



Design and Evaluation of Cold Fill Hold Process Applications for Acidified Foods

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- With VT since 2014
- With VCE since 2019
- B.S. Biological Sciences, Roanoke College
- M.S. Food Safety & Biosecurity, Virginia Tech
- Process Authority
 - A person having expert knowledge of thermal processing requirements for foods in hermetically-sealed containers
 - BPCS certified for Acidified Foods
- Food Safety Specialist
 - Acid/Predominantly Acid Foods
 - Fermented Foods
 - Water Activity-Controlled Foods
 - TCS Evaluations
 - Nutrition Fact Panel creation
 - Ingredient statement review



COLLEGE OF AGRICULTURE AND LIFE SCIENCES
FOOD SCIENCE
AND TECHNOLOGY
VIRGINIA TECH.

- 110+ undergraduate and 120+ graduate programs
- 38,000 students (80/20 UG/G)
- Research portfolio of more than \$556 million (top 6% of US universities)
- Land-grant institution
 - 2600 acre main campus in Blacksburg
 - Innovation campus in NoVA
 - Health Sciences and Technology campus in Roanoke
 - Other sites in Newport News, Richmond
 - 11 Agricultural Research & Experiment Centers (ARECs) across the state; spans CALS, CNRE, VMCVM

- Undergraduate degree ranked 9th best nationally
- Food Science major options:
 - Science
 - Food Business
 - Food and Health
 - Food & Beverage Fermentation
- Food Science minor options:
 - Science
 - Fermentation
- IFT-approved
- Recognized by Master Brewers Association of the Americas
- Masters and PhD programs
 - 43 graduate students
- Non-thesis program - OMALS

Food Producer Technical Assistance Network

<https://www.fst.vt.edu/extension/foodbiz.html>

- Has existed within the Food Science and Technology Department at Virginia Tech in some form since 1999
- During FY 2024, more than:
 - 645 products tested
 - 204 individuals served
 - 342 reports written
 - 140 nutrition facts panel reports



Image credit: Alex Hood, VT

- Sent and received more than 6100 emails (program inbox only)
- More than 360 hours on phone calls to producers, regulators, home cooks and anyone else that had questions
- Program operates as a cost recovery center to provide low-cost assistance in support of small entrepreneurs
 - During FY 2024, invoiced around \$45,000

Definitions most of us know by heart...right!?

- Acid foods: have a natural pH of 4.6 or below
- Low-acid foods: have a finished equilibrium pH greater than 4.6 (less than 4.7 for tomato products) and a water activity greater than 0.85
- Acidified foods: low-acid foods to which acid(s) or acid food(s) are added; finished equilibrium pH below 4.6 and a water activity greater than 0.85



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21 CFR 114.3



21 CFR 114.80(a) tells us that “the manufacturer shall (MUST!) employ appropriate quality control procedures to ensure that finished foods do not present a health hazard.”

Acidify

- Blanching
- Immersion
- Direct batch acidification
- Container acidification

Evaluate pH

- Frequency
- Recorded results
- Potentiometrically pH >4.0
- Any suitable method pH <4.0

Container examination

- Frequency
- No leakage or risk of contamination

Processing

- Finished equilibrium pH <4.6
- Follow scheduled process
- Thermally processed to an extent that is sufficient to destroy vegetative cells **unless...**

...unless

thermal
processing
degrades product
quality, such as
appearance,
texture, taste.



“Permitted preservatives may be used to inhibit reproduction of microorganisms of nonhealth significance (in lieu of thermal processing.)”

- 21 CFR 114.80(a)(1)



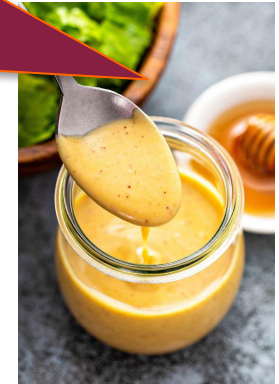
Many products lend themselves to hot fill processing.

- For safety –
 - Pickled vegetables
 - Barbecue sauces (using vegetable base)
 - Hot sauces
- For quality –
 - Fermented vegetables
 - Standardized jams, jellies and preserves
 - Syrups
 - Barbecue sauces (using commercially-prepared base)





Those that would suffer changes in flavor, texture or appearance may benefit from a cold fill hold scheduled process.



