Shelf-Life Constraints in Processed Meat Products

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AMSA Webinar Series

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Processed Meat Trends

- Natural
- Organic
- Local
- Nitrate / nitrite free
- Uncured
- No preservatives
- Pasture raised
- Grass fed
- No artificial ingredients
- Gluten free
- Reduced sodium / low sodium
- No phosphates
- Sustainable
- Hormone free
- Antibiotic free
- Humanely raised
- Free range
- No stimulants
- Ethically raised
- Happy

Trends and Realities

Trend

- Organic, Local, ABF, etc.
- No preservatives
- Nitrite free
- Reduced sodium

Concern

- Raw material availability
- Shelf life limitations
- Pathogen inhibition
- Loss of functionality

Shelf-life

More than just microorganism limitations

- In addition to microbial suppression and pathogen control, processed meat products must be formulated for:
  - Color stability and flavor protection
  - Yield and moisture management
  - Maintenance of texture and stability

Define shelf-life:

- The period between manufacture and retail purchase of a food product during which the product is of satisfactory quality. (IFT, 1974).
- The time during which the food product will:
    1. remain safe
    2. be certain to retain desired sensory, chemical, physical and micro-biological characteristics
    3. comply with any label declaration of nutritional data, when stored under the recommended conditions. (IFST, 1993)

Recommended Conditions

- Factors that mitigate “recommended conditions”
  - Temperature abuse
  - Light sources
  - Compromised packaging

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Contributing Factors to a Food Product's Shelf-Life

- Product
  - Moisture content
  - Fat content
  - pH (and type of acid)
  - Water activity
  - Enzyme activity
  - Native microflora
  - Salt
  - Other natural and chemical preservatives
  - Formula water characteristics
- Environment
  - Packaging (residual O2)
  - Package headspace gas composition
  - Light exposure (UV)
  - Storage temperature
  - Processing time and temperature
  - Cooking method
  - Consumer handling

Deterioration of Meat and Meat Products

Product	Deterioration Mechanisms	Limiting Changes
Fresh Red Meat	Oxidation Microbial growth	Loss of red color, rancidity, off-odors and flavors
Frozen Meat	Oxidation Ice sublimation	Rancidity, freezer burn
Fresh fish	Microbial growth Chemical reactions	Microbial, off-odors, appearance changes
Fresh poultry	Microbial growth	Microbial, off-odors
Fresh sausages	Microbial growth Oxidation	Microbial, rancidity
Fresh bacon	Microbial growth Oxidation	Microbial, rancidity, color change
Canned ham	Chemical reactions Can deterioration	Flavor loss, gas generation

Kilcast and Subramaniam, 2000

Influence of Packaging on Shelf-life

- Oxygen barrier using EVOH
- UV barriers to block the low wavelength UV spectrum, which is most harmful to cured meat color
- Shrink properties with bags or film minimize space and opportunities for purge to accumulate
- Full vacuum conditions – critical for removing the maximum residual oxygen
- O2 scavengers – either sachets or film based
  - Iron oxide formulated into films (RH activated)

