George J. Flick, Jr.

High Pressure Processing Laboratory and Service Center

Food Science and Technology Department

Virginia Tech (0418)

Blacksburg, Virginia 24061

High Pressure Processing Applications

- Ready-to-Eat Meat Products
- Ready-to-Eat Meals
- Seafood
- Value Added Fruits and Vegetables
- Beverages

Sales of High Pressure Processed Products

- A&P
- ACME
- Kroger
- Jewel/OSW
- Dominical
- Albertson's
- Trader Joe's
- Sysco
- Wal-Mart
- HEB
- Safeway
- Costco
- Sam's Club
- Subway
- H.E. Butt
- U.S. Food Service

High Pressure Processing of Seafood

- Reduces some pathogenic bacteria
- Reduces some viruses
- Reduces some parasites
- Reduces some allergens

HPP Has Been Used to Control Some Bacteria

- Listeria monocytogenes
- Staphylococcus aureus
- Salmonella spp.
- Escherichia coli
- Fecal coliforms
- Yeasts and Molds

HPP Has Been Used to Control Some Parasites

- Cryptosporidium parvum
- Giardia lambila
- Anisakis simplex
- Eimeria acervulina

HPP Has Been Used to Control Some Viruses

- Inactivation
  - Norovirus
  - Picornaviruses
  - Hepatitis A
  - Rotavirus
  - Influenza
  - Adenovirus
- Resistant
  - Poliovirus

Pressure-induced disassociation of viruses may be fully reversible or irreversible depending on the virus and treatment conditions. The higher the treatment parameters, the greater the potential for irreversibility.

Extension of Shelf-life

- Many foods are generally spoiled by Gram negative bacteria, which tend to be relatively pressure sensitive.
- Lactic acid bacteria survive HPP treatment and grow. Odors produced by lactic acid bacteria are generally less objectionable than normal micro flora.

Extension of Shelf-life

- High pressure processing can enhance the action of some enzymes while inactivating others.
  - Example: HPP increases the head blackening of shrimp

Potential Limitations of HPP

- Enzymes activity may be increased
- Sterilization may not be achievable
  - Product has cooked appearance
  - Most muscle foods have few intrinsic preservation properties

Sensory Quality of HPP-Treated Muscle Foods

- HPP does not change the taste of foods but can result in a flavor change.
- HPP may cause a hardening or a softening of a product.
- HPP may cause an opacity similar to light cooking.

Optimization of Treatment Parameters

- Low HPP can cause blackening of shrimp but high HPP can reduce blackening.
- Is the product more safe or less safe?
- Yield vs. Shelf-life vs. Appearance
- Cold vs. Hot processing
- Pulses may reduce spore-forming bacteria.

HPP for Crab Processing

Microorganisms isolated from vacuum-packaged unpressurized (control) and pressurized (550 MPa at 25°C for 5 min) crab meat stored at refrigeration temperature for 31 days

Microorganisms	Days of storage and treatment													
	Control							550 MPa						
	0	3	7	12	17	24	31	0	3	7	12	17	24	31
Acinetobacter														
johnsonii	●													
lwoffii	●													
Aerococcus														
viridans								●						
Aeromonas														
salmonicida							●							
Arthrobacter														
aurescens	●													
agilis			●											
Bacillus														
megaterium		●												
Brevibacillus														
agri	●							●						
Brevibacterium														
iodinum	●							●	●					
linens								●						
casei								●	●					
epidermidis								●						

● = isolated from aerobic plates ∗ = isolated from anaerobic roll tubes

Microorganisms isolated from vacuum-packaged unpressurized (control) and pressurized (550 MPa at 25°C for 5 min) crab meat stored at refrigeration temperature for 31 days

Microorganisms	Days of storage and treatment													
	Control							550 MPa						
	0	3	7	12	17	24	31	0	3	7	12	17	24	31
Carnobacterium piscicola	*	● *	● *	● *	● *	● *	● *				*		● *	
Chryseobacterium balustinum			●											
Corynebacterium auris										●	●			
Enterococcus mundtii								*	● *	● *	●	● *	*	*
avium								*			*	*	*	● *
solitarius								*			*	● *	*	● *
Exiguobacterium acetylicum	●	●		●										
Macrococcus caseolyticus		●						●	●	*				