Scheduled process comparison

	Hot Fill Hold (HFH)	Cold Fill Hold (CFH)
Final equilibrium pH (SU)	<ul style="list-style-type: none"> ☐ Less than 4.09 ☐ 4.1 to 4.6 	<ul style="list-style-type: none"> ☐ Less than 3.3 ☐ 3.3 to 3.8
Fill temperature	185°F (85°C) minimum	50°F (10°C) or higher
Hold time	6 seconds to 30 seconds	2 days to 19 days
Acetic acid concentration	Does not drive scheduled process parameters directly	1.5% to 2.5% in the aqueous phase
Expected quality-based shelf life	At least 1 year	About 6 months

Step 1:

Final equilibrium
pH

Acetic acid
concentration

Hold period

Final equilibrium
pH

Determination of 5-Log Reduction Times for Food Pathogens in Acidified Cucumbers during Storage at 10 and 25 °C. (Breidt, et al, 2007)

□ pH <3.3 SU

Determination of 5-Log Reduction Times for Escherichia coli O157:H7, Salmonella enterica, or Listeria monocytogenes in Acidified Food with pH 3.5 or 3.8. (Breidt, et al, 2013)

□ pH 3.3 – 3.5 SU
or
□ pH 3.5 – 3.8 SU

Step 2:

Final equilibrium
pH

Concentration of
acetic and
benzoic acids

Hold period

Concentration of acetic and benzoic acids

In products with a final equilibrium pH (SU)...

<3.3	3.3 – 3.8
<ul style="list-style-type: none">□ Acetic acid is the primary acidulent□ About 400mM or greater acetic acid□ Benzoic acid may or may not be present; maximum allowable limit – 0.1% by weight	<ul style="list-style-type: none">□ Acetic acid is at least 1.5% in the aqueous phase□ Benzoic acid may or may not be present; maximum allowable limit – 0.1% by weight

Finding Acetic Acid Concentration



Image credit: hannainst.com

□ Calculation

- Uses titratable acidity (TA) of ingredients
- Uses amount of ingredient in formulation
- Takes into account the aqueous phase of ingredients where a significant impact would occur

By definition, at least 65% oil; could be as high as 86%

□ Titration

- Hanna Instruments HI932 titrator
- 0.1N NaOH solution, standardized with oven dried and desiccated KHP
- Yields titratable acidity as acetic acid



Brand	Product	Product pH	Titratable Acidity (as acetic acid)
Heinz	Tomato Ketchup	3.52	1.41%
Heinz	No Sugar Added Tomato Ketchup	3.52	1.99%
Hunt's	Tomato Ketchup	3.52	2.00%
Kroger	Original Tomato Ketchup	3.47	1.50%
Heinz	Yellow Mustard	3.24	3.16%
French's	Classic Yellow Mustard	3.29	2.63%
Gulden's	Spicy Brown Mustard	3.52	2.70%
Grey Poupon	Dijon Mustard	3.58	2.44%
Simple Truth Organic	Dijon Mustard	3.46	2.31%
Sriracha	Hot Chili Sauce	3.76	2.04%
Texas Pete	Original Hot Sauce	3.06	2.32%

Brand	Product	Product pH	Titrateable Acidity (as acetic acid)
Hellmann's	Mayonnaise	3.65	0.41%
Duke's	Mayonnaise	3.70	0.44%
Kraft	Mayonnaise	3.56	0.37%
Kroger	Mayonnaise	3.61	0.48%
Miracle Whip	Light Mayonnaise Dressing	3.40	1.04%
Kikkoman	Soy Sauce	4.64	--
Kroger	Soy Sauce	4.71	--
Woeber's	Horseradish Sauce	3.45	1.24%
Reese	Prepared Horseradish	3.65	3.33%
Lea & Perrins	Original Worcestershire Sauce	3.47	2.79%
Kroger	Worcestershire Sauce	3.28	3.12%

Step 3:

