Advances in Nonthermal Food Processing Technologies

Roman Buckow | Research Group Leader
4th Asia-Pacific International Food Safety Conference & 7th Asian Conference on Food and Nutrition Safety, 11-13 October 2016, Penang, Malaysia

**History of Food Processing**

“... the three most important foods in Ancient Greece — bread, olive oil, and wine — were all products of complicated processing that transformed perishable, unpalatable, or hardly edible raw materials into safe, tasty, nutritious, stable, and enjoyable foods”

(Floros, et al. 2010, Compreh Rev Food Sci Food Safety)

**History of Food Preservation Processes**

- Drying
- Smoking
- Salting
- Fermentation
  - Thermal
    - Irradiation
    - High Pressure
    - PEF

Year:
- 3000 BC
- 1800 AC
- 1900 AC
- 2000 AC
The Prevention of Foodborne Diseases by Physical Treatments

Lost in Chile in 1885 - and found in 1989

High-Pressure Products commercially available

good for long-time storage, if done in the right way!

Consumer Dichotomies

Consumer demanding miracle foods:
- All Year
- New and Improved
- Good For You
- Safe
- Ready-to-Eat
- Low Price
- Convenient
- Local
- Traditional
- High Touch
- All-Natural
- “Green” packaging
- Eco-friendly
- Organic

Food preservation: finding the balance

Assessing the feasibility of processing technologies to deliver quality benefits & safe, shelf-life extension to foods

Emerging Food Preservation Technologies

Nonthermal
- High Hydrostatic Pressure
- Pulsed electric fields
- Ultrasound
- Ultraviolet
- Irradiation
- Cold Plasma
- Dense Phase Carbon Dioxide
- Ozone
- Chemicals

Thermal
- Microwave
- Radiofrequency
- Ohmic heating
- Advanced retorting
Emerging Food Preservation Technologies

**Nonthermal**
- High Hydrostatic Pressure
- Pulsed electric fields
- Ultrasound
- Ultraviolet
- Cold Plasma
- Dense Phase Carbon Dioxide
- Ozone
- Chemicals

**Thermal**
- Microwave
- Radiofrequency
- Ohmic heating
- Advanced retorting

Preservation Processes – Effectiveness and Costs

<table>
<thead>
<tr>
<th>Process</th>
<th>Process Parameters</th>
<th>Process Intensity</th>
<th>Lethality</th>
<th>Structure impact</th>
<th>Cost (~$/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying</td>
<td>T, t</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>7</td>
</tr>
<tr>
<td>Smoking</td>
<td>c, T, t</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>2.5</td>
</tr>
<tr>
<td>Salting</td>
<td>c, t</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>1.25</td>
</tr>
<tr>
<td>Fermentation</td>
<td>b, T, t</td>
<td>- -</td>
<td>+</td>
<td>+</td>
<td>2.5</td>
</tr>
<tr>
<td>Thermal</td>
<td>T, t</td>
<td>++</td>
<td>++</td>
<td>+ + +</td>
<td>0.05</td>
</tr>
<tr>
<td>Irradiation</td>
<td>Jw, T</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>0.4</td>
</tr>
<tr>
<td>High Pressure</td>
<td>p, T, t</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>0.3</td>
</tr>
<tr>
<td>Pulsed Electric Fields</td>
<td>E, T, t</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>0.15</td>
</tr>
</tbody>
</table>

+ major impact, - minor impact, b microbial growth parameters, c chemical efficiency parameters, E electric field strength, Jw specific total energy input, p pressure, T temperature, t exposure time

Irradiation

**Exposure of food to ionizing radiation**
- Inactivate bacteria, virus and insects
- Delay of ripening
- Sprout inhibition
- Used to decontaminate herbs, powders, fruit/veg, meat

Ultraviolet Light

The Germicidal properties of UV irradiation (200 – 280 nm)
- DNA mutations induced by DNA absorption of UV light
- Very effective to inactivate bacteria and some spores
- Retention of nutrients and flavour
- Penetration of UV is limited to a few micrometers
- Applied in industry for decontaminate water and some clear juices
Cold Plasma

Based on the interaction of a chemically and electrically reactive gas

- Fully ionised gas of low density
- Generally contains ions, atoms, singlet, photons and electrons
- Cool plasma is partially ionised gas at 30-60°C
- Inactivation of bacteria and spores on smooth surfaces
- Retention of nutrients and flavour
- Applied in industry for sterilisation of equipment and packaging materials

High hydrostatic pressure processing

**HPP – How does it work?**

- Inactivation of bacteria at 500-600 MPa
- Inactivation of some enzymes and fungal spores
- Pasteurisation in the final package
- Retention of nutrients and flavour
- Uniform treatment
- Good consumer perception

**HPP of food – early studies 1899**

**Hite 1899:**

- Pressure (600 MPa) applied at room temperature for 60 min can extend the shelf life of raw milk by 4 days
- Pressure also affects some native milk enzymes and proteins
- Some Coagulation of fat and proteins under pressure

**Total number of HPP industrial machines**

Source: Hiperbaric

Total machine number in production (Hiperbaric & competitors): >300 (2016)

Not included: 15 dismantled machines (all installed before 2003)
**High Pressure Processing of Foods**

- Inactivation of veg micro-organisms, viruses, some enzymes at room temperature
- Cold pasteurisation in the final package (no re-contamination)
- Retention of nutrients and flavours much better than heat treatments