● = isolated from aerobic plates **∗ = isolated from anaerobic roll tubes**

Microorganisms isolated from vacuum-packaged unpressurized (control) and pressurized (550 MPa at 25°C for 5 min) crab meat stored at refrigeration temperature for 31 days

Microorganisms	**Days of storage and treatment**													
	Control							**550 MPa**						
	0	3	7	12	17	24	31	0	3	7	12	17	24	31
Moraxella catarrhalis											●			
Providencia rustigianii							●							
Pseudomonas putida aureofaciens		● ●	●	●		●								
Psychrobacter immobilis										●	●	●		
Staphylococcus kloosii	●													

• = isolated from aerobic plates ⁎ = isolated from anaerobic roll tubes

Predominant microorganisms isolated from aerobic plates

Day	Control	550 MPa
0	***Exiguobacterium acetylicum*** ***Acinetobacter***	***Brevibacterium***
3	***Pseudomonas putida***	***Brevibacterium***
7	***Pseudomonas putida***	***Psychrobacter immobilis***
12	***Carnobacterium piscicola*** ***Pseudomonas putida***	***Psychrobacter immobilis***
17	***Carnobacterium piscicola***	***Enterococcus***
24	***Carnobacterium piscicola***	***Enterococcus***
31	***Carnobacterium piscicola***	***Enterococcus***

Predominant microorganisms isolated from anaerobic roll tubes

Day	Control	550 MPa
0	***Carnobacterium piscicola***	***Enterococcus***
3	***Carnobacterium piscicola***	***Enterococcus***
7	***Carnobacterium piscicola***	***Enterococcus***
12	***Carnobacterium piscicola***	***Enterococcus***
17	***Carnobacterium piscicola***	***Enterococcus***
24	***Carnobacterium piscicola***	***Enterococcus***
31	***Carnobacterium piscicola***	***Enterococcus***

HPP for Crawfish Processing

Organisms Identified on Day 0

Organism	Control samples	HPP samples
Bacillus marinus	yes	no
Bacillus sphraericus	no	yes
Bacillus subtilis group	yes	no
Corynebacterium aquaticum	no	yes
Enterococcus faecalis	yes	no
Enterococcus faemium	yes	no
Exiguobacterium acetylicum	yes	no
Klebsiella	yes	no
Kocuria varians	yes	no
Paenibacillus macerans	yes	no
Paenibacillus polyxma	yes	yes
Staphylococcus cohnii	yes	no
Staphylococcus kloosii	yes	no
Staphylococcus scuiri	yes	no

Organisms Identified on Day 7

Organism	Control samples	HPP samples
Bacillus marinus	yes	no
Bacillus pumilus	yes	no
Bacillus sphraericus	no	yes
Bacillus subtilis group	yes	no
Carnobacterium piscicola	yes	no
Corynebacterium aquaticum	yes	yes
Enterococcus faecalis	yes	no
Enterococcus faemium	yes	no
Exiguobacterium acetylicum	yes	no
Kocuria varians	yes	yes
Pseudomonas	yes	no

Organisms Identified on Day 10

Organism	Control samples	HPP samples
Bacillus sphraericus	no	yes
Carnobacterium piscicola	yes	no
Corynebacterium aquaticum	no	yes
Enterococcus faecalis	no	yes
Exiguobacterium acetylicum	yes	no
Pseudomonas	yes	no

