Agenda

• Define and distinguish
• The equipment and process
• What actually happens under pressure
• How pressure is used in the meat industry
• Considerations for making an HPP product
• Novel uses of pressure
• Questions
HPP Talking Points

• Effective as a food safety intervention
• Extends shelf life
• Non-chemical
• Non-thermal
• Minimal nutritional impact
• Clean label
Basic definitions

• High pressure processing (HPP) – basic, catch-all definition

• High hydrostatic pressure (HHP) – pressure applied submersed in liquid

• High pressure pasteurization (HPP) – specific application for food safety

• These phrases should be considered identical in a food processing context
  • Hydrodynamic pressure (HDP) is a different process
Other definitions

• Pressure Assisted Thermal Processing (PATP)
  • HPP using heated medium
  • Also called high pressure high temperature (HTHT) or pressure assisted thermal stabilization (PATS)

• High Pressure Low Temperature (HPLT)
  • HPP at subfreezing temperatures (solid-solid phase transitions)
  • HPP used to freeze/thaw products
    • High pressure shift freezing (HPSF)
    • High pressure assisted thawing (HPAT) or high pressure induced thawing (HPIT)
Components of an HPP system

• Vessel
  • Contains product and liquid
  • Must withstand pressure/temperature desired

• Intensifier pump
  • Forces liquid into chamber to increase pressure
  • Larger volumes require multiple intensifiers

• Medium
  • Most modern systems use water
Components of an HPP system

• Input/output system
  • Moves product in/out of the vessel
  • Basket-conveyor is most common

• Yoke
  • Holds system together, secures plug

• Chilling/heating units – optional
  • Maintain process temperature
HPP Systems (antique)

Oregon State 20 L HPP system
Equipment (modern)

NC Hiperbaric 55 system

Avure AV-10 system

Photos from NC Hiperbaric & Avure, respectively
High Pressure Principles

- How high is the pressure?

- Typical HPP run: 87,000 psi, 5,920 atm, 600 MPa
- Challenger deep (35,827 ft): 16,100 psi, 1,100 atm, 111 MPa
- 10 M (33 ft) under sea surface: 29.4 psi, 2 atm, 0.202650 MPa
- Atmospheric pressure: 14.7 psi, 1 atm, 0.101325 MPa
High Pressure Principles

• pH is decreased under pressure
  • Meat, poultry, fish have increased pH following pressurization (~0.1 units)

• Temperature rises – adiabatic heating
  • 2-3 °C/100 MPa for meat, 8 °C/100 MPa for fat

![Graph a](image)

Fig. 4 Predicted pressure-induced pH shift in citric acid buffer. Adapted from Paredes-Subja et al. (2007)

![Graph b](image)

![Graph c](image)

Figure 4—Temperature increase of selected substances high-pressure processed at initial temperature of 25 °C
High Pressure Principles

• The behavior of water/ice changes due to pressure

• Freezing point of water is -22 °C at 210 MPa

• Ice forms under pressure have greater density than water
High Pressure Principles

• Protein structure may change
  • Secondary, tertiary and quaternary structure are affected

• Enzymes may be activated or inactivated

• Protein filaments may be dissolved

• Protein crosslinking may be induced

Fig. 2
General scheme of the pressure-temperature phase diagram of proteins.
High Pressure Principles

• Free radicals are formed directly by pressurization >400 MPa

• Cell membranes may be disrupted
  • Selective diffusivity is degraded/lost
  • Exposure of long chain unsaturated fatty acids

• Pressure transmission is instantaneous

Fig. 3. Radical concentration in meat slurries submitted to high pressure processing over time at different pressures at 25 °C (experiment 2). ● 500 MPa, ○ 600 MPa, ▽ 700 MPa. Lines are from data analysis according to zero or first order reaction. Standard deviations are derived from repetitive ESR-measurements of free radical concentration.
What is HPP used for in the meat industry?

• Food safety
  • *Listeria monocytogenes* control on ready to eat (RTE) meats
    • Clean label alternative to antimicrobial additives
    • Ensure food safety in alternatively cured products
  • Salmonella*/E. coli* control in fresh poultry
  • Salmonella control in pet food

• Oyster/lobster shucking/yield
HPP and food safety

• Effect is based on multiple factors
  • Pressure level – higher is more effective
  • Dwell time at pressure – greater is more effective
  • Temperature – depends on the organism
  • Product water activity ($a_w$) – greater is more effective
  • Product pH – lower is more effective
  • Product salt & nitrite level
  • Bacterial characteristics
HPP and food safety

• Most common process to combat *Listeria* is 600 MPa for ~3 min.

• HPP conditions for HACCP plans need to match HPP conditions and product parameters in validation literature
  • If similar conditions can’t be found then a validation study should be carried out
Is HPP right for my product?

• What is your organism of concern?
• Is your product raw or cooked?
• What species is it?
• How is it packaged?
• What is the pH? Water activity?
• Are there any baroprotectants in the formulation?
• Is there room in the price for an increase?
Is my product right for HPP?

Untreated

HPP - 551 MPa, 4 min

Beef *semitendinosus* (eye of round) w/ 30 minutes bloom time at 4 °C
Is my product right for HPP?

• The package and product must withstand a 15% volume decrease at 600 MPa

• Vacuum bags and skin packaging work best
  • Some packaging companies offer dedicated materials for HPP

• Modified atmosphere packaging (MAP) can work with a controlled decompression rate
Is my product right for HPP?


• How much product do you want to pressurize?
• How much can fit in a basket?
• What pressure level? What dwell time?
• What temperature?
• Any further processing or repackaging?
• Shipping to a toll processor? Storage at the toll processor?
• Does a validation study need to be done?
How can I use HPP?

• Option 1: Buy/build your own HPP system
How can I use HPP?

• Option 2: Toll processors
  • http://www.avure-hpp-foods.com/tolling-centers/find-a-tolling-center/
  • http://www.hiperbaric.com/en/hpp-toll-processing
What about spore-forming organisms?

• *C. perfringens* & *C. botulinum* are very pressure resistant

• PATP is a potential solution
  • 600 MPa, >90 °C (194 °F)

• Drawbacks
  • Higher energy cost, more expensive equipment, not as thoroughly researched as conventional HPP
What are other potential uses of HPP?

• Enzyme inactivation/tenderization

• Minimize quality deterioration during freezing/thawing

• HPP of uncooked frozen products to protect quality (HPLT)
Enzyme inactivation/tenderization

• Low pressure levels (~200 MPa) on pre-rigor meat can positively influence tenderness and water holding capacity

• Drip loss, purge and cook loss may be decreased

Pre-rigor pressurized pork (215 MPa, 15s, 33 °C) – from Souza et al., 2011
Conclusions

• HPP is a potential solution for *Listeria* control on most RTE meat products
  • An increase in shelf life may be expected compared to other post-lethality treatments

• PATP (given further research) may provide an alternative means for commercial sterilization and shelf stable products

• Development of commercial equipment and a growing number of machines in operation should continue to reduce the cost of HPP
Conclusions

• Pre-rigor HPP may improve quality of hot-boned meat

• Other applications of hydrostatic pressure are probably years away

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  • Joy Waite-Cusic, Oregon State University, Corvallis, OR
References


Other recommended references:
