Preharvest Food Safety for Fruit and Vegetable Production

Leslie D. Bourquin, PhD
Professor of Nutrition and Extension Food Safety Specialist
Department of Food Science and Human Nutrition
College of Agriculture and Natural Resources
Michigan State University

© 2012 Michigan State University Board of Trustees | East Lansing MI 48824
OUTLINE OF PRESENTATION

• Background
  – foodborne illnesses and outbreaks associated with fresh produce

• Etiology of produce food safety problems
  – contamination with microbial pathogens (water, manure, personnel, facilities, environment)
  – chemical hazards: inappropriate pesticide use, patulin

• Control measures to manage major produce-associated hazards
  – soil amendments; animal intrusion
  – water quality (pre- and post-harvest)
  – sanitation and hygiene
  – post-harvest handling

• Primary Production Standards
FOODBORNE ILLNESSES & OUTBREAKS

CDC Estimates of Foodborne Illness, USA per year

<table>
<thead>
<tr>
<th>Category</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illnesses</td>
<td>47.8 million</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>127,839</td>
</tr>
<tr>
<td>Deaths</td>
<td>3,037</td>
</tr>
<tr>
<td>US Population</td>
<td>313.6 million</td>
</tr>
</tbody>
</table>

Fresh Produce Outbreaks in the US:

- Less than 1% of outbreaks in the 1970s.
- Approximately 6% of outbreaks in the 1990s.
- Large, multi-state (and multi-national) outbreaks associated with fresh produce are now common.
DOLE PRE-PACKAGED SPINACH

*ESCHERICHIA COLI* 0157:H7 OUTBREAK

- August-September 2006
- Bagged selections from California supplier – Natural Selection Foods

- **205** Confirmed Illnesses
- **26** US States
- **103** Hospitalizations
- **31** cases of Hemolytic Uremic Syndrome (HUS)
- **3** Deaths
DOLE PRE-PACKAGED SPINACH

*ESCHERICHIA COLI* 0157:H7 OUTBREAK

States affected by pre-packaged spinach outbreak

Confirmed cases, as of Sept. 2006

- 1-4
- 5-9
- 10-14
- 15 or more
ESCHERICHIA COLI 0157:H7 OUTBREAK

• 13 unopened packages of product tested positive for the outbreak strain – 11 packages with identifiable lot codes were from a single lot representing one shift on one day of production.
• Product for implicated lot sourced from four ranches.
• All four ranches used mechanical harvesters.
• Spinach harvested into plastic totes or bins.
• “Spotters” walked in front of machines to watch for hazards. Manual harvesting with sickles around hazards.
• Harvesters washed daily.
• Abundant livestock and wildlife in area.
• *E. coli* O157:H7 positive samples in environment.
US – 2008 SALMONELLA SAINTPAUL

- Tomato / Pepper *Salmonella* Saintpaul Outbreak
- 1442 reported illnesses as of August 2008
- 43 states, District of Columbia, Canada
- Tomatoes initially suspected:
  - Epidemiological association
  - History of outbreaks associated with tomatoes
States affected by outbreak strain of salmonella
Saint Paul, United States, by state, as of Aug. 25, 2008

Confirmed cases, as of April 2009

- 1-4
- 5-25
- 26-75
- 76+
First it was tomatoes, then......
And more notable outbreaks...

• 2009 Alfalfa sprouts – *Salmonella* Saintpaul
• 2010 Alfalfa sprouts – *Salmonella* Newport
• 2010 Alfalfa sprouts – *Salmonella* I 4,[5],12:i:
• 2011 Fenugreek Sprouts (Germany) – *E. coli* O104:H4
• 2011 Papaya (imported into US) – *Salmonella* Agona
• 2011 Cantaloupe – *Listeria monocytogenes*
• 2011 Romaine lettuce – *E. coli* O157:H7
• 2012 Clover sprouts – *E. coli* O26
• 2012 Cantaloupe – *Salmonella* Typhimurium and Newport
• 2012 Mango – *Salmonella* Braenderup
POTENTIAL SOURCES OF PATHOGEN CONTAMINATION

Fresh produce

Modified from Beuchat, 1996
CHEMICAL HAZARDS

Examples pertinent to fresh produce:

• Pesticide residues and other agricultural chemicals.

