AMSA Educational Webinar: An Update on Alternative Curing Systems with Food Safety Considerations

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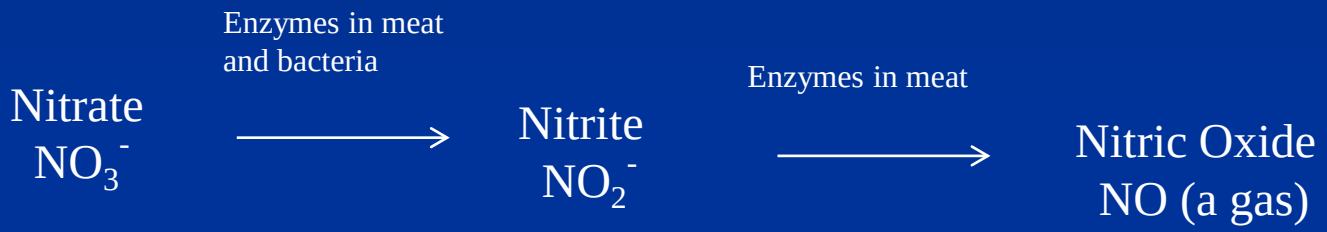
UW–MADISON ANIMAL SCIENCES

Purpose of Sodium Nitrate / Nitrite

- Cured meat color
- Cured meat aroma and flavor
- Powerful antioxidant
  - Effective in controlling fat oxidation
- Preservative/antimicrobial properties
  - *Clostridium botulinum, Clostridium perfringens, Listeria monocytogenes*

Cured Meat Color Chemistry



- Sodium nitrate from vegetables = $NaNO_3$
- Purified sodium nitrate = $NaNO_3$
- Sodium nitrite from vegetables = $NaNO_2$
- Purified sodium nitrite = $NaNO_2$

Cured Meat Color Formation

Addition of Sodium Nitrite

Nitric oxide (gas)

Oxymyoglobin

Nitrosomyoglobin/
Nitrosometmyoglobin

Heat

Nitrosohemochrome
(Pink cured meat color)

Natural, Organic and Conventional Labeling Claims

- Organic
  - 100% organic
  - Organic
  - Made with organic
  - Less than 70% organic
- Natural
- Uncured

Natural Labeling

- USDA, Food Standards and Labeling Policy Book
- 21 CFR 101.22
  - '(1) the product does not contain any artificial flavor or flavoring, coloring ingredient, or chemical preservative (as defined in 21 CFR 101.22), or any other artificial or synthetic ingredient; and (2) the product and its ingredients are not more than minimally processed….'

§ 101.22 21 CFR Ch. I (4–1–08 Edition)

(c) Among representations in the labeling of a food which render such food misbranded is any representation that expresses or implies a geographical origin of the food or any ingredient of the food except when such representation is either:

(1) A truthful representation of geographical origin.

(2) A trademark or trade name provided that as applied to the article in question its use is not deceptively misdescriptive. A trademark or trade name composed in whole or in part of geographical words shall not be considered deceptively misdescriptive if it:

(i) Has been so long and exclusively used by a manufacturer or distributor that it is generally understood by the consumer to mean the product of a particular manufacturer or distributor; or

(ii) Is so arbitrary or fanciful that it is not generally understood by the consumer to suggest geographic origin.

(3) A part of the name required by applicable Federal law or regulation.

(4) A name whose market significance is generally understood by the consumer to connote a particular class, kind, type, or style of food rather than to indicate geographical origin.

Subpart B—Specific Food Labeling Requirements

§101.22 Foods; labeling of spices, flavorings, colorings and chemical preservatives.

(a)(1) The term *artificial flavor* or *artificial flavoring* means any substance, the function of which is to impart flavor, which is not derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products thereof. Artificial flavor includes the substances listed in §§172.515(b) and 182.60 of this chapter except where these are derived from natural sources.

(2) The term *spice* means any aromatic vegetable substance in the whole, broken, or ground form, except for those substances which have been traditionally regarded as foods, such as onions, garlic and celery; whose significant function in food is seasoning rather than nutritional; that is true to name; and from which no portion of any volatile oil or other flavoring principle has been removed. Spices include the spices listed in §182.10 and part 184 of this chapter, such as the following:

Allspice, Anise, Basil, Bay leaves, Caraway seed, Cardamon, Celery seed, Chervil, Cinnamon, Cloves, Coriander, Cumin seed, Dill seed, Fennel seed, Fenugreek, Ginger, Horseradish, Mace, Marjoram, Mustard flour, Nutmeg, Oregano, Paprika, Parsley, Pepper, black; Pepper, white; Pepper, red; Rosemary, Saffron, Sage, Savory, Star aniseed, Tarragon, Thyme, Turmeric.

Paprika, turmeric, and saffron or other spices which are also colors, shall be declared as "spice and coloring" unless declared by their common or usual name.

(3) The term *natural flavor* or *natural flavoring* means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or any product of roasting, heating or enzymolysis, which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, seafood, poultry, eggs, dairy products, or fermentation products thereof, whose significant function in food is flavoring rather than nutritional. Natural flavors include the natural essence or extractives obtained from plants listed in §§182.10, 182.20, 182.40, and 182.50 and part 184 of this chapter, and the substances listed in §172.510 of this chapter.

(4) The term *artificial color* or *artificial coloring* means any "color additive" as defined in §70.3(f) of this chapter.

(5) The term *chemical preservative* means any chemical that, when added to food, tends to prevent or retard deterioration thereof, but does not include common salt, sugars, vinegars, spices, or oils extracted from spices, substances added to food by direct exposure thereof to wood smoke, or chemicals applied for their insecticidal or herbicidal properties.

(b) A food which is subject to the requirements of section 403(k) of the act shall bear labeling, even though such food is not in package form.

(c) A statement of artificial flavoring, artificial coloring, or chemical preservative shall be placed on the food

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Organic Meat and Poultry Products

- National Organic Program (NOP)
  - Agricultural Marketing Service (AMS)
  - www.ams.usda.gov/nop/NOP/standards/ListReg.html

- The National List of Allowed and Prohibited Substances
  - 7 CFR
    - § 205.605 Nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."
    - § 205.606 Nonorganically produced agricultural products allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."

USDA Definition of Uncured Meat Products

- Definition found in 9 CFR 317.17 and 9 CFR 319.2
  - Normal cured products that can be made without nitrites or nitrates added
  - Other normal ingredients are allowed
- Statements/words that must be added
  - "Uncured" before common name
    - i.e. *Uncured Frankfurters*
  - "No Nitrate or Nitrite Added ….." statement must be added
  - "Not Preserved – Keep Refrigerated Below 40°F At All Times" statement must be added

Exceptions to Labeling for Uncured Meat Products

- "Not Preserved – Keep Refrigerated Below 40°F At All Times" not required if:
  - Thermal processed to F_o 3
  - Final pH $\leq$ 4.6
  - Water activity $\leq$ 0.92
- No labeling changes are needed if brine concentration greater than 10%
- Product not covered by curing regulations

Types of Natural / Organic Meat Products

- Fresh Products
- Traditionally uncured, cooked products

Types of Natural / Organic Meat Products

- Traditionally cured, cooked products
  - No intention of replacing nitrate/nitrite
    - Uncured appearance and flavor

Types of Natural / Organic Meat Products

- Traditionally cured, cooked products
  - Intention to replace nitrate/nitrite
    - Cured appearance and flavor

New Approach: Clean Label

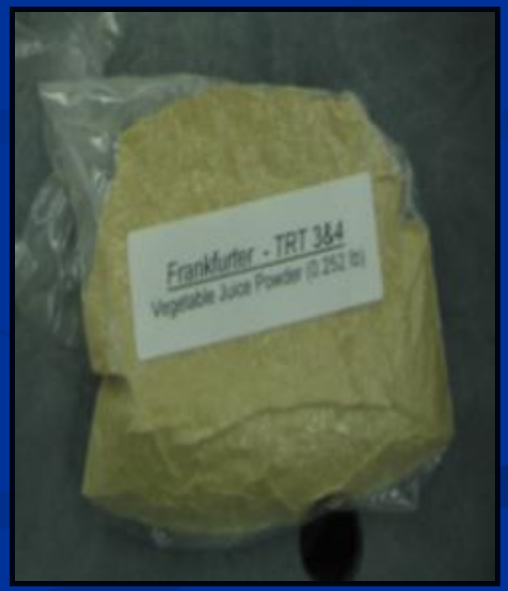
INGREDIENTS: BEEF, WATER, CULTURED CORN SUGAR*, CONTAINS LESS THAN 2% OF DEXTROSE, SALT, CULTURED CELERY JUICE*, VINEGAR*, SODIUM PHOSPHATES, CHERRY POWDER, LEMON JUICE SOLIDS, FLAVOR, EXTRACTIVES OF PAPRIKA.
*Ingredient to preserve quality.

