth of E. coli O157:H7

Damaged tissue can support growth

- Higher isolation rates in damaged or decayed produce
- Peppers
  - E. coli O157:H7 attaches preferentially to damaged tissue
  - Cells may migrate or flow from sound tissue to damaged tissue during drying of inocula
  (Han et al., 2000)

Innovative Packaging

- Modified atmosphere packaging
- Vacuum packaging
- Shrink-wrap packaging
- Customized films
- Controlled atmosphere storage
- Changes in atmosphere/humidity may influence survival, growth of pathogens

Toxin Production by Clostridium botulinum

<table>
<thead>
<tr>
<th>Product</th>
<th>Temp.</th>
<th>Days to Toxin</th>
<th>Product Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Romaine</td>
<td>21</td>
<td>14 to 21</td>
<td>Inedible</td>
</tr>
<tr>
<td>Shredded cabbage</td>
<td>21</td>
<td>7</td>
<td>Inedible</td>
</tr>
<tr>
<td>Sliced potatoes</td>
<td>22</td>
<td>4 to 6</td>
<td>Acceptable</td>
</tr>
<tr>
<td>Sulfited potatoes</td>
<td>22</td>
<td>3</td>
<td>Marginal</td>
</tr>
</tbody>
</table>

Washing Doesn’t Eliminate Pathogens

- At best 1-3 log (1 to 1000-fold) reductions can be expected under commercial conditions regardless of antimicrobial used
- Issues
  - Complexity
  - Stem scar area
  - Apples
    - Bacteria can enter core through blossom and stem end difficult access
  - Presume knife can transfer to edible flesh
  - Demonstrated for melons and tomatoes

Infiltration Can Occur in Some Products

Fruit pulp must be < 9°F warmer than water temperature to prevent infiltration.

Maintaining water sanitation critical

<table>
<thead>
<tr>
<th>Microbes in water</th>
<th>Temp</th>
<th>Pressure</th>
<th>Depth</th>
<th>Water deficit</th>
<th>Vacuum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Melons</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Peppers</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Mango</td>
<td></td>
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</tr>
</tbody>
</table>
Not all surfaces equal

- Smooth surfaces
  - Honeydew melon, tomato, oranges, apples

- Complex surfaces - hard
  - Netted rind difficult to “clean”
  - Scrubbing with clean brush significant improvement

- Complex surfaces - soft
  - Strawberries, broccoli, lettuce, parsley, sprouts

Some surfaces may attract bacteria

- Lettuce
  - E. coli O157:H7 found in cut edges and stomata (Seo and Frank, 1999)
  - L. monocytogenes and Salmonella attach to cut edges (Takeuchi et al., 2000)

Guiding Principles of Food Safety for Fresh Produce

- Once contaminated, removing or killing pathogens is VERY difficult

- THEREFORE

- Prevention of contamination is favored: layered risk reduction strategies

Approach for risk reduction in fresh produce - proactive

- Integrated farm-to-fork risk reduction
  - Good Agricultural Practices - production
    - FDA/USDA Document 1998
  - Good Packinghouse Practices - harvest/packing
    - Application of sanitation and hygiene GMPs
  - Good Manufacturing Practices - processing
    - CFR 21 110

- Generating appropriate data

FSMA January 4, 2011– Food Safety Modernization Act

- Divided into 4 titles
  1. Prevention of Food Safety Hazards
     - Preventative controls
     - Produce safety rule
  2. Detection and Response to Food Safety Problems
  3. Improving the Safety of Imported Foods
  4. Misc. provisions
Preparing for the Produce Safety Rule

- Good Agricultural Practices
  - Including harvest and post-harvest activities
- If you have plans in place
  - Review and update
- Work with grower suppliers to ensure they have plans in place
  - Verify they are following them

Produce Safety Alliance

- FDA, USDA, Cornell University
- Aim is to help produce growers, packers access food safety educational materials
- http://producesafetyalliance.cornell.edu/psa.html

Preventative Controls

- Require facilities that make or handle food for people and animals to put measures in place to help prevent foodborne illness

Examples of Compliance with Prevention Standards

- Sanitation
  - Written sanitation program and records
- Training for supervisors and employees
  - Documented
- Environmental controls and monitoring
  - Written plan and records of results
- Food allergen controls
  - Documented
- Recall contingency plan
  - Written
- Good Manufacturing Practices (21CFR110)
  - Written and documented
- Supplier verification activities
  - Documented

Modified from FDA slides

Preventative Control Alliance

http://www.iit.edu/ifsh/alliance/

- Established at the Illinois Institute of Technology’s Institute for Food Safety and Health (grant from FDA)

Summary

- Fresh fruits and vegetables have been associated with significant foodborne illness
  - Illness to Total Servings per Year ratio is exceptionally small
- Pathogens associated with fruits and vegetables are associated with human or animal feces
- Prevention of contamination throughout the supply chain is preferred
  - Washing and temperature control important
  - Do not stand alone