• Mycotoxins – patulin
AGRICULTURAL CHEMICALS

• All chemical inputs (pesticides, fungicides, growth regulators, chemical fertilizers, etc.) must be used appropriately.
• Only use chemicals which are approved/registered for specific crops.
• Follow label directions.
• Use potable water for foliar spray applications.
• Make certain that application equipment is appropriately calibrated.
• Observe recommended time intervals from application to harvest.
• Applicators must use appropriate personal protective equipment.
PATULIN

- A mycotoxin produced by certain species of mold (*Penicillium expansum* is most common source)
- Has been found in a number of foods including apple juice, apples and pears with brown rot.
- There is significant concern with juice prepared from moldy or rotten apples and apple juice concentrates.
- FDA action level 50 parts per billion in apple juice, apple juice concentrate (at final dilution), and apple sauce.
Penicillium spp.

http://www.uoguelph.ca/~gbarron/MISCELLANEOUS/penicill.htm

http://keshilluesibujqesor.al/?p=1778
BLUE MOLD DECAY
Apples with stempull wounds

http://www.ars.usda.gov/pandp/people/people.htm?personid=2774&pf=1
*Penicillium expansum* can cause mold during CA storage when inoculated into cut stems

http://www.plantmanagementnetwork.org/pub/php/research/2006/storage/
PATULIN CONCENTRATIONS

Michigan Apple Cider: 2002-2004

# PATULIN CONCENTRATIONS

*Apple Juice Obtained from Retail Grocery Stores*

## TABLE 2. Patulin concentrations in apple-based beverages sold in Michigan retail grocery stores, 2005 through 2006

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. of samples</th>
<th>Presence detected (% of samples)</th>
<th>Above ≥50 µg/liter (% of samples)</th>
<th>Average Patulin Concentration (µg/liter)</th>
<th>Range (µg/liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>159</td>
<td>23.3 ± 3.4</td>
<td>11.3 ± 2.5</td>
<td>226.0 ± 85.4</td>
<td>8.8–2700.4</td>
</tr>
<tr>
<td>Ingredients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>49</td>
<td>40.8 ± 7.1_A</td>
<td>18.4 ± 5.6_A</td>
<td>85.2 ± 25.5_E</td>
<td>8.8–417.6</td>
</tr>
<tr>
<td>Concentrate</td>
<td>99</td>
<td>13.1 ± 3.7_B</td>
<td>7.1 ± 2.6_B</td>
<td>472.7 ± 228.7_D</td>
<td>13.4–2700.4</td>
</tr>
<tr>
<td>Both</td>
<td>11</td>
<td>36.4 ± 15.2_AB</td>
<td>18.2 ± 12.2_AB</td>
<td>128.4 ± 78.8_DE</td>
<td>13.6–347.4</td>
</tr>
</tbody>
</table>

## FDA PATULIN SURVEILLANCE
### Apple Juice Products 1994-2008

<table>
<thead>
<tr>
<th>Year</th>
<th>n</th>
<th>Detectable (%)</th>
<th>At or above 50ppb (%)</th>
<th>Average (ppb) ± Range (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Years</td>
<td>3061</td>
<td>50.2</td>
<td>4.4</td>
<td>24.4 ± 1.4 ± 0.4 – 1031</td>
</tr>
<tr>
<td>1994-1998</td>
<td>619</td>
<td>56.2</td>
<td>4.9</td>
<td>25.3 ± 2.7 ± 1-708</td>
</tr>
<tr>
<td>2002</td>
<td>366</td>
<td>63.9</td>
<td>6.0</td>
<td>30.4 ± 5.6 ± 0.7 – 1031</td>
</tr>
<tr>
<td>2003</td>
<td>376</td>
<td>46.8</td>
<td>5.9</td>
<td>29.1 ± 3.9 ± 0.8 – 344</td>
</tr>
<tr>
<td>2004</td>
<td>469</td>
<td>49.0</td>
<td>3.0</td>
<td>24.0 ± 3.9 ± 0.8 – 502</td>
</tr>
<tr>
<td>2005</td>
<td>437</td>
<td>50.6</td>
<td>5.3</td>
<td>20.0 ± 2.4 ± 1 – 322</td>
</tr>
<tr>
<td>2006</td>
<td>299</td>
<td>44.5</td>
<td>4.0</td>
<td>20.3 ± 2.2 ± 0.8 – 145</td>
</tr>
<tr>
<td>2007</td>
<td>267</td>
<td>39.0</td>
<td>1.1</td>
<td>14.4 ± 1.4 ± 0.4 – 75</td>
</tr>
<tr>
<td>2008</td>
<td>228</td>
<td>39.0</td>
<td>3.5</td>
<td>25.1 ± 4.4 ± 1.1 – 241</td>
</tr>
</tbody>
</table>
Likelihood of products containing ≥ 50 ppb patulin (summarized for all years):

- Apples > Concentrate as the ingredient
- Organic > “Conventional”
- Domestic > Imported
CONTROL OF PATULIN FORMATION

Successful prevention and control of *Penicillium* rots are dependent on good crop handling and hygiene.