"Alternative Curing" Systems-"Cultured"

- Vegetable juice powders and juices
  - Standardized up to 30,000 ppm nitrate (ion)
  - Can be labeled as "celery powder", "flavoring" or "natural flavoring"
- Lactic Acid Starter Cultures
  - Staphylococcus carnosus
  - Staphylococcus carnosus / vitulinus
  - Staphylococcus carnosus / utilis
  - Staphylococcus carnosus / Micrococcus varians
- Cure Accelerators
  - Cherry /Acerola Powder (Ascorbic acid)
  - Lemon powder (pH reducer)

"Alternative Curing" Systems-"Pre-Converted"

- Pre-converted vegetable powders and juices
  - Standardized up to 10,000-15,000 + ppm nitrite (ion)
    - 20,000 – 25,000+ sodium nitrite
    - nitrite ion vs. sodium nitrite
- Cure Accelerators
  - Cherry /Acerola Powder (Ascorbic acid)
  - Lemon powder (pH reducer)



Available/Generated Nitrite Comparison Between Pre-converted & Cultured System

- Ingoing nitrite via "cultured system"
  - 45,000 ppm (sodium nitrate) x 0.40% = 180 ppm
    - 50% conversion = 90 ppm sodium nitrite
    - 75% conversion = 135 ppm sodium nitrite
- Ingoing nitrite via "pre-converted system"
  - 22,500 ppm (sodium nitrite) x 0.50% = 112 ppm

**Nitrate/nitrite vs. Sodium nitrate/nitrite

-Nitrate vs. Sodium nitrate=1.37:1 conversion

-Nitrite vs. Sodium nitrite=1.50:1 conversion

Proper Use of Ingredients

- Vegetable Juice or Powder
  - Goal is to maximize levels
    - Minimum of 0.2%
    - Maximum of 0.4% …?
    - Depends on amount of spices in product

- Starter Culture
  - Per manufacturer's recommendations
    - *e.g.* 25 g per 225 kg recommended

“Alternative Cured” Product Manufacture – Cultured System

Step # 1:

Addition of ingredient containing naturally occurring nitrates
&
Nitrate reducing starter culture

Curing Ingredient Activity

- Sodium/Potassium Nitrate = INACTIVE COMPOUND

- Sodium/Potassium Nitrite = ACTIVE COMPOUND

Natural Sources of Nitrate

- Vegetable sources of "natural" nitrate (avg. ppm):
  - Radishes 2600
  - Celery 3151
  - Lettuce 2330
  - Spinach 2470
  - Carrots 274
  - Beets 3288
  - Cabbage 712
  - Beans 466
  - Tomatoes 80
  - Potatoes 150
  - Turnip Greens 9040
  - Onions 235
  - Melon 4932
  - Rhubarb 2900
  - Broccoli 1014

R. Walker (1990), Food Add. Contam. 5:717-768.

"Alternative Curing" Cured Meat Color Development

Addition of nitrate source and starter culture.

Myoglobin

Incubation reduces nitrate to nitrite

Nitric oxide (gas)

Nitrosomyoglobin

Heat

Nitrosohemochrome
(Pink cured meat color)

Nitrate and Nitrite Found in "Alternative Cured" Sausages

	PPM Residual Nitrite		PPM Residual Nitrate	
TRT	Pre-Incubate	Post-Incubate	Pre-Incubate	Post-Incubate
1 (0.20% VJP + 30 min)	0^{h}	5.6^{ij}	51.2^{i}	38.5^{h}
2 (0.20% VJP + 120 min)	0^{h}	24.5^{h}	52.0^{i}	14.0^{j}
3 (0.40% VJP + 30 min)	0^{h}	7.7^{j}	99.2^{g}	89.7^{g}
4 (0.40% VJP + 120 min)	0^{h}	46.0^{g}	99.6^{g}	26.3^{i}
C (156 ppm nitrite)	59.1^{g}	NA	34.8^{h}	NA
SEM	0.62	1.22	1.35	2.02

$^{g-j}$ Means within same column with different superscripts are different ($P<0.05$).

Sindelar et al. (2007), J. Food Sci. 72(5): 324-332.

Residual Nitrite in "Alternative Cured" Sausages

	DAY				
TRT	0	14	28	56	90
1 (0.20% VJP + 30 min)	$^{r}16.1^{e}$	$^{r}10.6^{f}$	$^{r}8.8^{fh}$	$^{r}4.9^{gh}$	$^{r}4.9^{gh}$
2 (0.20% VJP + 120 min)	$^{pq}24.7^{e}$	$^{pq}21.7^{e}$	$^{pq}17.2^{f}$	$^{pq}12.0^{gh}$	$^{pqr}9.1^{h}$
3 (0.40% VJP + 30 min)	$^{qr}21.3^{e}$	$^{q}16.6^{f}$	$^{qr}12.9^{fh}$	$^{qr}9.9^{gh}$	$^{qr}8.5^{g}$
4 (0.40% VJP + 120 min)	$^{n}58.5^{e}$	$^{n}44.3^{f}$	$^{n}33.1^{g}$	$^{n}22.3^{h}$	$^{n}16.3^{i}$
C (156 ppm nitrite)	$^{o}46.9^{e}$	$^{o}31.4^{f}$	$^{op}22.0^{g}$	$^{opq}12.4^{hi}$	$^{opqr}8.7^{i}$

SEM = 1.02

$^{e-i}$ Means within same row with different superscripts are different (P<0.05).
$^{n-r}$ Means within same column with different superscripts are different (P<0.05).

Sindelar et al. (2007), J. Food Sci. 72(5): 324-332.

Step #2:

Incubation - Conversion of nitrate to nitrite

Requirements for Nitrate Conversion

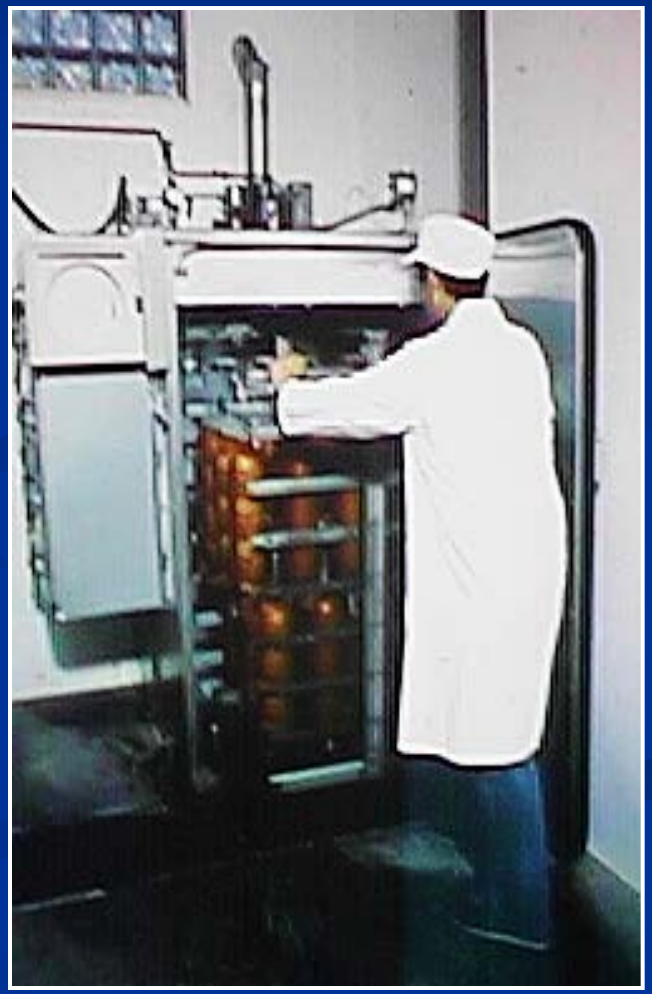
- Proper incubation of product essential
  - Goal is to convert as much nitrate to nitrite as possible
  - Internal temperature held for optimum starter culture function temperatures
    - i.e.: 50-113 °F (86 °F optimum)
    - ~ 1-2 hours
    - Depends on product diameter
      - Frankfurters = 2 hours
      - Ham = 1 hour (or less)
  - Optimum time for starter culture function
    - Nitrate reductase enzymes reduce nitrate to nitrite

Step #3:

Cooking

Cooking Requirements

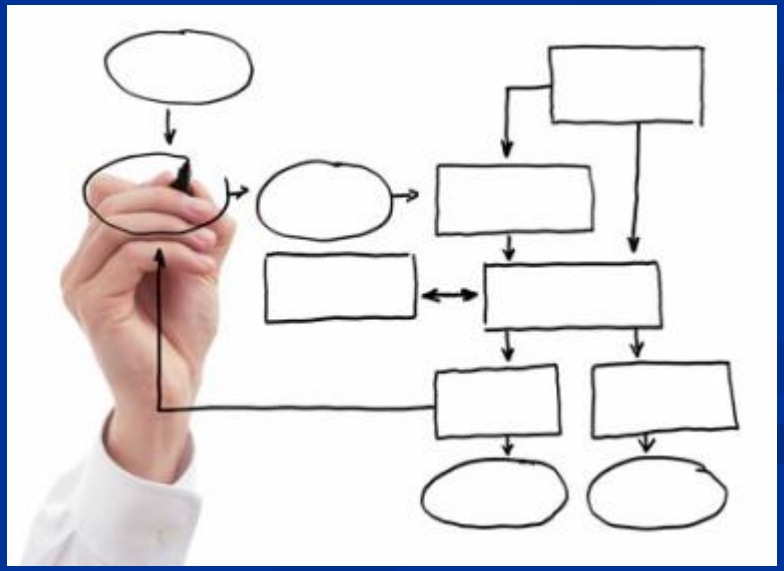
- Besides the addition of an incubation step, no other changes are necessary



