High Pressure Processing: Opportunities and Challenges

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High Pressure Processing (HPP)

• A novel food processing technology
  • Early studies were done in late 1800s.
  • Engineering advancements made the technology feasible

• Pressures of up to 1000 MPa (145,000 psi) is applied to foods to extend the shelf life
  • Typical pressure range: 300 to 700 MPa

• Environmentally friendly – no by-products

• Flurry of R&D and commercial developments around the world
Why HPP?

- Extended shelf-life & improved food safety
  - Inactivates yeast, molds, bacterial cells and most viruses
- Minimal change in food flavor, color, texture, nutritional value
  - Food maintains fresh-like characteristics
  - Improved food quality
- HPP enables food manufacturers to use fewer/no additives (Public concern with chemical preservatives in foods) → CLEAN LABEL
- Can alter products high in protein/starch
  - Novel food products
200 elephants weighing 3000 kg each standing on a piston with a diameter of a CD, create a pressure of 600 MPa, 6000 bar or 90,000 psi.
Where Can We Find High Pressures??

Marina Trench: 10,994 meters deep
How does High Pressure Processing Work?

- Pressure is transmitted instantaneously & uniformly throughout the food product independent of size and shape
  - Food will not be crushed
- No gradient of effectiveness from outside to inside
Principles of High Pressure Processing (HPP)

- Product compressed, returns to original shape; water relatively incompressible
- Due to adiabatic heating, temperature of the product increases (water: 3 °C increase for every 100 MPa; temperature increase depends on the food components)
- Batch or semi-continuous process
- Can alter some food products
Pre-packaged (Batch) Production

24 L High Pressure Unit
IFSH pilot plant
Max: 890 MPa @ 131°C
HPP Mechanism of Inactivation

- Lethal effects on microorganisms
  - affects cell morphology, membranes, spore coats
  - denatures proteins & enzymes
  - permeability of membranes $\rightarrow$ leakage
- Sensitivity to HHP
  - Gram Negatives $>$ Yeast/Mold $>$ Gram Positives $>$ Spores
- Product specific; inactivation dependent on pH, RH, medium/food, exposure time, pressure level, etc.
Listeria monocytogenes

Untreated

Pressure-treated

600 MPa
2 min
Chemical Effects

- Disruption hydrophobic & ionic bonds, unlike heat which breaks covalent bonds
  - different textures created
- Enzyme response varies; inactivated or stimulated depending on tertiary structure, internal charges
- Vitamins, flavors, color compounds minimally affected
- Gels starchy substances (e.g. viscosity of pectin is increased $\rightarrow$ less pectin is sufficient)
Products on International Market
Product Examples: Oysters

Key Drivers

Shucking, Labor intensive

Export Opportunities

Food Safety Concern
Raw Oysters

Outputs & Outcomes

HPP in Shell-Shucking
Increased yields

Extended Shelf-life

Enhanced Safety
‘Cold Pasteurization’

Research Challenges

Validation of Viral and Bacterial kill step
Optimization of process
Packaging and distribution
Shelf-life & Sensory Studies

www.theperfectoyster.com
Product Examples: RTE Meats

Key Drivers

- Current shelf-life Limited
- Food Safety Concern
- Fermented Products *E.coli*
- Chilled products, *Listeria*

Outputs & Outcomes

- Extended shelf-life
- New and existing markets
- Enhanced Safety
- ‘Cold Pasteurization’

Research Challenges

- Validation of Bacterial kill step
- Packaging and distribution
- Shelf-life & Sensory Studies
**Product Examples: Horticultural Products**

**Key Drivers**
- Freshness & Convenience
- Food Safety Concern
  - *E.coli/Salmonella*

**Outputs & Outcomes**
- Minimal effect on texture/flavour/nutrition
- Extended shelf-life
- Enhanced Safety
  - ‘Cold Pasteurization’

**Research Challenges**
- Enzyme inactivation/inhibition
- Validation of bacterial kill step
- Packaging and distribution
- Shelf-life & Sensory Studies
Chemical Analyses of HPP treated juices

- Viscosity
- Brix
- pH
- Titratable acids
- Colour
- Browning
- Dissolved oxygen
- Sedimentation

HPP had no significant effect compared with untreated juice.
Nutrient Analysis Orange Juice: Ascorbic acid and β-carotene

