Technologies to improve food safety of Raw Meat

Keith Warriner
Department of Food Science
University of Guelph
ONTARIO FOOD PROTECTION ASSOCIATION

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OFPA

Dr Martin Appelt – CFIA
Dr Gavin Downing – OMAF
Dr Rick Holley – UoM
Dr Charmine Kuran - Health Canada
Peter Gould - DFO
Tom Graham - CFIA
Dr Kathleen Glass – UoW-M
Dr Emma Allen- Vercoe- UoG
Jennifer McCreary – NSF-GFTC
Pathogens of Concern

- Virus: Hepatitis E, Calicivirus, Norovirus
- Parasites: Cryptosporidium, Giardia, Toxoplasma, Trichinella, Taenia
- Bacterial: Shiga Toxin producing Escherichia coli (STEC), Salmonella, Campylobacter jejuni, Listeria monocytogenes, Staphylococcus aureus, Yersina enterolitica

- Endospore formers: Clostridium botulinum, C perfringens, C difficile

Most contamination is on the surface but not always
Toronto restaurants flout regulations to serve raw pork

By Staff

The Star News Service

Jesse Grosso, head chef at The Black Hoof which serves rare pork dishes, displays the regulations prohibiting it.
Parasites

- Giardia
- Cryptosporidium
- Ascaris
- Swine Influenza
- Trichinella
Hepatitis E

• Young adults (30-60%)
• High mortality in pregnant women (30-50%)
• Endemic within pork production (30% carriage)
• Liver: No chronic phase (2% fatality rate)

>60,000 carriers (UK)
Farming Practices EU vs North America

**Europe**
- Non-intervention
- Small production and processing
- Subsidized
- Net importer
- Preventative approach
  - GAP
  - GMP
  - HACCP

**North America**
- Major producer
- Growth promoters
- Intensive farming
- Intervention based HACCP
EU distribution of farms by size, 1997

Source: European Commission.

U.S. distribution of farms by size, 1997

Source: National Agricultural Statistics Service, USDA.
The diagram compares the prevalence of Salmonella, Campylobacter, and E. coli O157:H7 in the US and EU. The prevalence is measured in percentage (%). The diagram shows that Salmonella and Campylobacter have higher prevalences in the EU compared to the US. E. coli O157:H7 has a lower prevalence in both regions.
Sources of Contamination and Dissemination Routes
Pathogen Reduction Interventions in Meat Chain

• On-farm

• Processing

• Retail and food service
On-farm interventions

• Water quality: Electrolyzed water
• Feed: HACCP certification
• Housing: manure removal system
• Wildlife exclusion
• Animal density
• Probiotics and prebiotics
• Vaccination
Processing
Poultry Processing

• Scald tank
  • Counter current water flow
  • Temp >50°C
  • Sanitizers (limited selection)

Chill tanks
• 50 ppm chlorine pH 7 (Only in US)
• Counter-flow
• Fresh water recharging
• Air chilling using ozone
Pork Processing
Arguello et al., 2013
Simulated *Salmonella* Prevalence
Stun and Dehide
Evisceration and Splitting
Large Capacity Beef Slaughter Line
600 Carcasses per day

Holding Area

Bleeding Area

Air

Dehiding

Inspection

Air

Evisceration

Steam Vacuum

Air

Cooler

Acid Wash

Air
Average E. coli Counts at different Carcass Locations

log cfu/100cm²

Predehiding  Post-dehiding  Pre-vaccuming  Post-vaccuming  Pre-washing  Post-washing

Neck  Brisket  Round
Interventions in Meat Processing
Carcass Decontamination

- Physical
- Chemical
- Biological
Pre-Processing Interventions

• Live wash: Water or chlorinated warm water
• Chemical dehairing (sodium sulfide)
Animals cleanliness and carcase microbiology

![Bar chart showing log counts per sq. cm for Shoulder and Abdomen with varying tag scores.]