“Alternative Cured” Product Manufacture – Pre-converted System

Process Adjustments

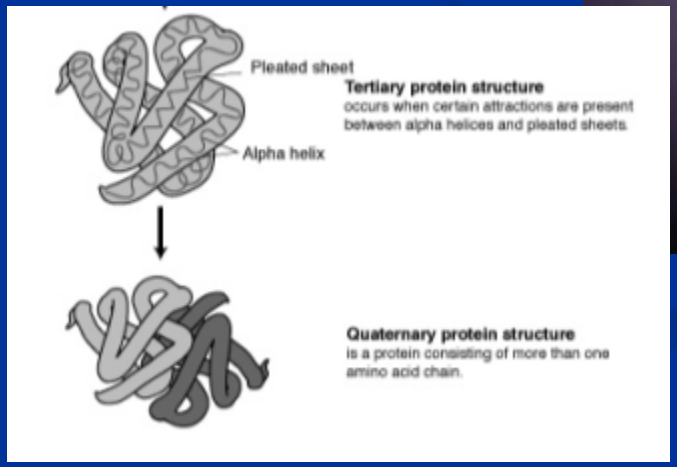
- Step 1—Ingredients
  - Pre-converted juice or powder
  - Alternative cure accelerator
- Step 2 – Incubation Step
  - None needed
- Step 3 – Cooking
  - No changes necessary



Quality Discussion

Quality Considerations

- Water and protein binding
  - Control of raw materials
  - Control of pH
  - Ingredient choices
  - Modifications to processing



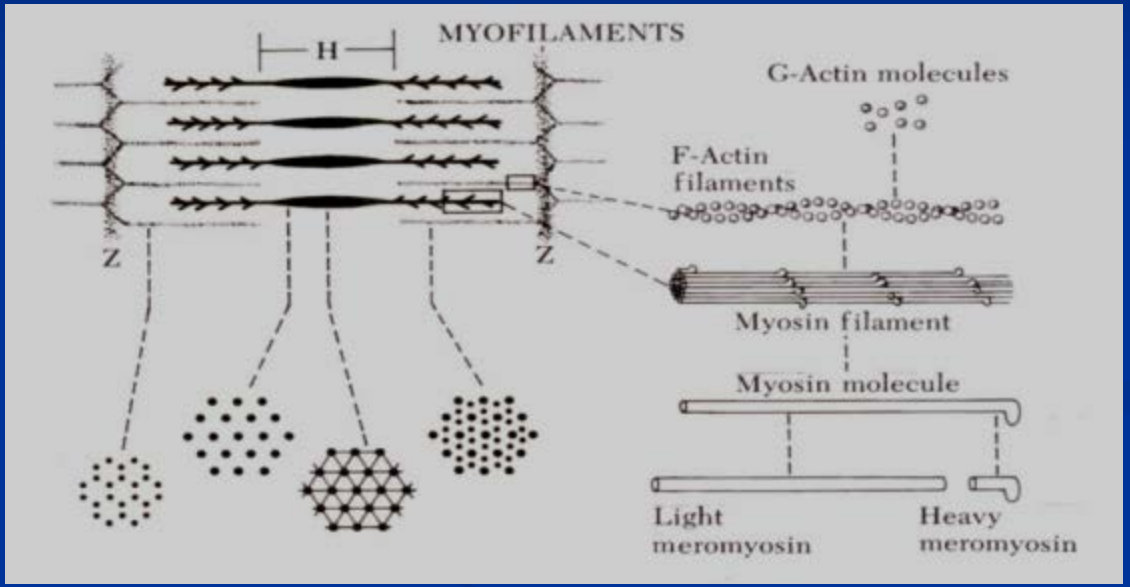
Raw Material Considerations

Meat	Protein	Moisture	Fat	Collagen[2]	Color[3]	Bind[4]
	(%)				(index)	
Bull meat, full carcass	20	68	11	20	100	100
Cow meat, full carcass	19	70	10	21	95	100
Beef shank meat	19	73	7	66	90	80
Beef chucks	18	61	20	30	85	85
Beef trimmings, 90% lean	17	72	10	30	90	85
Beef trimmings, 75% lean	15	59	25	38	85	80
Beef plates	15	34	50	—	—	—
Beef flanks	13	43	42	—	55	50
Beef head meat	17	68	14	73	60	85
Beef cheeks, trimmed	17	68	14	59	10	85
Poultry meat (dark)	19	67	12	—	80	90
Pork trimmings, 80% lean	16	63	20	24	57	58
Pork trimmings, 50% lean	10	39	50	34	35	55
Pork blade, 95% lean	19	75	5	23	80	95
Picnic trimmings, 85% lean	17	67	15	24	60	85
Pork jowls	6	22	72	43	20	35
Pork cheeks, trimmed	17	67	15	72	65	75

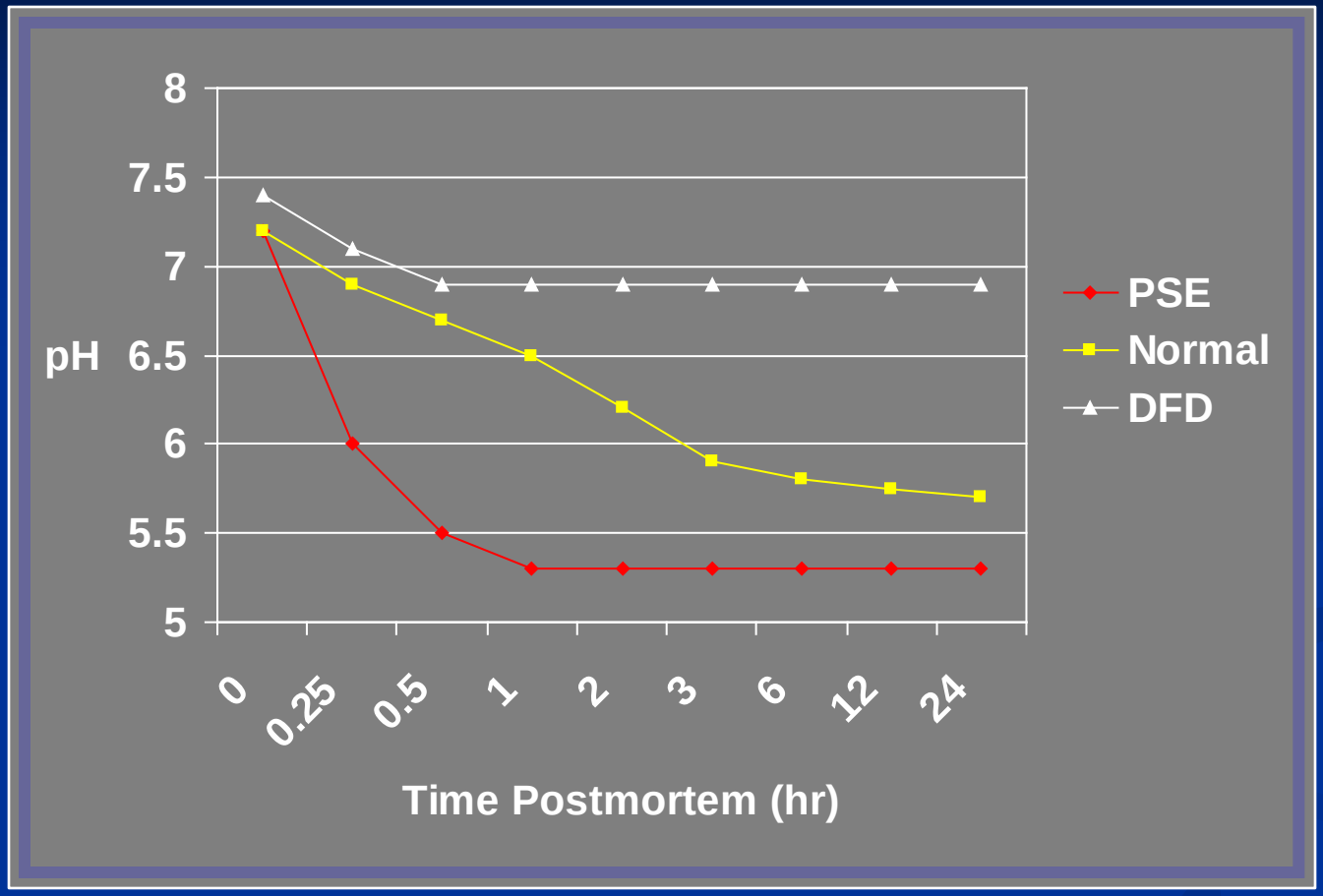
The Meat We Eat, 2001

Focus on Myofibrillar Proteins

- Salt soluble
  - 32-34 °F
- Contractile proteins
  - Myosin
  - Actin
- Functions in Meat
  - Texture
  - Water holding capacity (WHC)
  - Form strong heat-set gels



