Good Agricultural Practices (GAP) for Fresh Fruit and Vegetable Growers
GAP:
Micro 101
Foodborne Illness: The Symptoms

- Nausea
- Vomiting
- Diarrhea
- Headache
- Fever
Foodborne Illness: People at Greatest Risk

- Infants & Children
- Elderly
- People with weakened immune systems – cancer, diabetes, HIV/AIDS
Foodborne Illness (2010): Dangers

- Cases: 48 million per year
- Hospital: 128,000 per year
- Deaths: 3,000 per year
- Cost: Billions per year
Foodborne illness: How you get sick from food

**5 Steps**

- Food
- Contamination
- Mishandling
- Ingestion
- Illness
Foodborne Illness:
Most likely sources

• Ready to Eat Foods

• Potentially Hazardous Foods
Food Safety Hazards:
3 Types of Contamination

Physical
Chemical
Biological
Physical Food Safety Hazards

- Wood
- Plastic
- Metal
- Glass
- Tools
- Gloves, bandages, pens and other personal items
Chemical Food Safety Hazards

- Cleaning chemicals, sanitizers
- Lubricants, other plant chemicals
- Pesticides
- Heavy metals, such as lead
- Allergens, such as milk protein
- Toxins, such as patulin
Biological Food Safety Hazards

- Parasites
- Viruses
- Bacteria
Some Frequent Contributors

- **Salmonella**
  - cantaloupes, tomatoes, sprouts
- **E.coli 0157:H7**
  - leafy green vegetables
- **Cycolspora (parasite)**
  - raspberries
- **Hepatitis A (virus)**
  - green onions
- **Listeria**
  - Making a strong showing recently
Biological Hazards

Parasites

• Cyclospora cayetanensis
• Cryptosporidium parvum
• Giardia lamblia
Biological Contamination

Viruses

- Hepatitis A
- Norwalk virus
- Rotavirus
Sources of Biological Contamination

- **Animals** (manure and manure, animal living spaces, carcasses)

- **People** (food handlers, pickers, packers, and consumers)

- **Environment** (contaminated water, air, plants)
Bacteria from Animals

*Salmonella* - millions of cases of FBI each year

- **Source:** Intestinal tract of animals and humans
- **Foods:** Raw and undercooked eggs
  Undercooked poultry
  Fruits and vegetables
Bacteria from Animals

*E. coli O157:H7* - Can produce deadly toxins in you

- **Source:** Lower Intestinal tract of animals (cattle) and humans
- **Foods:** Raw and undercooked ground beef
  Produce
  Apple cider
Bacteria from People

Shigella

- **Source**: Human hands
- **Foods**: Produce
  - Salads
  - Milk and dairy products
Bacteria from the Environment

Listeria monocytogenes

• **Source**: Soil, water, animals

• **Foods**: Raw vegetables

  Unpasteurized milk and cheese

  Raw and undercooked meat
Bacteria: Conditions to Grow

- Food
- Correct acid levels (pH)
- Time
- Correct temperature
- Oxygen/No oxygen
- Moisture
To Grow, Bacteria Need:

Food
To Grow, Bacteria Need:
Neutral pH

<table>
<thead>
<tr>
<th>Acid</th>
<th>Alkaline</th>
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<tbody>
<tr>
<td>0</td>
<td>8.0</td>
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<tr>
<td>1.0</td>
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<td>2.0</td>
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</tr>
<tr>
<td>6.0</td>
<td>14.0</td>
</tr>
<tr>
<td>6.4</td>
<td>Distilled Water</td>
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<tr>
<td>7.0</td>
<td>Egg White</td>
</tr>
<tr>
<td>Limes</td>
<td>Commercial Mayonnaise</td>
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<tr>
<td>Pickles</td>
<td>Beef, Veal</td>
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<tr>
<td>Vinegar</td>
<td>Pork</td>
</tr>
<tr>
<td></td>
<td>Carrots, Pumpkins</td>
</tr>
<tr>
<td></td>
<td>Sweet Potatoes</td>
</tr>
<tr>
<td></td>
<td>Chicken Milk</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td>Crackers</td>
</tr>
<tr>
<td></td>
<td>Soda</td>
</tr>
<tr>
<td></td>
<td>White</td>
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To Grow, Bacteria Need: Moisture