- **Tag Score** 1, 2, 3, 4, 5
- **Log** $\log_{10}$ counts per sq. cm
- **Sholder** (red bars)
- **Abdomen** (blue bars)
1. Adsorption
2. Injection
3. Infection
4. Release

Lytic pathway:
- Synthesis of copies of genetic support and proteins of bacteriophage

Lysogenic pathway:
- Assembly of new bacteriophages

Bacteriophages (enlarged X10 compared to bacteria)
Bio-sanitizers

- Applied in animal environment
- Hide/skin treatment
- Direct application on foods
**E coli O157 Phages on Hides of Cattle**

Goffey et al., 2011
Control of *Salmonella* on Pig Skin

- *Salmonella* applied to pig skin
- Spray with phages
- Only effective with MOI>10

Hooton et al., 2011
## Hide/Skin Bacteriophages Treatment

<table>
<thead>
<tr>
<th>Surface</th>
<th>Target</th>
<th>MOI</th>
<th>Log Reduction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle Hide</td>
<td><em>E. coli</em> O157</td>
<td>10,000</td>
<td>1.5</td>
<td>Coffey et al., 2003</td>
</tr>
<tr>
<td>Poultry</td>
<td><em>Campylobacter</em></td>
<td>100,000</td>
<td>2.0</td>
<td>Goode et al 2003</td>
</tr>
<tr>
<td>Poultry</td>
<td><em>Pseudomonas</em></td>
<td>1000</td>
<td>2.0</td>
<td>Greer, 1982</td>
</tr>
<tr>
<td>Pig skin</td>
<td><em>Salmonella</em></td>
<td>10</td>
<td>4.0</td>
<td>Hotton et al., 2011</td>
</tr>
</tbody>
</table>
Electrolysed Water

Salt (NaCl) and Softened Tap Water (H₂O)

Electrodes

Negative ions Cl⁻ and OH⁻ are attracted to the anode
Positive ions, N⁺ and H⁺ are attracted to the cathode

SANITIZING
Acidic Solution
Very High ORP
Water - 1100mv

CLEANING
Alkaline Solution
NT: Not treated
W: Water
PAA: Peroxyacetic Acid
NEW: Neutral EO water
AEO: Alkaline EO water
A-NEW: AEO followed by NEW
HAEO: Hot alkali EO
LA: Lactic acid

Jadeja and Hung, 2014
Octenidine

Baskaran et al. (2012)
On-hide Water Wash

• Birko HardScald

• Hot water dip or spray (60 -83°C)

• Strong alkali
  • Antimicrobial
  • Hair removal

![Bar chart showing STEC Log cfu/cm² for different treatments: Initial, Scald, and Post-LA Wash. The treatments include Scald and Scald + Additive.](chart)
Mechanical Hide Puller

Aerosols reduced by pinning back hide

Post-hide removal lactic acid (5%) wash
Large Capacity Slaughter House

Steam Vacuum of Round

Post-Slaughter Acid Wash
Vacuum-Steam-Vacuum Pasteurization (VSV)

- Vacuum: Remove air & surface moisture
- Steam: Thermal Inactivation
- Vacuum: Remove condensed steam & cooling

- 1s Treatment
  - Meat
  - Fruit
  - Vegetables
• Sprays
  • Organic acids - lactic, acetic

• Temperature
  • Hot water
  • Steam vacuum
  • Steam pasteurization
Log Count Reductions on Meat

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Treatment conditions</th>
<th>LCR cfu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water</td>
<td>80C 5-15 s</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Steam</td>
<td>80 - 95C 5 - 15s</td>
<td>1- 2</td>
</tr>
<tr>
<td>VSV</td>
<td>70C 1s</td>
<td>1.0 – 1.8</td>
</tr>
</tbody>
</table>
Chemical Treatments

- Chlorine
- Ozonated water
- Electrolyzed water
- Organic acids (2.5-5%)
- Lauric arginate
- Acidified Sodium Chlorite (ASC)-citric acid activated
- Peroxyacetic acid
- Trisodium phosphate
- Hydrogen peroxide
- Sodium bisulfate
- Potassium sorbate
- Cetylpyridinium chloride
- Chlorine dioxide
- Dibromo-5,5 dimethylhydabtoin
- Activated lactoferrin
Lactic Immune Surface Adhesion Limitation (LactiSAL)

- Milk serum apo-proteins and free fatty acids
  - Lactoferrin
  - Lipases
  - Butyric
  - Caproic
  - Caprylic
  - Lauric
- Effective against *Salmonella* and *E. coli* O157:H7
- Cost?