- Remove discarded or windfall apples from the orchard floor to minimize *Penicillium* growth.
- Clean up packhouse and other areas so that old rotting fruit is not left where it can provide *Penicillium* inoculum for the new crop.
- Do not dump rot discards from grading back into orchards. These can act as sources of rot inoculum for the next crop. Dispose of in a suitable dump/hole where it can be soil covered.
- Supervise packers at harvest to minimize damage to fruit.
CONTROL OF PATULIN FORMATION

Hygiene of bins

- Dirty bulk bins are an important source of *Penicillium* inoculum. This is particularly true if floating apples out of bins.
- Bins must be cleaned immediately after emptying.
- Physically remove fruit and rots remaining and hose out.
- Particularly dirty bins should be set aside for special cleaning with soapy water, scrubbing brush and hose.
- Spraying bins with disinfectant alone is not effective and **not** a substitute for scrubbing and hosing.
PREVENTION is the Key to Reducing Microbial Contamination of Fresh Fruits and Vegetables
ENVIRONMENTAL ASSESSMENT

Environmental assessments are intended to identify any issues related to the produce field, adjacent land uses, or intrusion by animals that might impact produce safety

• Conduct assessments of:
  – Animal encroachment in produce fields
  – Adjacent land use (e.g. CAFOs)
  – Historical land use (e.g. hazardous wastes)
  – Flooding potential
MANURE = FECAL MATTER = MICROBES

- Human or animal: **Do everything** you can to keep manure off produce.
- **Preventing contamination** is the goal.
ALL MANURE CAN CARRY PATHOGENS

- Livestock
- Cattle, swine, poultry, horse, & sheep
- Dog and Cat
- Bird
- Rodent
- Deer
- Fly or other insect
- Human
ON-FARM MANURE HANDLING

Manure

• Active composting is preferred
• If not composted, store for 6 months prior to field application.

Slurry storage systems and waiting periods

• Wait 60 days in summer and 90 days in winter prior to spreading.
• Consider satellite storage or special management for slurry destined for vegetable ground.
COMPOST MANURE PROPERLY

Manage piles to have active, uniform composting.

- High temperatures, good moisture, proper aeration, and mixing.
- Weed seeds killed means good composting conditions were achieved.

Exclude animals from compost area to prevent recontamination.
MANURE APPLICATION

- Do not assume any manure is ‘clean’.
- **Incorporate, Incorporate, Incorporate**
- Absolutely **NO SIDEDRESSING** with fresh manure.
- If applying untreated manure in spring to fruit and vegetable fields, wait 120 days to harvest.
- Note that California Leafy Greens Marketing Agreement stipulates a **one year** interval between application of untreated manure and planting of leafy greens.
KEEP RECORDS OF MANURE AND COMPOST USE

• Know your source of manure or compost.
• Know the methods used to produce compost or the manure storage time.
• Keep records of application rates, timing, and fields receiving manure or compost.
CROPS FOR MANURED FIELDS

- Avoid root/low growing crops (lettuce, beets) in season manure is applied.
- Avoid crops consumed fresh or those where leaves are eaten by humans.
- Apply manure to ground where perennials are being planted.
EXCLUDE ANIMALS

• Exclude livestock from production areas including orchards, especially in the months leading up to harvest.
• Keep wildlife out of production areas as much as possible.
• Don’t allow dogs or other pets in the field.
• Manage rodents and birds in packing houses and storage areas.
WATER CARRIES PATHOGENS

- *E. coli* 0157:H7 viewed primarily as a water-borne pathogen.
  - Many outbreaks associated with recreational water.
- *Salmonella, Giardia* and *Cyclospora* outbreaks on produce caused by contaminated water.
WATER MANAGEMENT

• Select water source based upon agricultural use.
• Clean water quality is most important when in direct contact with edible portion of crop close to or at harvest.
WATER MANAGEMENT

• Choose application method and treatment to reduce risk
  • Drip has a lower risk than overhead irrigation
  • Chlorinate dump tanks and wash water
• Keep records of water tests
KNOW WATER
SOURCE QUALITY

• Best source (lowest risk) is drinking water, such as municipal.