Water Activity

0 0.1 0.2 0.3 0.4 0.5 0.6 0.67 0.7 0.75 0.8 0.85 0.9 0.92 0.95 0.98 1.0

Minimum needed for bacteria to grow

Potentially Hazardous Foods

- Distilled Water
- Meats
- Poultry

Dry Egg Noodles Crackers
Jams & Jellies
Flours Candy
To Grow, Bacteria Need:
The right Temperature (and time)

“Danger Zone”

140 °F

40 °F
The effects of time and temperature on bacterial growth:

- **95°F**: Rapid growth followed by a decline.
- **50°F** and **44°F**: Moderate growth over time.
- **42°F**: Minimal growth or no growth at all.

Days: 0 1 2 3 4 5

Number of Salmonella per gram
The effects of temperature on bacterial growth
Not All Bacteria Created Equal

- Different temperature
- Different pH
- Different water controls
- Different survival conditions
- Different adaptations
- Different growth on different commodities

Different…….
Survival of Bacteria

- Impacted by temperature, pH, sunlight exposure, source of contamination, other microflora and organism of interest
  
  *E. coli, Salmonella spp., Listera, Shigella*

- Studies show different survivals of pathogens depending on commodity, surface soil or water, and viability/survival vs. growth

*Salmonella spp.*  
*E. coli*
Some survival values reported:

- **Water** – 15-30 days, 109 days; May be greater in ground water since cooler, protected from sun, less biological activity

- **Soil** – 20 and 161-231 days

- **Crops** – 7-15 days, 30 days, 49 days, 63-231 days, 3-5 months, 84-203 days depending on crop, contamination route etc.


© 2004 Dennis Kunkel Microscopy, Inc.
- Studies have shown *S. enterica* and *E. coli* at planting time can persist for prolonged time – including until harvest.
- Interactions of enteric pathogens with plant microflora – may enhance growth or survival.
- Certain plant disease, such as soft rot, has been shown to have higher incidences of pathogens. Not all plant disease equal.
- Damage – attachment greater than intact fruit or vegetables.

**Very complicated !!!**
### Persistance of E.Coli 0157:H7

<table>
<thead>
<tr>
<th>Product</th>
<th>Survival on product</th>
<th>Survival in soil *</th>
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<tbody>
<tr>
<td>Parsley</td>
<td>177 days</td>
<td>217 days</td>
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<tr>
<td>Carrots</td>
<td>175 days</td>
<td>196 days</td>
</tr>
<tr>
<td>Onions</td>
<td>84 days</td>
<td>168 days</td>
</tr>
<tr>
<td>Lettuce</td>
<td>77 days</td>
<td>154 days</td>
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</tbody>
</table>

* 10\(^7\) and 10\(^5\) cells added to compost and water, respectively


Survival Continues

- E. coli 0157:H7 and Salmonella survival in soil 7-25 weeks
  - soil type
  - moisture level
  - temperature
  - contamination source
- Addition of animal waste in soil broadens pathogen profile

Olaimat and Holley. 2012. Factors affecting microbial safety fresh produce: a review. Food Micro. 32(1-19.)
How do you “inactivate” E. coli in soil?