**Guacamole**
- Wet salads
- RTE vegetable meals

**Pathogens-free sliced cooked meats**

- Listeria-free dry-cured products
- Raw beef products
- Preservative-free sausages

**Oysters shucking**
- Lobster meat extraction
- Clams & mussels shucking
- RTE seafood meals

**Fruit juices**
- Smoothies
- Vegetable juices

**Toll processing**
- Cheese / Eggs products

**Application: Refrigerated shelf life extension**

HPP in 2015: + 600 millions Kg

**Microbial inactivation by HPP**

Lethal effects on microorganisms may include
- denaturation of proteins & enzymes
- changes in the permeability of membranes = leakage & susceptibility to other hurdles

Differences in sensitivity to HPP
- Gram negatives > Yeast/Mould > Gram positives > Spores (only with heat also) “rule of thumb”

**Product specific**: inactivation dependent on pH, water activity, salt concentration, etc.

**Process specific**: exposure time, pressure level, etc.

**Listeria monocytogenes after 180 s at 600 MPa**

Variation in pressure (600 MPa/2 min/20°C) resistance of *L. monocytogenes* in cooked chicken

(Patterson, 2011)

HPP inactivation of bacteria at different temperatures

Buckow & Heinz (2008) Chem Ing Techn
HPP inactivation of exotic virus in chicken

Reduction in titre of various avian viruses in chicken meat slurry after treatment at 600 MPa and room temperature

<table>
<thead>
<tr>
<th>Virus</th>
<th>Pressure holding time (sec)</th>
<th>Titration method</th>
<th>Start titres</th>
<th>End titres</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIV (H7N7)</td>
<td>60</td>
<td>AS</td>
<td>6.5</td>
<td>0.2 ml</td>
</tr>
<tr>
<td>NDV (Hertz)</td>
<td>120</td>
<td>AS</td>
<td>8.3</td>
<td>0.2 ml</td>
</tr>
<tr>
<td>IBDV (Tasik94)</td>
<td>120 CAM</td>
<td>≥ 5.7</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>IBDV (52/70)</td>
<td>120 Chick</td>
<td>≤ 2.7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IBDV (variant)</td>
<td>15 Chick</td>
<td>2.1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IBDV (variant)</td>
<td>120 Chick</td>
<td>≤ 2.8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IBDV (GLS-5)</td>
<td>120 Chick</td>
<td>2.5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IBDV (GLS-5)</td>
<td>15 Chick</td>
<td>2.5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Reduction in titre of various avian viruses in chicken meat slurry after treatment at 600 MPa and room temperature

Comparison of C. botulinum strain resistance

Products from HPP treated meat
HPP treated meat

https://youtu.be/xkwrcHt2AXU

PEF inactivation microorganisms

Inactivation kinetics of S. cerevisiae in apple juice during PEF processing at 30°C

Inactivation kinetics of L. rhamnosus in apple juice during PEF processing 30°C

PEF microbial inactivation efficiency is highly dependent on:
1. applied electrical field strength, treatment time, temperature
2. type of targeted microorganism
3. environmental factors (pH, water activity, etc)

Pulsed Electric Field Processing

- Short high voltage (kV/cm) pulses
- Ruptures cell membranes
- Can inactivate vegetative cells of bacteria at mild temperatures (<50°C)
- Does not affect flavours & nutrients
- Treatment times in micro seconds
- Commercial systems (~10-50 t/h) available

Commercial Products

Inactivation of Salmonella Senftenberg in apple juice subjected to PEF treatments (13 to 25 kV/cm electric field strength) at 45°C.
PEF processing for shelf life increase of “non-pasteurised” juices and smoothies

"mild" PEF processing at ~30°C

Shelf life extension for “fresh” and preservative-free juices from 6 to 21 days

S. Toepfl (2012)

Energy use in large scale processing

<table>
<thead>
<tr>
<th>Technology</th>
<th>Processing conditions</th>
<th>E. coli strain</th>
<th>Capacity (L/s)</th>
<th>Specific Energy (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HTST</td>
<td>71.6 °C x 6 s</td>
<td>O157:H7</td>
<td>1.0</td>
<td>180.4</td>
</tr>
<tr>
<td>HPP</td>
<td>500 MPa x 40 °C x 180 s</td>
<td>O157:H7</td>
<td>1.25</td>
<td>283.5</td>
</tr>
<tr>
<td>PEF</td>
<td>25 kV/cm x ~50 °C x 50 μs*</td>
<td>ATCC 11775</td>
<td>0.670</td>
<td>137.2</td>
</tr>
<tr>
<td>UV</td>
<td>1.56 kW x 25 °C x 89 s</td>
<td>K-12</td>
<td>1.1</td>
<td>5.2</td>
</tr>
<tr>
<td>UF</td>
<td>0.02 μm, 1.474 kPa, 5 L/m².s</td>
<td>Pseudomonas diminuta</td>
<td>1.0</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Opportunity to significantly reduce energy use if decontamination can be performed by UV or membrane filtration treatments

The future of food preservation

It’s not just about innovative processing, but innovative thinking

Secure a safe & stable food supply that minimises waste

Premium convenience foods that are fresh-like & more nutritious

Economic growth in the food sector through export

Need to transform the way we process / preserve foods

Drivers

Secure a safe & stable food supply that minimises waste

Premium convenience foods that are fresh-like & more nutritious

Economic growth in the food sector through export

Flexibility to innovate

Need to transform the way we process / preserve foods
Thank you

Roman Buckow
Research Group Leader

+61 3 9731 3270
roman.buckow@csiro.au
www.csiro.au