Pearce and Bolton, 2008
<table>
<thead>
<tr>
<th>Food commodity</th>
<th>Surface decontamination treatment^a</th>
<th>Typical bacterial reduction log cfu^b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw meat</td>
<td>Hot water 80–95°C; 5–15 sec</td>
<td>1–3</td>
</tr>
<tr>
<td></td>
<td>Steam 80–93°C; 5–15 sec</td>
<td>1–2</td>
</tr>
<tr>
<td></td>
<td>Microwave; 30 sec</td>
<td>0.2–0.8</td>
</tr>
<tr>
<td></td>
<td>Irradiation 2–3 kGy</td>
<td>3–5</td>
</tr>
<tr>
<td></td>
<td>UV 4 J cm^2</td>
<td>0.5–1.0</td>
</tr>
<tr>
<td></td>
<td>High-pressure processing 400 MPa; 50°C</td>
<td>&gt;5</td>
</tr>
<tr>
<td></td>
<td>Electrolyzed water; acidic fraction</td>
<td>1–2</td>
</tr>
<tr>
<td></td>
<td>Ozonated water</td>
<td>0.6–2</td>
</tr>
<tr>
<td></td>
<td>Chlorine</td>
<td>0.7–1.5</td>
</tr>
<tr>
<td></td>
<td>Organic acid washes 1–30% v/v</td>
<td>0.4–2.4</td>
</tr>
</tbody>
</table>
## Carcass Decontamination

<table>
<thead>
<tr>
<th>Sanitizer</th>
<th>Concentration</th>
<th>Log Reduction cfu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypochlorite</td>
<td>50 ppm 10s</td>
<td>1-2</td>
</tr>
<tr>
<td>Electrolyzed water</td>
<td>Acid Fraction</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>Ozonated water</td>
<td>2 ppm</td>
<td>0.6-2</td>
</tr>
<tr>
<td>Organic acid washes</td>
<td>1-3%</td>
<td>0.4 – 2.4</td>
</tr>
<tr>
<td>Organic acid</td>
<td>2% 10 psi 90 s</td>
<td>2-4</td>
</tr>
</tbody>
</table>
Control Pre- and Post-evis hot water wash Acid wash; Steam Past

On-Farm Interventions

Vaccination: Processing Interventions

Smith et al., 2013
Innovations in Carcass Decontamination

- Beefxide (pH 2.3; lactic acid & citric acid blend)
- Citflow (pH 1.2, HCl & citric acid blend)
- Electrostatic spraying
- Flaming
Decontamination of Veal Carcasses

- **Post-inoculation**
- **Post-wash**
- **Antimicrobial wash**
- **24h post Wash**
- **Second Antimicrobial wash**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Water</th>
<th>Lactic Acid</th>
<th>Beefide</th>
<th>Citflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEC Log cfu/cm²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Electrostatic Carcass Sprays

• Containment of spray

• Efficient coverage

• Previous application in the produce sector

• Potential application for carcass decontamination
Flaming (Beef Carcasses)

![Image of flaming carcasses]

- **E coli**: Log Count Reduction
- **Coliforms**: Log Count Reduction
- **Entero**: Log Count Reduction
- **TAC**: Log Count Reduction

Log Count Reduction ranges from 0 to 2.
Dry Heating

• Dry heat 300 – 400°C for 15s

• Surface drying

• Limited efficacy

• Log reductions increased when used in combination with antimicrobial sprays
Excimer Lamps

High intensity UV
Less power input
Low temperature
Pulsed Light

High intensity (1000 W/cm²) Short Pulses (1μs – 0.1s)

Xenon discharge lamps
UV-light Based Treatments

- Uneven surface
- Protective niches
- 1-3 log cfu reduction
- No evidence of toxin photoproducts
- Used in combination with other treatments.
Synergistic Action of UV and Hydrogen Peroxide
UV: Hydrogen Peroxide (Advanced Oxidative Process)
Gyrotron: High Frequency Microwave Amplifier

\[ P = N^\text{th} \left( \omega_{n,n+1} \rho_{n,n+1} - \omega_{n,n-1} \rho_{n,n-1} \right) \]
Gyrotron

• High energy microwaves (MW)
• High frequency (170 GHz)
• Long wavelength
• Rapid heating (600C within 1s)
• Low penetration (<1mm)
• No need to label
• 5 log reduction (no peer review papers)

News

Microwave meat decontamination technology patent filed

Gyrotron Technology has filed a provisional patent application for its technology for decontaminating carcasses and other foodstuffs. The company said this technology was successfully tested on the laboratory scale and independently verified.