• Ground water is less likely to have microbial contaminants than surface water.

• Surface water quality and pathogen levels are affected by watershed activities and season.
SURFACE AND WELL WATER CONTAMINATION SOURCES

Surface water:
- Livestock
- Sewage treatment facilities
- Wildlife

Well water:
- Poorly maintained wells or pumps
- Livestock in active well recharge area
IRRIGATION WATER
BEST MANAGEMENT PRACTICES

• Drip Irrigation has lowest risk of spreading contamination with microbial pathogens

• Overhead irrigation
  – Source determines risk
  – Longer periods between overhead irrigation and harvest lowers risk
SPRAY WATER QUALITY

• Use potable (drinking) water for pesticide sprays.
• When potable water is not available, test water quality and keep records.
• Low water volumes reduce risk.
WATER TESTING

Research relating to field irrigation water quality and risks is still needed.

- Fecal coliform count < than 100 per 100 mls is one recommendation
- Fecal coliform as an indicator of water quality only partially useful, as coliforms are not always correlated to presence of pathogens.

CA Leafy Greens Marketing Agreement standard

- Generic *E. coli* used as indicator organism
- Must be < 235 MPN / 100 mL for a single sample, and < 126 MPN / 100 mL for a rolling 5-sample geometric mean.
WATER TESTING FREQUENCY

General Advice

- At least annually with municipal water
- Quarterly with groundwater
- Test surface water for quality assurance
  - 3 times during season in temperate climates
  - at planting
  - at peak use
  - at harvest
- Quarterly in more southern (US) climates
- Maintain good records of results
HARVEST CONSIDERATIONS

• Teach workers about proper hand-washing and provide proper facilities.
• Utensils, totes, bins and other harvesting equipment must be clean and sanitary.
• Ideally pick dry fruits or vegetables.
• Leave produce that has bird droppings on it.
• Cool product quickly to minimize growth of pathogens.
HARVEST CONSIDERATIONS

• Handle produce carefully during and after harvest.
• **Punctured or bruised produce provides points of entry for:**
  • Plant Pathogens
  • Foodborne Illness Pathogens
• So proper harvesting/culling is important to both safety and quality.
FIELD SANITATION

• Clean and sanitize storage facilities prior to harvest.
• Clean fields daily
  • Remove garbage, objects that harbor pests
• Clean and sanitize harvest bins and totes daily.
• Avoid standing in harvest bins. Clean and disinfect harvest aids
• Clean harvest and packing equipment
• Remove visible dirt and other contaminants
• Avoid direct contact of packages, containers or products with the soil
• All containers, baskets, boxes should be clean and free of visible dirt, oil/grease, chemical contaminants
HARVEST TOTES AND CONTAINERS

• When not in use, must be stored in a location that will prevent contamination.

• During use, must be cleaned and sanitized daily to prevent them from becoming a source of contamination.

• Dirt and organic load on containers can be detrimental to effectiveness of chlorine and other sanitizers used in water.
BIN & TOTE STORAGE

Outside storage – bins must be washed and sanitized prior to use.

Proper storage of totes – protected from contamination (same for packaging materials)
FIELD HANDWASHING & RESTROOMS

• Clean and adequate handwashing and restroom facilities encourage appropriate worker behaviors.
• Growers and packers must comply with legislative or buyer requirements.
• Handwashing facilities shall have an adequate supply of potable water, soap, and single-use towels.
PORTABLE TOILET AND HANDWASHING

Facilities examples
Make certain that field toilets don’t become a source of contamination!
Postharvest Wash Water Quality and Its Importance
WHY FOCUS ON WATER DISINFECTION?

Singular critical point capable of amplifying an error in sanitation or hygiene management during production, harvest, or postharvest.
WASH WATER QUALITY

- Use potable water for all produce washing, cooling, dipping, icing, and processing.
- Avoid water temperatures in dump tanks that are more than 10°F cooler than produce.
CHLORINATION OF WATER

Proper chlorination reduces survival of microorganisms that may contaminate wash water.

• Maintain constant chlorine by monitoring. In general 100-150 ppm is recommended.