- Exposure to sun
- Dessication
- Poor nutrient conditions
- Temperature extremes
- Competing soil microbes
- Turn soil to hasten kill – expose to inhospitable conditions
- Keep them out – animal barriers, safe practices for handling compost and manure.
Research – Continues

- Prolonged survival of Campylobacter species in bovine manure compost
  - reached or exceeded 55°C
  - detected after ~10 months in compost
- Salmonella can enter tomatoes through leaves: potential, so irrigation and wild animal issues need to be addressed
- Norovirus in ground water – infectious for at least 61 days
- Are oblong Roma for bacteria susceptible then round or green tomatoes?
- Studies on different sanitation treatments

Inglis, et al. Applied and Environmental Microbiology. 2010  76(4);1110-1119 – canada
Research – Continues

- Examples:
  - Broccoli rotation and bacteria die off
  - Chicken pellets heated 300 F, 1 hour – safe?
  - Minimum distance requirement animals?
    - Leafy greens a distances ≤ 600 ft. still at risk
      - Guidance distance has been 400 ft. from animal feeding operations (CA Leafy Greens Agreement, 2013)
    - Wind takes particles with contamination
      - E. coli
    - Distance only one factor
  - E. coli 0157:H7 – spread >0.1 mile downwind cattle feedlot*

Center for Produce Safety:
www.centerforproducesafety.org
Contamination With Microbial Pathogens: Where Can It Occur?

- In fields or orchards – soil, water, manure, animals, humans
- During harvesting and transport – humans, equipment
- During processing or packing – water, animals, insects, humans, equipment
- In distribution and marketing – humans, trucks
- In restaurants and food service facilities – humans
- In the home

From Rutgers University- NJ Ag Station; Jahid and Ha, 2012, Review of microbial biofilms.
Prevalent Pathogens on Pathogens

- Norovirus
- E. coli 0157:H7
- Salmonella spp.
- Listeria monocytogenes
- Shigella spp.
- Campylobacter spp.

Prevalent Pathogens on Pathogens

Presence, Growth, Survival depends on:

- Microflora characteristics
- Available nutrients
- Environmental conditions
- Internalization
- Biofilms

Internalization: Control More Difficult

Fig. 4. Internalization of *E. coli* in leaf stomata (from Berger et al., 2010).

Olaimat and Holley. 2012. Factors affecting microbial safety fresh produce: a review. Food Micro. 32(1-19.)
Internalization: How Does This Happen?

- Stomata, calyx, stems, damage to cuticle
- Damaged/cut edges produce/physiological disorders
- Roots or seeds – internalized during sprouting
- Might be inaccessible to water, disinfectants
- High temperatures, excess humidity during sprouting
  - conditions “ripe” for foodborne pathogen internalization
- Photosynthesis and light – stomata open?
- Sanitizing agents in wash/cooling water to avoid cross-contamination and internalization.
  - Lodge in stomata, crevices of produce exposed to contaminated water, postharvest

Olaimat and Holley. 2012. Factors affecting microbial safety fresh produce: a review. Food Micro. 32(1-19.)
Internalization: New Research

- USDA/NIFA, 2015
- University of Maine, Dr. Vivian Wu
- Magnetic Resonance Imaging (MRI)
  - Observation of foodborne pathogens in produce
  - Trace bacterial internalization – understand process
  - Ways to prevent
Biofilms

- Biofilms we know well
- Attachment
- Quroum sensing – bacterial communication, multi species
- Formation of polysaccarides – hard to remove
- Dispersal of cells
- Maybe different from biofilms on food contact services since interaction between cells and plant surface
- High temperature, humidity, injury pre- and post harvest. Injured “skin” suscepible
- Disinfectants – little or no efficacy

Biofilms

- Biofilm formation on (so far):
  - spinach
  - lettuce
  - celery
  - leek
  - basil
  - parsley
  - endive

Sources of Pathogens on Produce: On the Farm

- Contaminated irrigation water
- Handling by infected workers
- Poor personal hygiene
- Fresh/uncomposted manure/fecal material
- Incomplete compost
- Wild and domestic animals
- Cross-contamination
- No time/temperature control when needed

Adapted from Rutgers University- NJ Ag Station
Food Safety for the Producer: Good Agricultural Practices – Key Food Safety Principles

- Water and Water Quality
- Manure and Biosolids Management
- Worker Health and Hygiene
- Sanitation in field, packing area and PYO operations Facilities
- Temperature Control
- Traceback