During those tests, heating the surface of meat for a small fraction of a second with a gyrotron, which is a very powerful source of high-frequency microwaves, reportedly cut the bacteria count on that surface by a factor of greater than 300,000, without compromising meat appearance.

Potential advantages of GYTI’s technology include a drastic decrease in bacteria count; an environmentally friendly process that would sharply reduce water consumption and eliminate the use of certain chemicals in existing decontamination processes; significant cost savings in the decontamination process; and prolonged shelf-life for raw meat.
Gyrotron

- Rapid heating low penetration
- No change in color or texture
- $2m^2$ treatment area $<1s$
- Comparable performance to electron beams
- Processing aid

- Cost?
- Maintenance?
## Carcass Decontamination

<table>
<thead>
<tr>
<th>Method</th>
<th>Treatment</th>
<th>LCR cfu</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV</td>
<td>4 J cm(^{-2})</td>
<td>0.5 – 1.0</td>
</tr>
<tr>
<td>Pulsed Light</td>
<td>5.6J per pulse; 16 Pulses</td>
<td>0.24-0.91</td>
</tr>
<tr>
<td>AOP</td>
<td>1% H(_2)O(_2) 19 mJ cm(^{-2}) UV</td>
<td>1-2</td>
</tr>
<tr>
<td>Microwave</td>
<td>1s</td>
<td>5</td>
</tr>
</tbody>
</table>
High Pressure Processing

Gridpath Solutions Inc

NC Hyperbaric
New Technologies

- Novel food designation
- Canada
- New Zealand and Australia
- China
- EU

- Not process but the food product
- Validation of most tolerant pathogen likely to be encountered
- Demonstrate no negative effects
- EU: More restricted on decontamination techniques that can be applied
Consumer Outreach
Plan to name and shame supermarkets selling chicken contaminated with dangerous food poisoning bug ditched after pressure from retailers

- Plan would have seen stores selling chicken with campylobacter bug named
- Idea has now been scrapped by the FSA following pressure from retailers
- Data on number of contaminated birds will be released without naming retailers
- Supermarket chicken named the biggest cause of food poisoning in the UK

By Sean Poulter, Consumer Affairs Editor

Published: 16:31 GMT, 22 July 2014 | Updated: 17:58 GMT, 22 July 2014
Consumer Education

• Sanitation

• Food storage

• Minimize cross-contamination events

• Thermometers to verify adequate cooking
Food Standards Agency UK

• Don’t wash chicken

• Coordinated media campaign
  • Public health units
  • TV
  • News outlets
  • Twitter
  • Facebook
  • National and International

>20 million google hits
Simple message but reinforced
### Blade/Needle/Mechanically Tenderized Beef

<table>
<thead>
<tr>
<th>Year</th>
<th>Meat</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Needle-tenderized</td>
<td>2</td>
</tr>
<tr>
<td>2003</td>
<td>Needle Injected Marinade</td>
<td>11</td>
</tr>
<tr>
<td>2004</td>
<td>Needle Injected Marinade</td>
<td>4</td>
</tr>
<tr>
<td>2007</td>
<td>Needle Injected Marinade</td>
<td>124</td>
</tr>
<tr>
<td>2009</td>
<td>Blade Tenderized</td>
<td>17</td>
</tr>
<tr>
<td>2012</td>
<td>Needle-tenderized</td>
<td>5</td>
</tr>
</tbody>
</table>
Conclusion

- North America reliance on interventions due to nature of production systems
- No golden bullet: Combination of methods throughout the chain
- Aqueous based washes: Water usage Wastewater treatment
- Novel technologies
  - Commercial feasibility
  - Effect on meat quality
  - Efficacy
- Consumer outreach of increasing importance
Acknowledgements

• Azadeh Namvar
• Xe Yi
• Micreos-Bacteriophages
• OMAF Food Safety and Innovation program
  • Meat decontamination using Advanced Oxidative Process
  • Application of bacteriophages to control Salmonella in pigs and production environment.