Final equilibrium
pH

Acetic acid
concentration

Hold period

TABLE 2. *The 5-log reduction times of E. coli O157:H7, Salmonella, and Listeria and parameters for Weibull curves*

Parameter ^a	Estimate	SE of the estimate	Predicted 5-log reduction time ^b
<i>E. coli</i> data			
Alpha	8.693	0.157	
Beta	0.567	0.015	
Tstar	105.4 h	6.5 h	137.9 h (5.75 days)
<i>Listeria</i> data			
Alpha	8.448	0.189	
Beta	1.173	0.125	
Tstar	9.3 h	0.4 h	11.2 h
<i>Salmonella</i> data			
Alpha	8.292	0.188	
Beta	0.823	0.175	
Tstar	25.8 h	5.1 h	51.3 h

^a Parameters for the Weibull model include alpha and beta, parameters controlling the shape of the nonlinear killing curve. Tstar is the time in hours for the predicted 5-log reduction in bacterial cell numbers.

^b The recommended 5-log reduction time, based on the Tstar estimate plus five times the standard error, as described (3).

Scientific reference: *Determination of 5-Log Reduction Times for Food Pathogens in Acidified Cucumbers during Storage at 10 and 25°C.* FRED BREIDT, JR., J. Hayes, and R. McFeeters. *Journal of Food Protection*, Vol. 70, No. 11, 2007, Pages 2638-2641.

TABLE 2. Acid solutions and 5-log reduction times of inoculated pathogens in brined cucumbers

Species ^a	Acid concn (%) ^b			5-log reduction time (days)		R ^{2c}	No. of replicates
	Acetic acid	Benzoic acid	pH	Mean	SE		
<i>E. coli</i>	2.5	0	3.5	4.0	0.23	0.88	12
	2	0	3.5	11.7	0.43	0.90	11
	2	0.1	3.5	1.5	0.05	0.99	3
	1.5	0.1	3.5	3.6	0.43	0.79	6
	0 ^d	0.1	3.5	14.5	0.97	0.88	3
	2.5	0	3.8	11.3	0.75	0.90	3
	2.5	0.1	3.8	3.6	0.14	0.99	3
	2	0.1	3.8	10.2	0.51	0.95	3
	1.5	0.1	3.8	13.5	1.03	0.88	3
<i>Salmonella</i>	2.5	0	3.5	1.5	0.11	0.91	3
	2.5	0.1	3.8	1.6	0.08	0.97	3
	1.5	0.1	3.5	0.6	0.03	0.97	3
<i>L. monocytogenes</i>	2.5	0	3.5	0.6	0.03	0.95	3
	2.5	0.1	3.8	1.5	0.24	0.79	3
	1.5	0.1	3.5	0.3	0.01	0.98	3


^a Each species cocktail contained five strains.

^b All acid concentrations were $\pm 0.1\%$ of the indicated target concentrations.

^c Value for the linear regression used to calculate the 5-log reduction time.

^d This acid solution contained 0.5% citric acid buffer.

Scientific reference: Determination of 5-Log Reduction Times for *Escherichia coli* O157:H7, *Salmonella enterica*, or *Listeria monocytogenes* in Acidified Food with pH 3.5 or 3.8. FRED BREIDT, JR., K. Kay, J. Cook, J. Osborne, B. Ingham, and F. Arritt. Journal of Food Protection, Vol. 76, No. 7, 2013, Pages 1245-1249.

Final equilibrium pH	Acetic acid concentration	Benzoic acid concentration	Hold time	Minimum initial fill temperature, lowest hold temperature
<3.3	About 400 mM	Not required	6 days	 <p>Only 1.4 days at 25°C</p> <p>50°F (10°C) or higher</p>
3.3 – 3.5	1.5%	0.1%	6 days	
	2.0%	0.1%	2 days	
	2.0%	0%	14 days	
	2.5%	0%	5 days	
3.5 – 3.8	1.5%	0.1%	19 days	
	2.0%	0.1%	13 days	
	2.5%	0.1%	5 days	
	2.5%	0%	16 days	

DISCLAIMER: This information has been compiled and provided solely for the presentation shown below and should not be considered scheduled process parameters.



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and Technology

Product assessment-related
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