Organisms Identified on Day 14

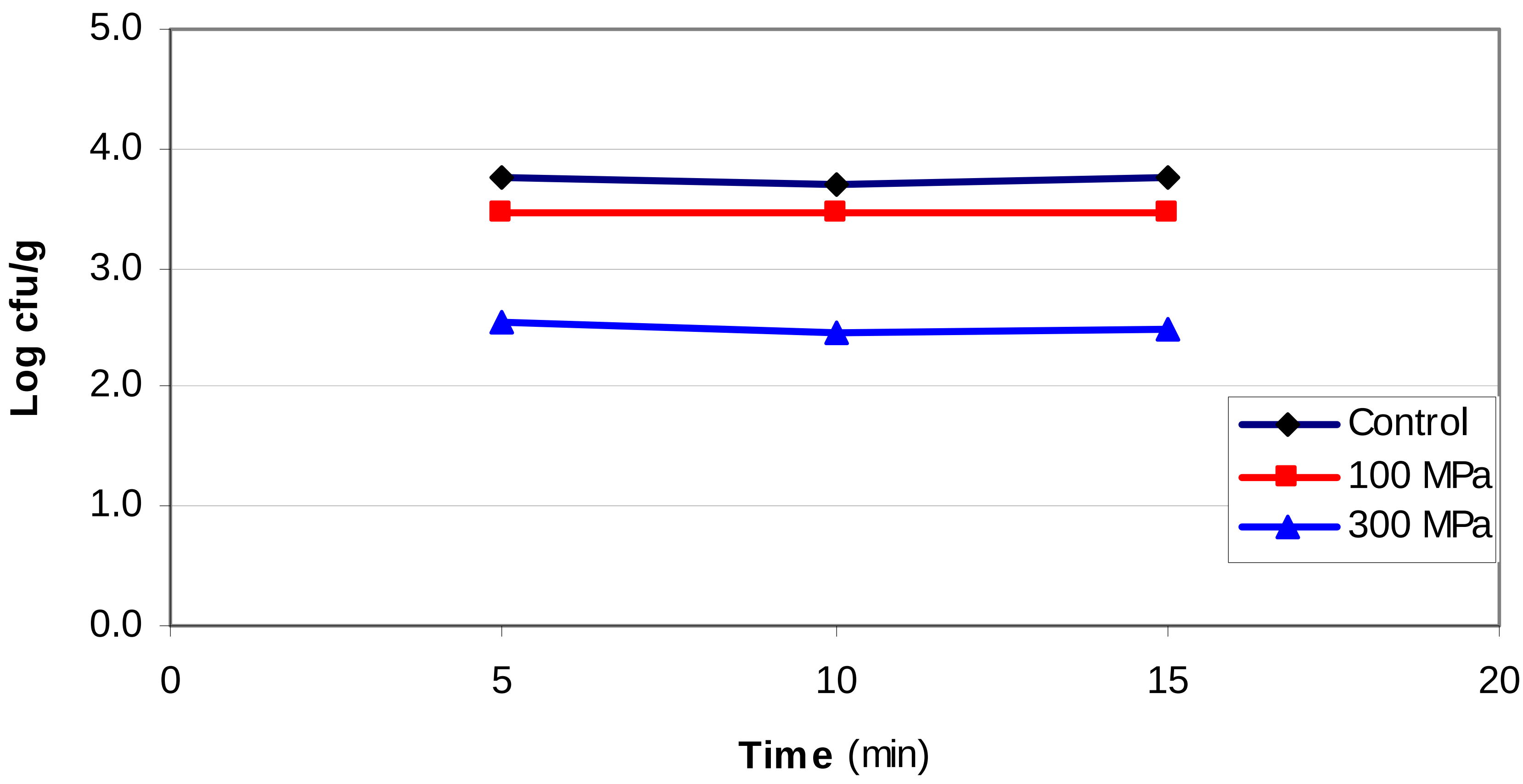
Organism	Control samples	HPP samples
Bacillus marinus	no	yes
Bacillus pumilus	no	yes
Bacillus sphraericus	no	yes
Carnobacterium piscicola	yes	no
Enterococcus faecalis	no	yes
Exiguobacterium acetylicum	yes	yes
Paenibacillus macerans	no	yes
Paenibacillus polyxma	no	yes
Pseudomonas	yes	no

Organisms Identified on Day 21

Organism	Control samples	HPP samples
Bacillus marinus	not run	yes
Bacillus sphraericus	not run	yes
Enterococcus faecalis	not run	yes
Enterococcus faemium	not run	yes
Paenibacillus macerans	not run	yes

Control samples for Day 21 were not run because they were considered spoiled after Day14.