pH Considerations



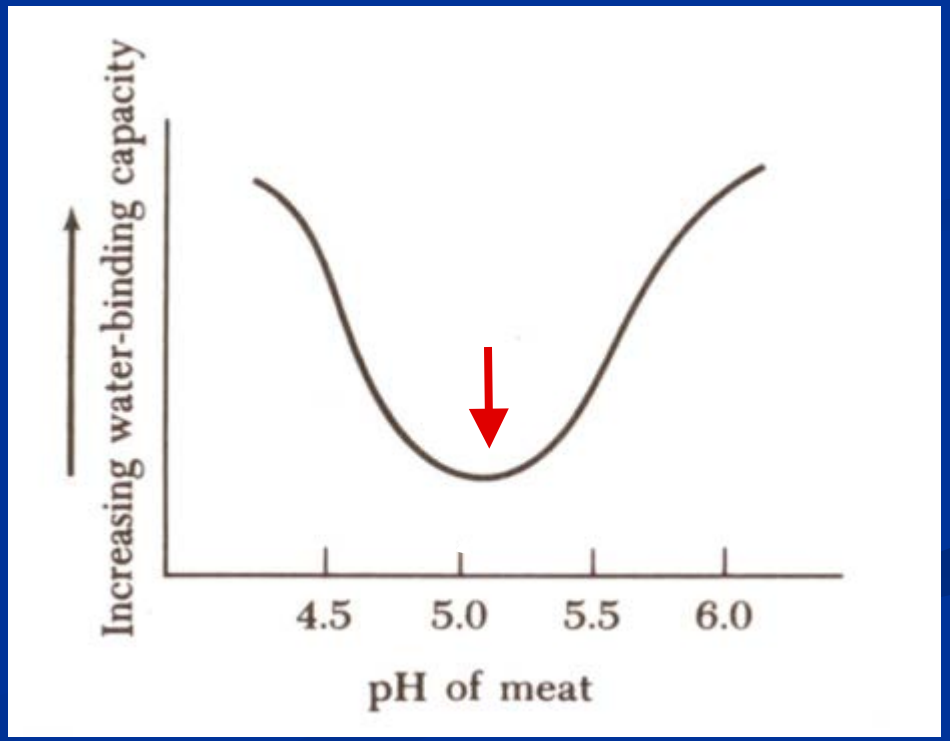
Normal

PSE

DFD

Water Holding Capacity (WHC)

- Isoelectric point (pI)
  - Occurs when positive charges equal negative charges
  - pI of meat is approximately 5.2



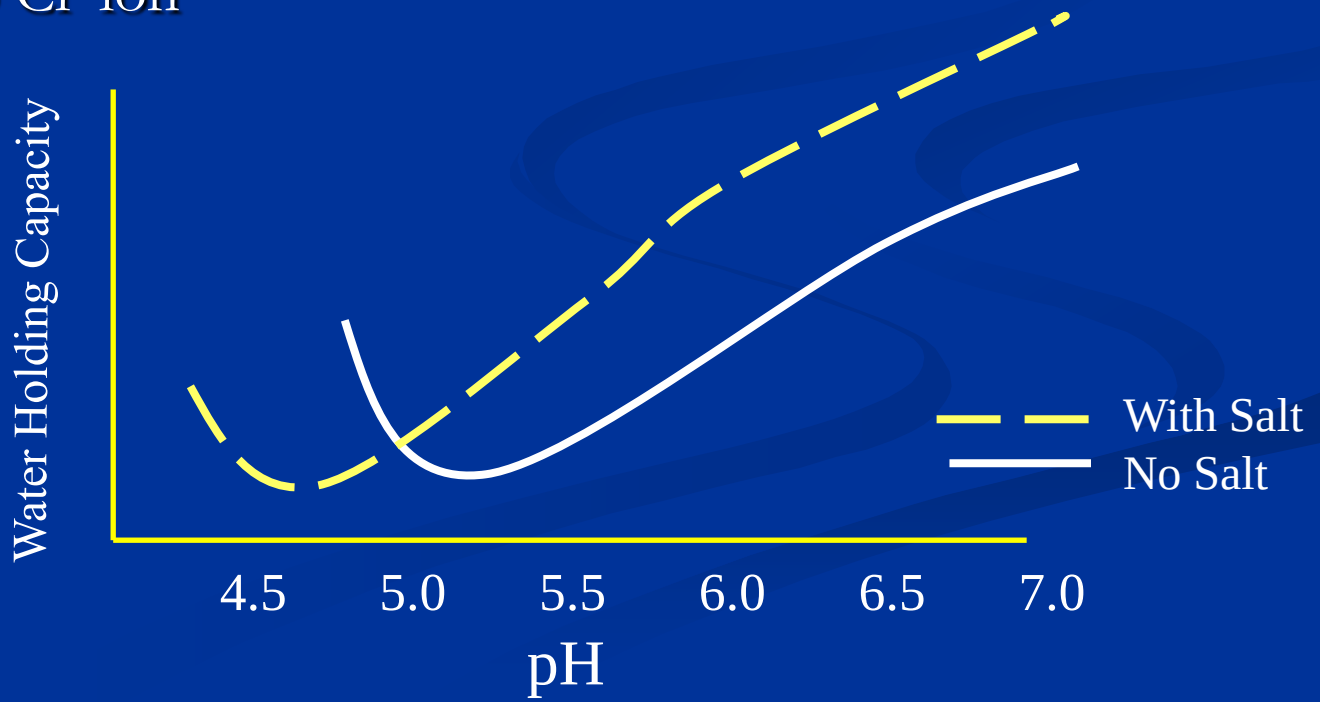
The Science of Meat & Meat Products, 2001

Ingredient Considerations

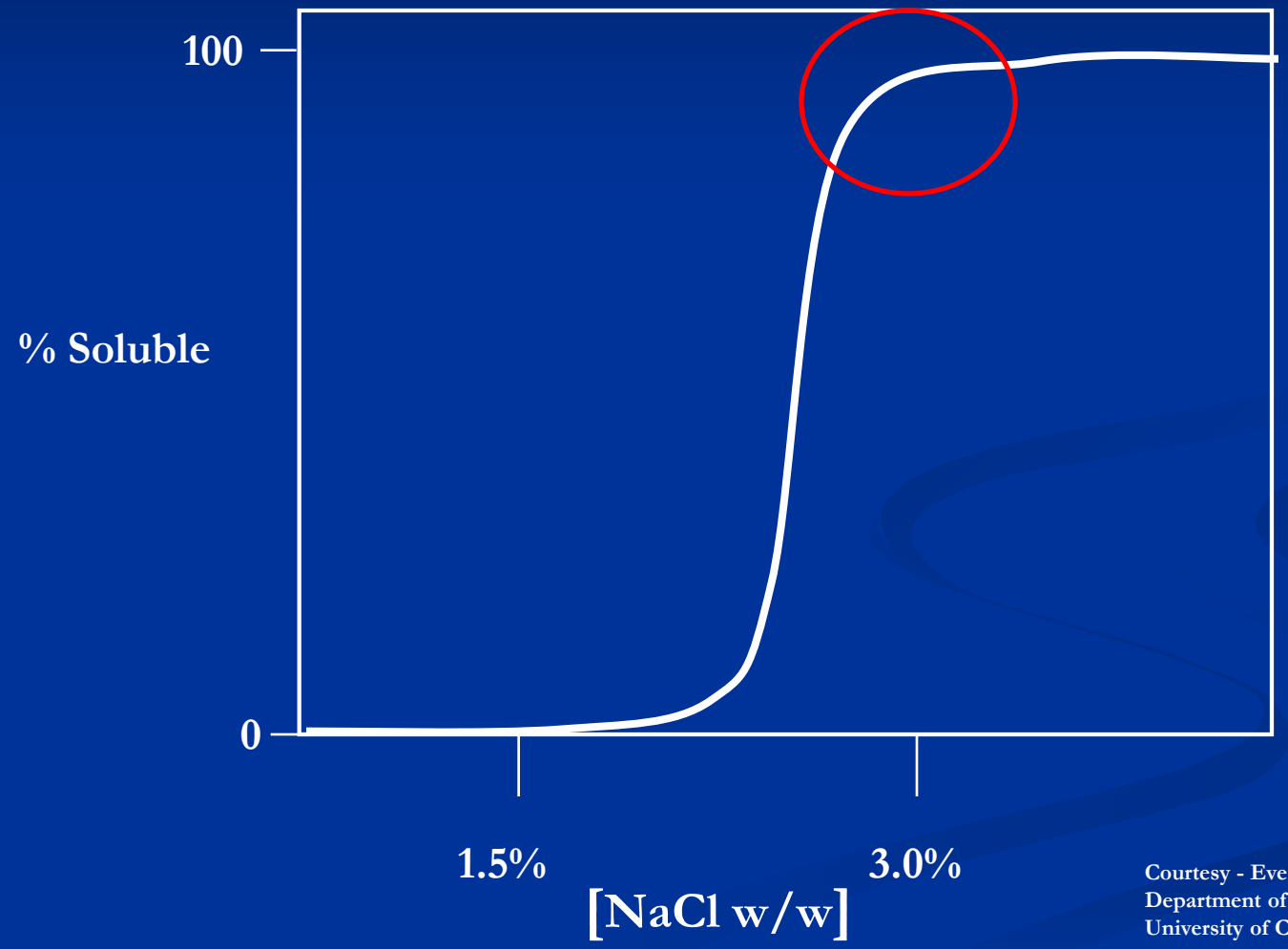
- Challenges
  - Identifying functional ingredients that meet labeling requirements
  - Replacing/removing ingredients and impact on meat system and finished product
- Important to understand function of each ingredient and impact on system.