- **L-ascorbic acid:**
  - ~7% loss after HPP (600 MPa, 1 min)
  - No significant difference in vitamin C loss during storage (90 days, 4 °C)

- **β-carotene:**
  - HPP did not affect β-carotene content
  - Content did not decrease with storage
# Pectin Methylesterase (PME) Deactivation

## Navel Oranges

<table>
<thead>
<tr>
<th>Time (min) at 600 MPa</th>
<th>(Adjusted) pH 3.0</th>
<th>Early-season pH 3.55</th>
<th>Mid-season pH 3.65</th>
<th>Late-season pH 4.05</th>
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Valencia orange juice: Consumer Perception of “Freshness”

Baxter et al., 2005
High pressure inactivation of Salmonella in orange juice

Conditions needed for 5-log reduction

<table>
<thead>
<tr>
<th>Pressure (MPa)</th>
<th>Processing Time (s)</th>
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<td>25</td>
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<tr>
<td>500</td>
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</table>

Bull et al., 2005
HPP Treated Feline Calicivirus

Lee et al., 2002
Example: High Pressure Processing Shellfish and Virus Inactivation

Feline Calicivirus

Hepatitis A

Grove et al., 2008
J. Food Protection
Some HPP opportunities

- Extended shelf-life yogurts
- Fresh fruit and yogurt products
- Milk cheeses
  - Flavor of raw milk cheeses
  - Improved texture and yield
- Post packaging microbial contamination removal for many products (juices, milk, salads, wine, cheeses)
- Selected functional properties
  - in products and ingredients
- Improved microbial quality of bioactive products
HPP opportunities for food

- **Yogurts**
  - **Full-fat**: prevent rise of acidity after packaging & maintained initial # viable lactic acid bacteria and yogurt texture
  - **Low-fat types**: creamy, thick consistency requiring no additional polysaccharides, improved flavor and texture

- **Milk for reduced fat cheese**
  - Improved yield, coagulation and texture scores
  - More flavour development

- **Synergy** (e.g. lacticin 3147 (bacteriocin) and 250 MPa)
  - Staphylococcus & Listeria 1 and 2 log reduction separately and 6 log when combined.
HPP opportunities for food

- **Wine**
  - Reduction of SO$_2$
  - Control of flavor development and enzyme reactions.
  - Stop (in package) fermentation
- **Fruit and vegetables**
  - Superior fresh flavour quality juices
  - Superior quality salsa’s, guacamoles
  - Extended shelf-life salads and dips
  - Flavour and texture of fruit salads
  - Disinfestation
Pressure Assisted Thermal Sterilization (PATS)

- Sterilization of foods → combined effect of temperature and HPP
  - Inactivation of spores → shelf stable foods
- FDA Approval
- Initial temperatures (60 to 90 °C) → final temperatures (80 to 130 °C)

Compared to traditional canning:
- Shorter time
- Better Quality
HPP Market segmentation matrix

ESL, Reduce Cost, New functions

Value Creation

Low Value-Added

Low

High

Food Safety Profile

Source: Dr. Patrick Dunne, US Army Natick (retired) & Avure
Other applications of HPP

- Tenderization of meat
  - Modification of protein structure
- Nutrients enhancement (more study is needed)
  - Some pressure levels are shown to increase antioxidants and other nutrients
  - Other pressure levels are shown to decrease nutrient content (minimal compared to thermal processing)
Limitations of HPP

- Bacterial spores are not inactivated by pressure alone
  - Most suitable for acid foods
  - Products need refrigeration for shelf-life and non-acid foods for food safety without other preservation measures
- Some food enzymes resistant to pressure
- Can alter food products with high protein or starch contents
- Batch process or semi batch process
- Cost is a factor, but technological advances have brought equipment costs down & made commercialisation feasible

(Cost reduced 50,000 times over the last 100 years !)
Other processing techniques

Thermal → Nonthermal

High pressure

Pulsed electric field

Electron beam irradiation

UV Light & Pulsed light
Food Processing Balance

Need to destroy
Pathogens
Spoilage Organisms
Enzymes

Optimize
Flavor
Texture
Color
Nutritional quality

VS
References


- IFT’s Nonthermal Processing Division’s news bulletin featuring hpp and other technologies
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Questions?
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