Effects of processing times of 5, 10, and 15 min at 25 °C at 300 and 550 MPa on total aerobic plate counts



Recommendations for Implementation of HPP

1. Consider applications
    - Shelf-life extension
    - Pathogen control
2. Further steps
    - Perform pilot studies
    - Consider variation in barotolerance of microorganisms
3. Review the literature

Applications of HPP

1. Inactivation of prions (BSE)
    - 690, 1,000, and 1,200 MPa at 121-137 °C
2. Riboflavin and thiamine in pork are stable at 600 MPa. Vitamin decay in model system was 30 times faster.
3. Listeria monocytogenes
    - 1 min at 500 MPa at 40 °C – 3.8 log reduction
    - 1 min at 500 MPa at 1 °C – 1.4 log reduction
    - 1 min at 500 MPa at 20 °C – 0.9 log reduction

Tailing is a problem for minimally processed foods.

Applications of HPP (continued)

4. Blood sausage shelf-life was increased by 15 days
   - 600 MPa for 10 min at 4 °C
5. High pressure (400 MPa, 10 min, 17 °C) with nicin reduced slime-producing lactic acid bacteria, Listeria monocytogenes, and Salmonella spp. (enterocins A and B, sakacin K, pediocin AcH, or nicin)

Applications of HPP (continued)

6. Raw and marinated beef loins, when treated at 600 MPa, 10 min, 30 °C, had reduced Salmonella spp and Listeria monocytogenes and a longer shelf-life
7. Meat enzymes (0-600 MPa, 0-300 sec)
   - Acid phosphatase – not affected
   - Cathepsin D – affected by pressure/time

Applications of HPP (continued)

8. L. monocytogenes on sliced ham was reduced by 5 logs at 500 MPa, 10 min
9. Cooked, sliced ham was subjected to 400 MPa, 10 min, 30 °C
   - Microbial growth with pressurized and non-pressurized samples was equal
   - Tyramine formation was reduced in pressurized samples compared to control
   - Histamine and putrescine were also reduced in concentration

Applications of HPP (continued)

10. Meat batter before sausage fermentation
    - Inhibition of biogenic amines (putrescine, cadaverine, tyramine)
    - Inoculate decarboxylase-negative strains from indigenous sausage bacteria prevented Enterococci development and reduced enterobacteria counts
    - Starter culture was more protective against biogenic amine formation than just pressure

Applications of HPP (continued)

11. Frankfurters were vacuum packaged and pressurized at 400 MPa, 10 min, 30 °C and stored at 2 °C up to 120 days
    - Tyramine, putrascine and cadaverine exhibited the greatest change. Histamine was also reduced.
    - HPP had no effect but lowered the population by >3 log.

Applications of HPP (continued)