Salt/Water Relationship

- Isoelectric point shift
  - Myofibrillar swelling for improved water binding
    - Theoretical swelling capacity= 2.8x diameter & 8x volume
    - Change in ionic strength
  - Effect due to Cl^- ion



Myosin Solubility in NaCl

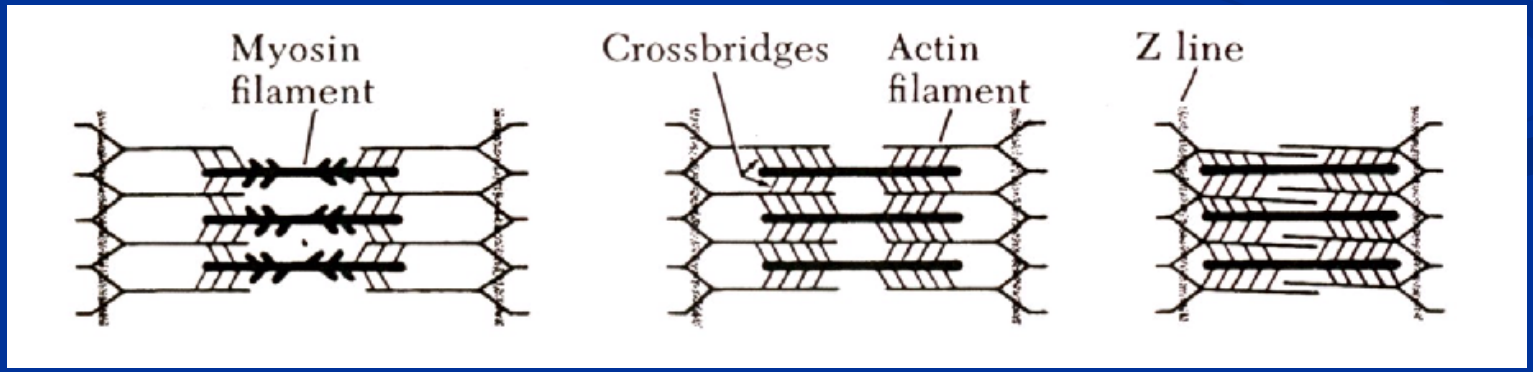


Courtesy - Everett Bandman
Department of Food Science & Technology
University of California, Davis

adapted from Samejima et al., 1984

pH Manipulation/Water Relationship: Phosphate Example

- Phosphates dissociate actomyosin
  - Mimic ATP
  - Allow for more room for added water to bind
- Increases ionic strength
  - More negative charges available to bind water
  - Swelling of the proteins



Binders & Extenders

- A broad group of non-meat ingredients used to improve water binding and retention or to extend a product for economical reasons

- Understanding function
  - Moisture absorption
  - Protein, fat, moisture interaction
  - Gelation properties

Binders & Extenders

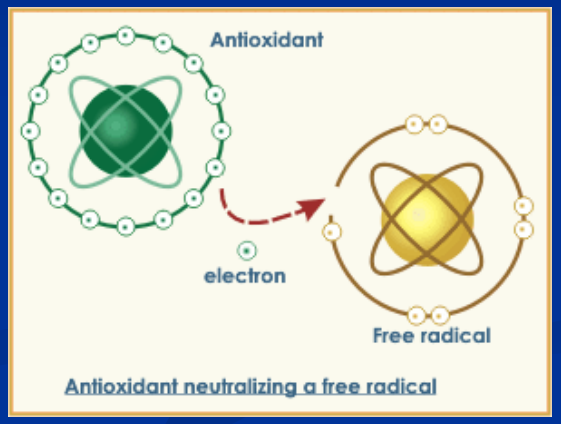
- Examples
  - Cereal products/
    - *e.g* starches, flours
  - Carborhydrates
    - *e.g.* starches, hydrocolloids, gums
  - Carrageenan
  - Alginate
  - Milk products
    - *e.g.* Casein, nonfat dry milk
  - Soy protein
    - *e.g.* Flour, concentrate, isolate
  - Protein-enzyme
    - *e.g.* Transglutaminase
  - Proteins
    - *e.g.* Fibrimex, gelatin, collagen

Limited Functional Ingredients

- "Natural" binders and extenders
  - Sodium carbonate
  - Sodium bicarbonate
  - Carageenan
  - Guar gum, locust bean gum
  - Potato starch
  - Rice starch
  - Potato fiber
  - Etc.

Quality Considerations: Antioxidants

- Antioxidant protection
  - ~ 50 ppm sodium nitrite
  - Dependent on amount of unsaturated lipids



- Antioxidant replacement
  - BHT and BHT replaced with rosemary, green tea, etc.
  - Removal of other catalysts
    - Oxygen, light, etc.

Quality Considerations: Color

- Maintaining cured color
  - 2-14 ppm sodium nitrite induces cured color
  - 40-50 ppm sodium nitrite generally considered adequate for maintaining for shorter shelf-life
  - 70+ ppm sodium nitrite needed for longer shelf-life
- Cure accelerator inclusion
- Important to follow good meat curing procedures
  - Hold time for curing
  - Removal of oxygen and light post processing

Cure Accelerators-Reductants/Acidulants

- Reductants
  - Sodium ascorbate/Sodium erythorbate
    - Accelerate nitrite reduction to nitric oxide (NO)
    - Provide reduced environment Fe+2 for NO binding
    - Improves flavor stability, shelf life
- Acidulants
  - Sodium acid pyrophosphate / Citric acid
  - A decrease of 0.2-0.3 pH units can result in a doubling of nitrite-to-nitric oxide

Sarcoplasmic Proteins

Species	Color	Myoglobin Concentration
Cow/Bull	Dark red	16-20 mg/g
Beef	Bright cherry red	4 mg/g
Veal	Brownish pink	0.7 mg/g
Chicken Leg	Dull red	0.4 mg/g
Pork	Grayish pink	0.3 mg/g
Chicken Breast	Grayish white	0.01 mg/g