• Monitor pH of water. Optimum range is 6.0-7.0. Note that chlorine is ineffective at higher pH (hypochlorite), but can be corrosive to equipment at lower pH (hypochlorous acid)

• Be conscious of the temperature of the water. High temperature results in quicker pathogen kill, but also results in rapid loss of chlorine due to gas formation
BEYOND CHLORINE

• There are other water disinfectants available.

• If you choose a new product, make sure it is effective and be aware of how to properly handle, mix, and store the material.

• Seek out additional information.

For example: *Introduction to ORP as a Standard of Postharvest Water Disinfection Monitoring*, Trevor Suslow, UC Davis.
FARM FOOD SAFETY RECORDS

- Manure storage and handling
- Animal exclusion (domestic & wild)
- Irrigation and drainage management
- Equipment sanitation
- Harvest and post harvest handling
- Employee training program
- Restroom & handwashing facilities
- Crisis management strategy
If you did not RECORD it, you did not do it

• Record keeping allows you to keep track of farming operations and worker training.

• Record keeping documents your activities should this information ever be required.
PRIMARY PRODUCTION STANDARDS
EXAMPLES OF GAP STANDARDS
And other Food Safety Standards for Primary Production

- FDA Guidance Document (USDA AMS Audits)
- GlobalGAP
- SQF 1000
- Primus GFS
- NSF Davis Fresh
- CanadaGAP
- Etc.

- Note that several buyers have instituted requirements for compliance with GFSI-benchmarked food safety schemes (e.g. GlobalGAP, SQF, Primus GFS, CanadaGAP) or other standards.
- GFSI benchmarking process ongoing against version 6.2 of the GFSI Guidance Document.
PRIVATE STANDARDS

• Industry-led standards for food safety assurance
• Generally rely on third-party audits for monitoring
• Numerous private food safety schemes exist
• Several schemes have been benchmarked for equivalence by GFSI and other organizations
• Accredited schemes likely are more robust than non-accredited schemes
• The scope of several private standards extends beyond food safety (e.g. environment, social responsibility)
GLOBALGAP

Integrated Farm Assurance Standard
US GOOD AGRICULTURAL PRACTICES

• 1998 FDA guidance document
• “Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables”

http://www.fda.gov/food/guidancecompliance/regulatoryinformation/guidancedocuments/produceandplanproducts/ucm064458.htm

• Not a federal regulation – guidelines only
• Produce buyers may require compliance
• Later – required audits (by AMS) for suppliers to the federal school lunch program
US GOOD AGRICULTURAL PRACTICES

• Broadscope
  • The guide provides general advice for the fresh fruit and vegetable industry. Commodity-specific considerations can be applied.

• Guidance Only
  • The recommendations contained in the guide do not supersede any existing federal or state regulations.

Focus on Risk Reduction – not Risk Elimination
COMMODITY SPECIFIC GAPs
GUIDANCE DOCUMENTS

US Examples

Tomatoes
http://www.unitedfresh.org/assets/files/Tomato%20Guidelines%20July08%20FINAL.pdf

Melons
http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ProduceandPlanProducts/ucm174171.htm

Leafy Greens
http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/ProduceandPlanProducts/ucm174200.htm

California Leafy Greens Marketing Agreement
http://www.caleafygreens.ca.gov/
UNITED FRESH

Produce GAPs Harmonization Initiative

• Led by United Fresh Produce Association
• Series of working group meetings held from late 2009 – October 2010
• Develop draft harmonized standards for:
  • Field Operations and Harvesting
  • Post-Harvest Operations
• Draft harmonized standards released
  http://www.unitedfresh.org/blog/topics/gaps-harmonization/
US FEDERAL FOOD SAFETY LEGISLATION

• Food Safety Modernization Act (FSMA).
• Signed into law on January 4, 2011.
• Promulgation of produce food safety standards was required within one year.
• Produce food safety standards were drafted by FDA and have been in regulatory review by OMB since early 2012.
• Anticipate eventual release – uncertain timeline.
FOR ADDITIONAL INFORMATION

Leslie D. Bourquin
Professor and Food Safety Specialist
Department of Food Science and Human Nutrition
Michigan State University
139A G. M. Trout Bldg.
469 Wilson Road
East Lansing, MI 48824-1224 USA
Phone: +1-517-355-8474 Extension 112
Email: bourqui1@msu.edu