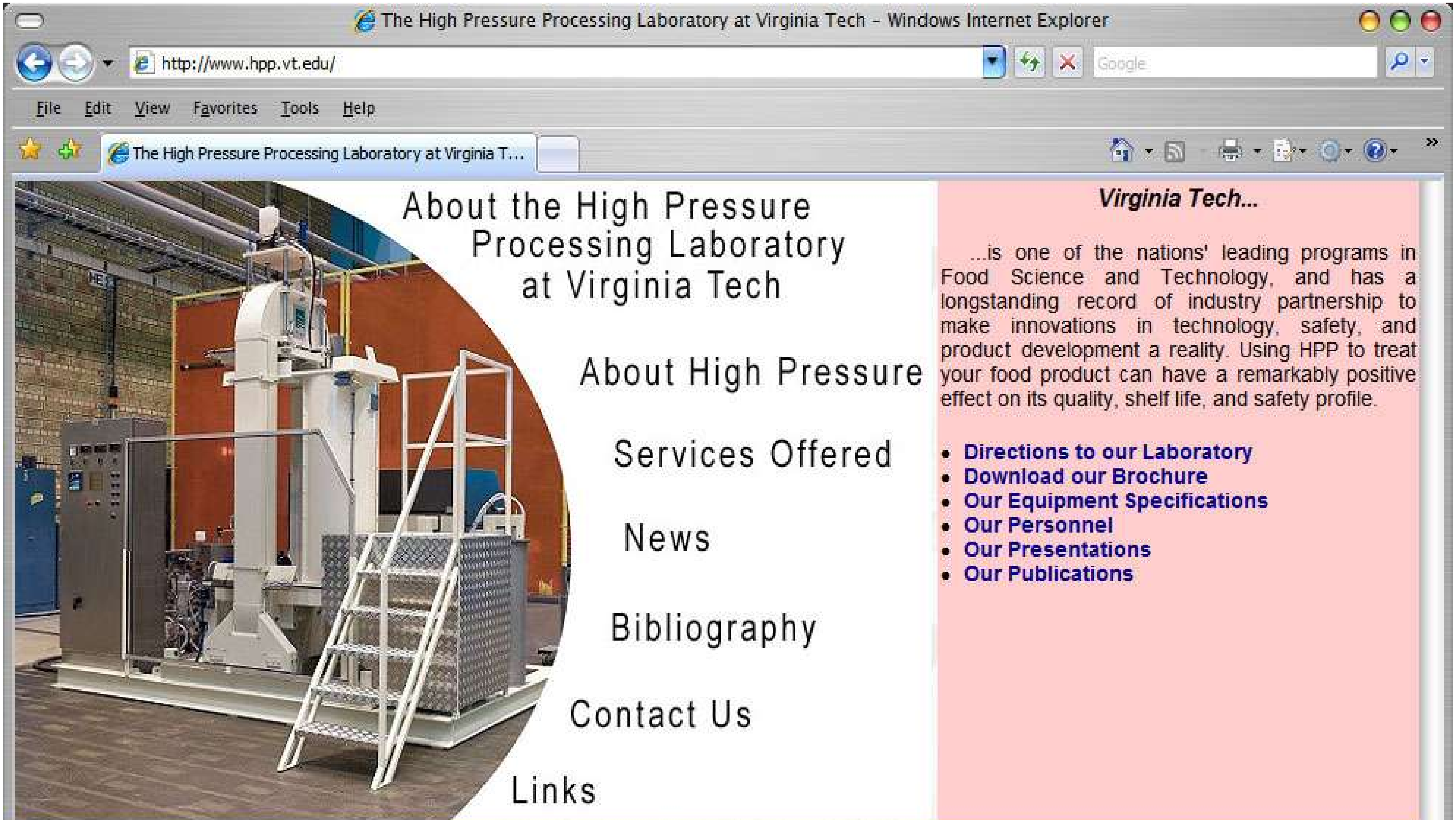
12. Baroresistant strains of Campylobacter jejuni and C. coli were reduced by 6 logs at 450 MPa, 1 min, 70 °C and at 30 sec, 15 °C.
13. HPP treatments ≥ 400 MPa increased lipid oxidation (TBARS) in beef and chicken muscle.

Applications of HPP (continued)

14. Beef patties with E. coli O157:H7 had reduction of:
    - 0.82 log at 400 MPa, 1 min, 12 °C
    - 4.39 log at 400 MPa, 20 min, 12 °C
    - 4.96 log at 400 MPa, 3-5 min cycles, 12 °C
15. Yersenia enterocolitica was reduced 5 logs at 275 MPa, 15 min

Applications of HPP (continued)

16. HPP at 500 MPa, 5 min, 6 °C extended the shelf-life of several Spanish dry sausages up to 120 days without destroying sensory properties
    - Enterobacteria, Enterococci, and Pseudomonads were suppressed
17. HPP treatment at 550 MPa, 2 min, and 4, 20, or 40 °C reduced Eimeria acervulina non-pathogenic to chickens
    - The inactivated parasite also provided some immunity to the chicken



http://www.hpp.vt.edu

* Extensive searchable database of HPP research

* Details on contract services