Processing Considerations

- Grinding
- Mixing
- Macerating
- Tumbling/massaging
- Thermal processing

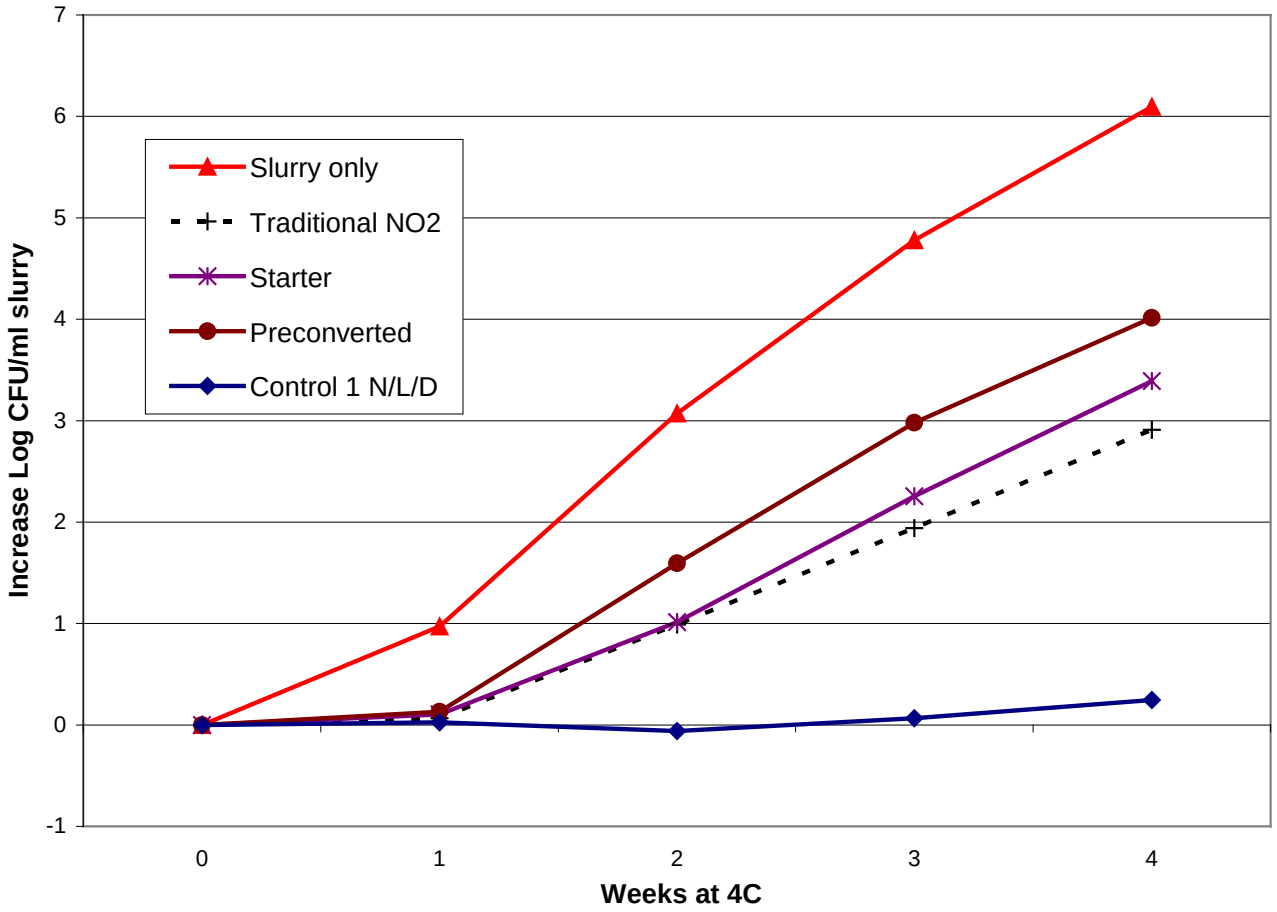
Food Safety Discussion

Safety Considerations

- Clostridium botulinum inhibition
  - 50-60 ppm ingoing nitrite?
  - Difficult to assess without challenge studies
    - Difficult to quantify true amount of nitrite generated
- Clostridium perfringens
  - 100 ppm + ?
- Listeria monocytogenes
  - 70-80 ppm minimum?

AMIFoundation

Figure 2. Growth of *L. monocytogenes* over time in uncured, nitrite cured, "naturally cured", and nitrite-cured-antimicrobial (control) added turkey slurries.



"Slurry only" = 2% salt
"Traditional NO2"= 2% salt + 156 ppm nitrite + 547 ppm erythorbate
"Starter"= 2% salt + 0.4% vegegtable juice powder + starter culture + 0.28% cherry powder
"Preconverted"= 2% salt 0.3% preconverted vegetable juice powder + 0.28% cherry powder
"Control 1N/L/D"= 2% salt + 156 ppm nitrite + 547 erythorbate + 2.8% lactate/diacetate

Clostridium botulinum Growth in "Alternative Cured" Frankfurters

Time until botulism toxin was detected during vacuum-packed storage of inoculated frankfurters at various storage temperatures

	Inoculated frankfurters		
Products stored at:	72°F	50°F	40°F
uncured control (no nitrite)	5 days	14 days	63 days
conventional cure (156 ppm)	14 days	none/84 days	none/84 days
natural cure	5 days	14 days	63 days
natural cure + VS507	5 days	none/84 days	none/84 days
natural cure + VD55	none/84 days	none/84 days	none/84 days

Sebranek et al. (2010; unpublished data)

Reduced Levels of Nitrite Impacting *Clostridium Botulinum*

TABLE 2. *Cell counts and toxigenesis of group II* Clostridium botulinum *type B inoculated into meat products formulated with various concentrations of nitrite and incubated at 8°C*

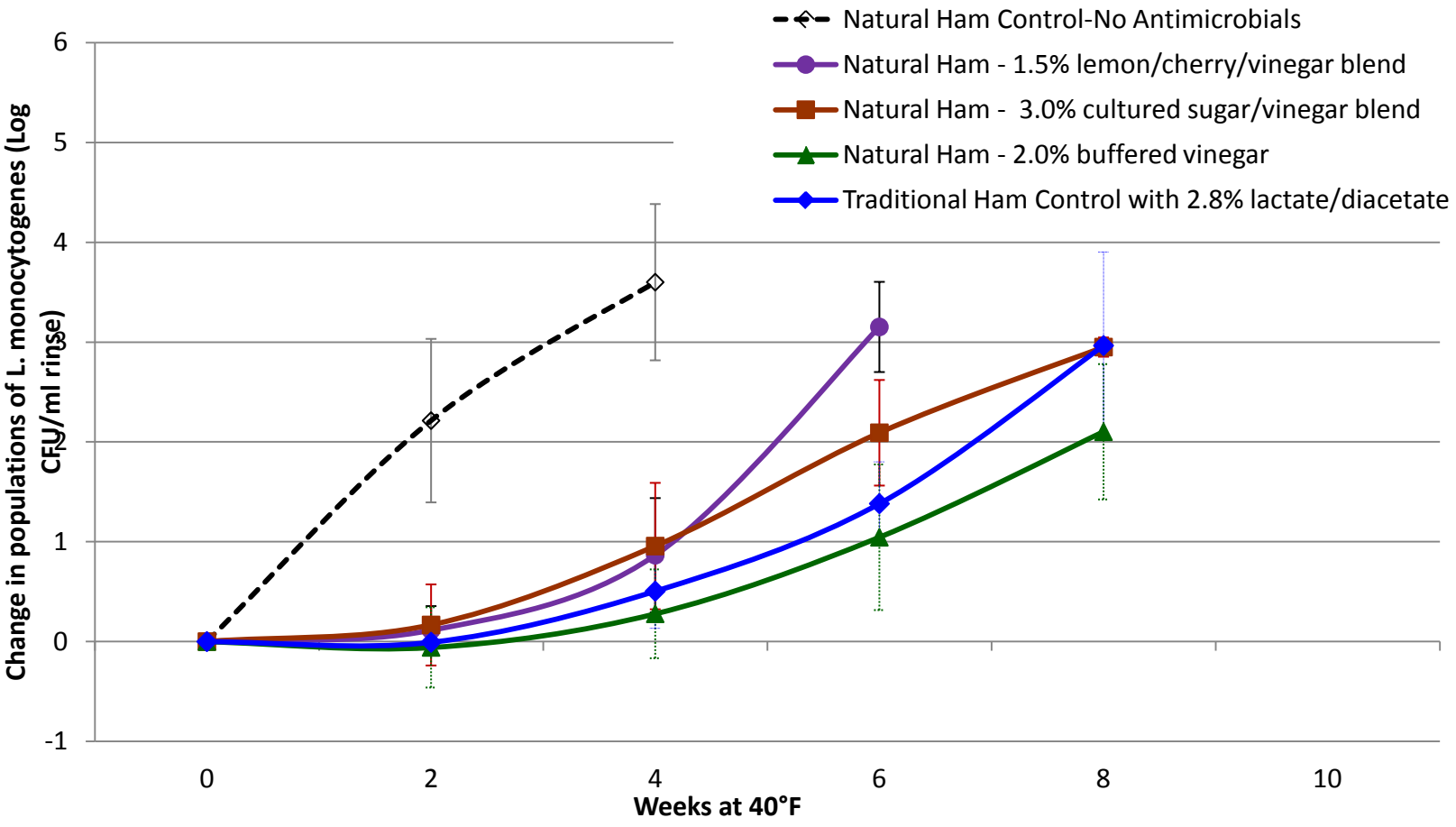
Product	Inoculation level (log CFU/g)	Storage time (wk)	Nitrite concn (mg/kg): 0 *C. botulinum* count[a]	0 Toxigenesis[b]	75 *C. botulinum* count	75 Toxigenesis	120 *C. botulinum* count	120 Toxigenesis
Bologna-type sausage	2.0	1	2.11 (1.32–2.85)	0/5	2.48 (2.04–2.85)	ND[c]	2.34 (1.90–2.66)	ND
		3	2.08 (1.49–2.69)	5/5	2.12 (0.52–4.20)	0/5	1.93 (1.52–2.38)	0/5
		5	2.80 (2.11–3.73)	ND	1.63 (1.23–2.04)	0/5	2.02 (1.38–2.52)	0/5
Wiener-type sausage	2.0	1	0.73 (0.52–1.23)	ND	0.50 (−0.47–1.38)	ND	1.04 (0.69–1.52)	ND
		3	>4.0 (>4.0)	0/5	−0.44 (−0.96–0.11)	ND	0.36 (0.11–0.69)	ND
		5	3.23 (0.11–5.38)	2/5	−0.50 (−0.89–0.60)	0/5	0.34 (−0.10–0.66)	0/5
Cooked ham	2.0	1	2.49 (2.23–2.69)	ND	2.59 (1.90–3.23)	ND	2.58 (2.32–3.04)	ND
		3	3.27 (2.66–3.96)	0/5	2.13 (1.67–2.52)	ND	1.96 (1.34–2.45)	ND
		5	1.93 (1.52–2.38)	3/5	1.41 (0.90–1.85)	0/5	1.64 (1.23–2.04)	0/5
	4.0	1	2.61 (2.11–3.04)	0/5	2.23 (1.65–2.52)	ND	2.50 (2.36–2.69)	ND
		3	2.93 (2.38–3.38)	5/5	1.84 (1.32–2.23)	ND	1.66 (1.15–2.11)	ND
		5	1.93 (1.49–2.90)	ND	1.14 (0.65–1.34)	0/5	1.35 (0.30–2.79)	0/5

[a] Mean log MPN estimate of cell count (CFU per gram); minimum and maximum cell counts are shown in parentheses.
[b] Number of toxin positive samples/total number of samples analyzed.
[c] ND, not determined.

Keto-Timonen, et al. (2012), J. Food Prot. 75(7): 1346-1349

Natural Growth Inhibitors, *Listeria* on Ham

40°F, 1.6-1.7% NaCl; ~70% moisture, pH 6.2-6.4

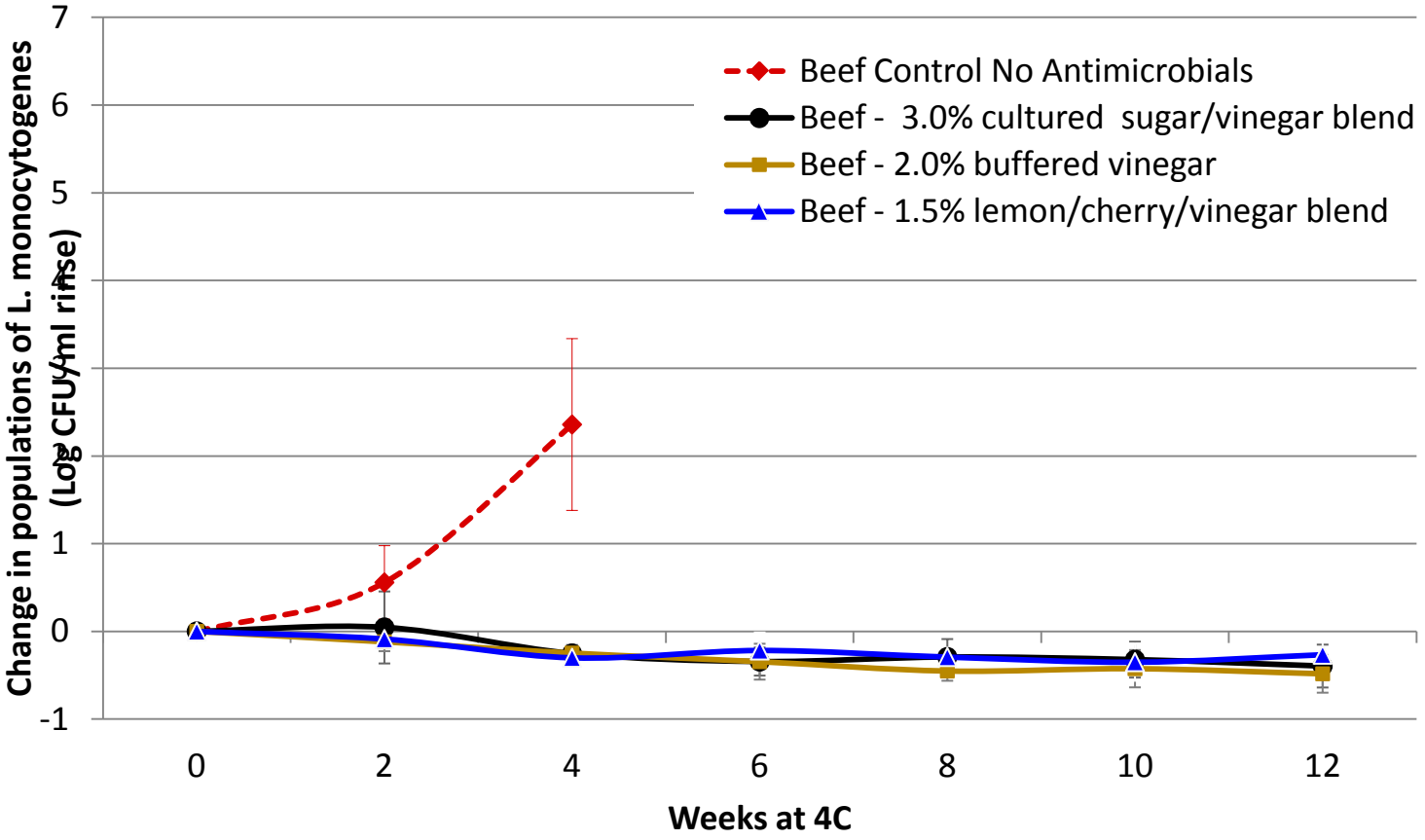


McDonnelll et al. (2013), J. Food Prot. 76(8): 1366-1376.

Natural Growth Inhibitors, *Listeria* on Roast Beef

40°F, 0.5% NaCl; ~65-67% moisture, pH 5.7-5.9

AMI Foundation



McDonnell et al. (2013), J. Food Prot. 76(8): 1366-1376.

Impact of "Natural" Ingredients on Frankfurters

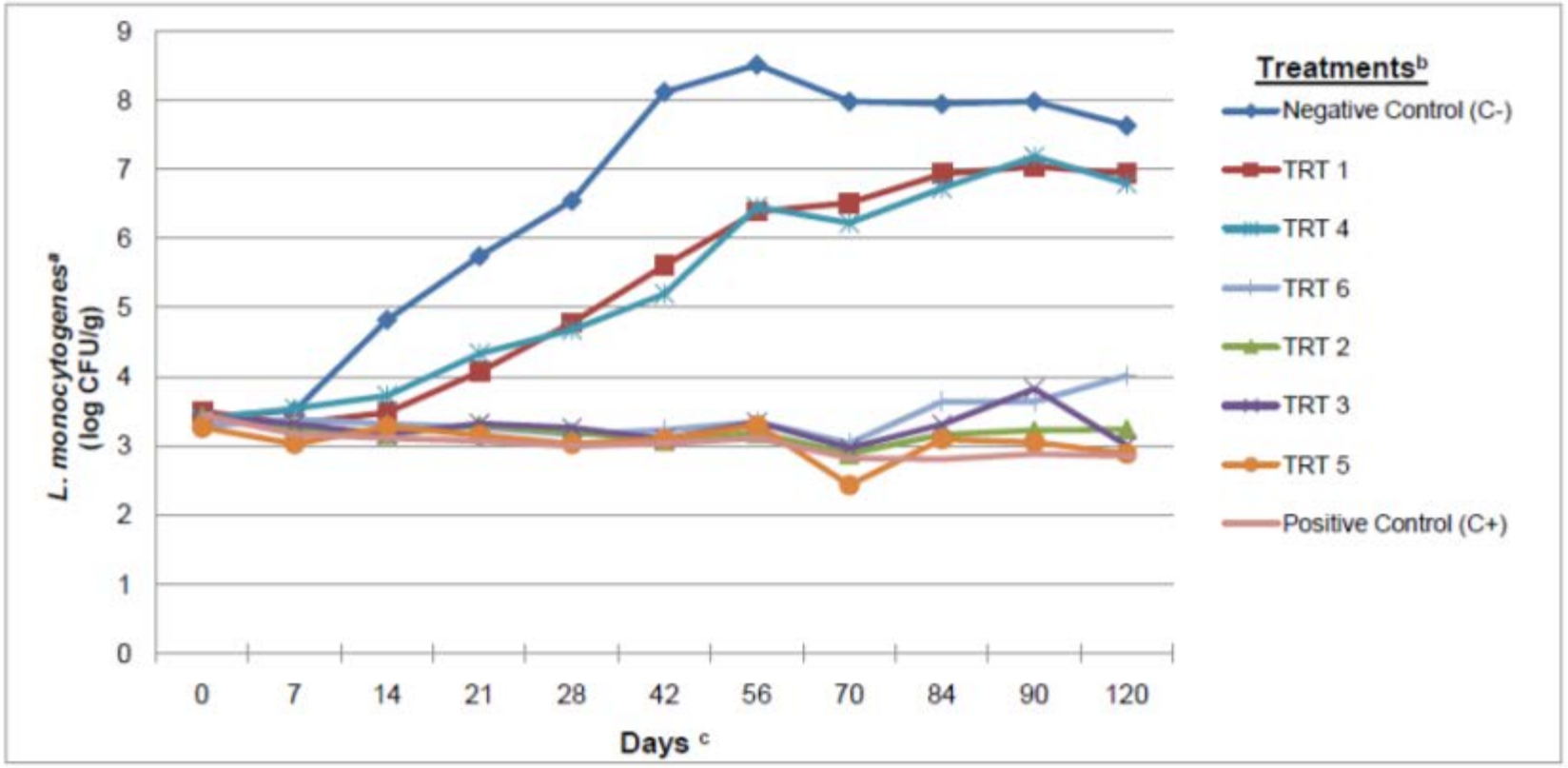
- "Alternative Cured" System

TRT	Vegetable Juice Powder (nitrate or nitrite source)	Antimicrobial (cherry/lemon/vinegar or cultured sugar/vinegar)
1	0.2% pre-converted	NA
2	0.2% pre-converted	1.4% cherry/lemon/vinegar (c/l/v)
3	0.2% pre-converted	3.0% cultured sugar/vinegar (cs/v)
4	0.45% nitrate source	NA
5	0.45% nitrate source	1.4% cherry/lemon/vinegar (c/l/v)
6	0.45% nitrate source	3.0% cultured sugar/vinegar (cs/v)
Control	156 ppm Na nitrite	2.5% Potassium lactate/sodium diacetate

Adapted from Schrader, 2010. Ph.D. Thesis, ISU.

Impact of "Natural" Ingredients on Frankfurters

Figure 9. Growth of L. *monocytogenes*[a] on uncured, no-nitrate-or-nitrite-added (TRT 1-4) and nitrite added control (C+) uncured control (C-) EFSC sausages.



TRT 1 (nitrite-NA); TRT 2 (nitrite-c/l/v); TRT 3 (nitrite-cs/v)
TRT 4 (nitrate-NA); TRT 5 (nitrate-c/l/v); TRT 6 (nitrate-cs/v)

Adapted from Schrader, 2010. Ph.D. Thesis, ISU.

Antimicrobial Ingredients with Mixed Results

1. 150 ppm purified nitrite
2. No nitrite
3. $NaNO_2$ + 1% cranberry
4. $NaNO_2$ + 2% cranberry
5. $NaNO_2$ + 3% cranberry
6. $NaNO_2$ + 0.5% grape seed extract

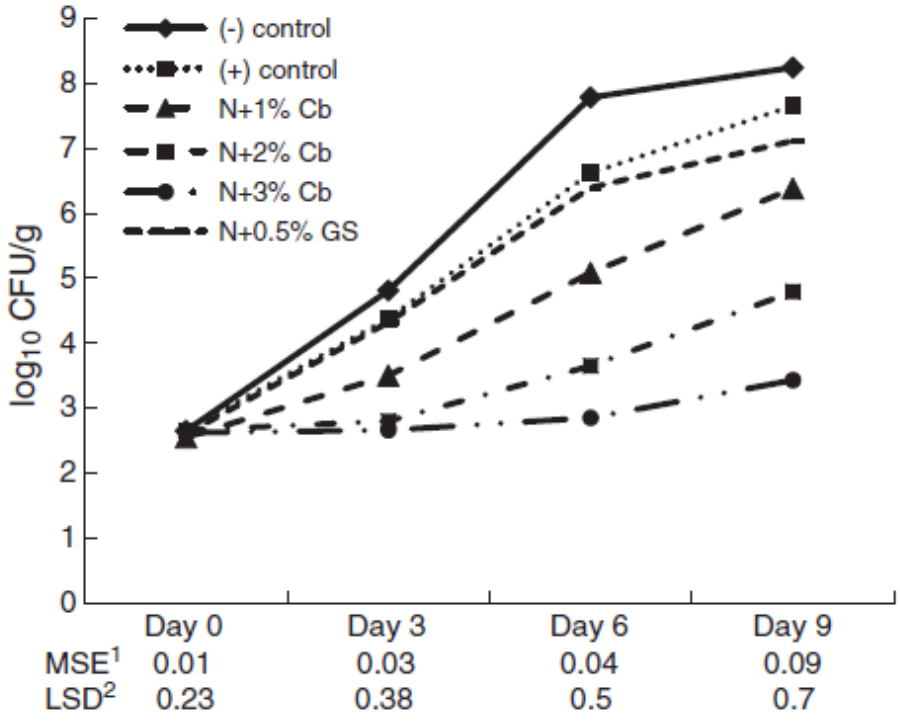
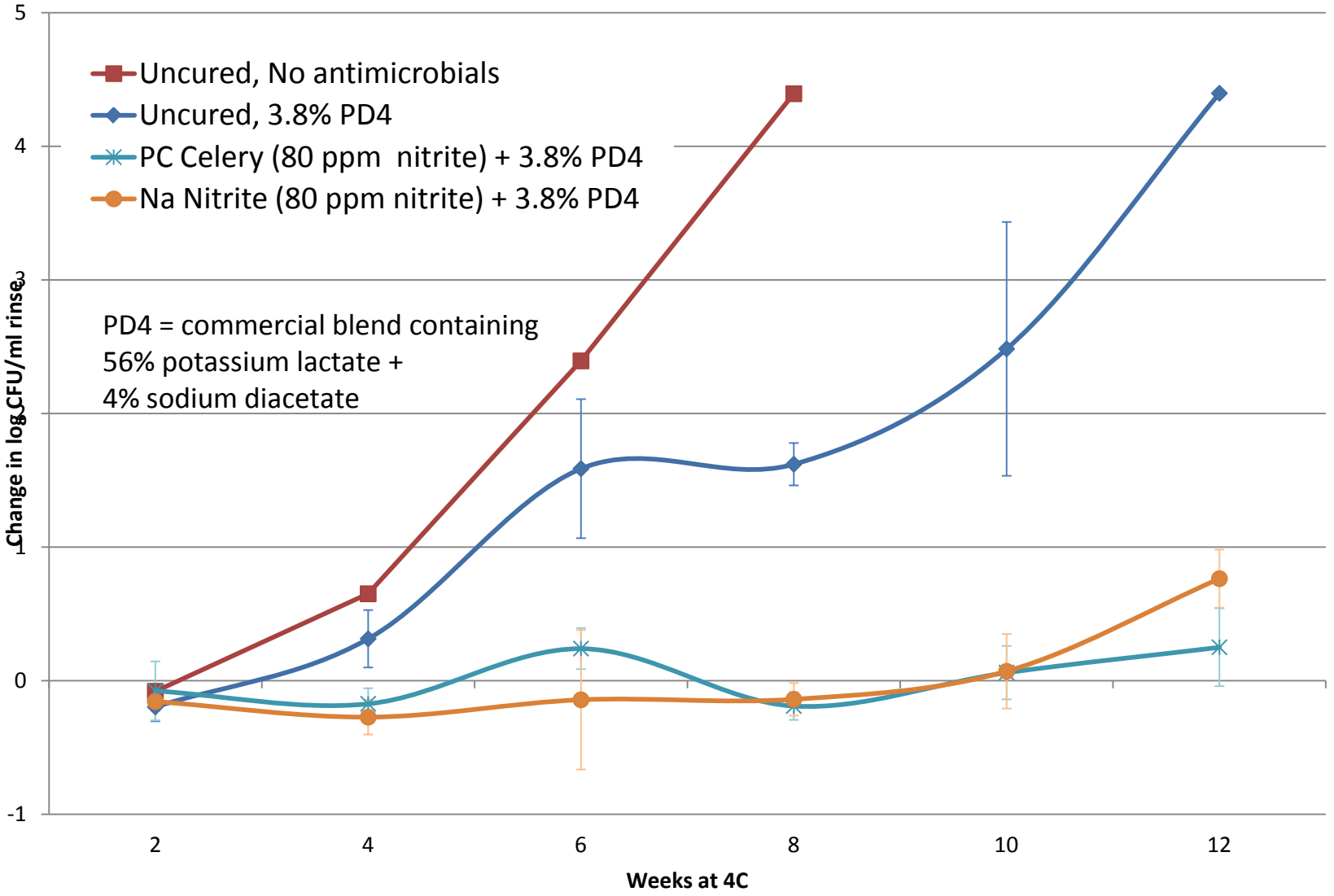


Fig. 5. Growth of *Listeria monocytogenes* in a cooked meat model system following addition of sodium nitrite, cranberry powder and grape seed. N: 150 ppm added sodium nitrite, Cb: cranberry powder, and GS: grape seed. [1]MSE: mean square error and [2]LSD: least significant difference, expressed for each day.

Xi et al. (2011), Meat Sci. 88: 503-511

Inhibition of Listeria monocytogenes in Deli-Style Turkey



UW-Madison, 2012, unpublished data

Need for Change in Food Safety Approach?

- Important to evaluate products
  - Fresh
  - Not Fully Cooked
  - Fully Cooked
  - Shelf Stable
- Important to evaluate processes
  - A change in food safety risk?
  - Need for adjustment?

Alternative Curing Next Steps

- A need to understand/confirm equivalence
  - Food safety
  - Labeling change
- Additional ingredient work
  - "Natural", organic, and clean label antimicrobials
    - Improved effectiveness and cost consideration
  - Nitrate/nitrite sources
    - Increased concentration and cost consideration

Questions?