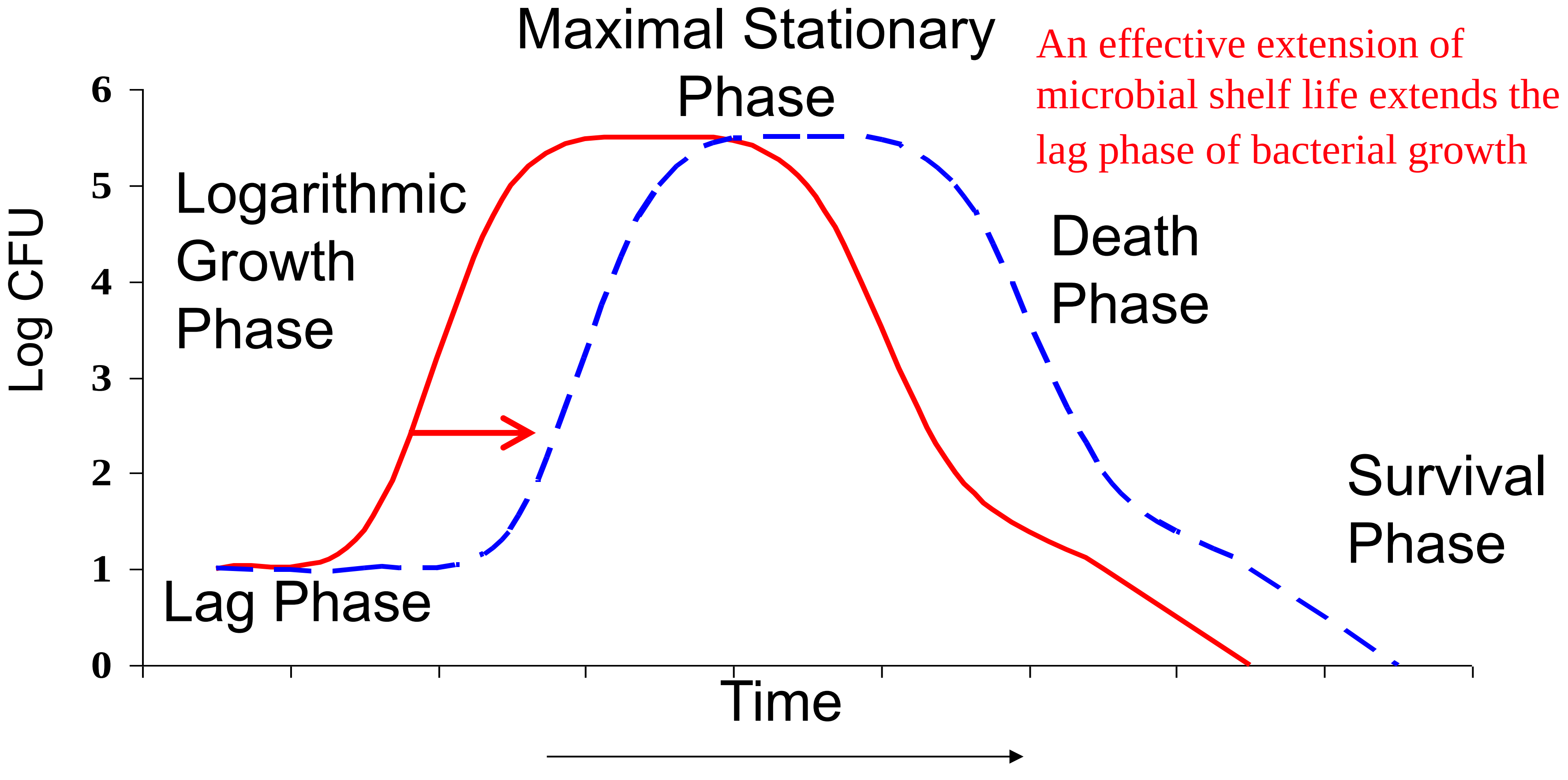
Packaging Defects

Photo Credit: Robert Campbell

Microbial Shelf-life

- In general, microbiological changes are of primary importance for short-life products, and chemical and sensory changes for medium- to long-life products; all three types of change can be important for short- to medium-life products (McGinn, 1982).

Bacterial Growth Curves



Microbial population change during fabrication of beef carcasses into subprimals

Aerobic plate count	> by 0.8 to 1.1 log cfu/100 cm^2
Total coliform count	> by 1.4 to 1.5 log
Generic *E. coli* counts	> by 0.7 to 0.9 log
Salmonella spp. positive	> by 0.2%
Listeria spp. positive	> by 29.0%
Listeria monocytogenes positive	> by 17.8%

Limiting Conditions for Growth of Certain Pathogens

	Min. a_w	Min. pH	Max. pH	Max. % water phase salt	Min. temp.	Max. temp.	O_2 requirement
Listeria monocytogenes	0.92	4.4	9.4	10	31.3º F -0.4º C	113º F 45º C	Facultative anaerobe*
Shigella spp.	0.96	4.8	9.3	5.2	43º F 6.1º C	116.8º F 47.1º C	Facultative anaerobe*
Salmonella spp.	0.94	3.7	9.5	8	41.4º F 5.2º C	115.2º F 46.2º C	Facultative anaerobe*

*grows either with or without oxygen

Adapted from USDA CFSAN Fish and Fisheries Products, Hazards & Control Guidance. 2001, 3rd ed. Appendix 4, Bacterial Pathogen Growth and Inactivation

Antimicrobial agents

- Compounds added to meat that suppress, inhibit or destroy pathogenic and/or spoilage microorganisms

Factors affecting the efficacy of antimicrobial compounds

- Solubility of the antimicrobial compound
- Water activity of the substrate
  - Moisture content
  - Water phase salt/solute content
- Nitrite
- Temperature
- pH
  - pKa (dissociation constant) of the antimicrobial compound
- Synergies
- Initial bacterial load
- Competitive microflora
- Package type/atmosphere

Organic acid salts of note

- Sodium lactate ($C_3H_5O_3Na$)
  - Prepared commercially by the neutralization of lactic acid with sodium hydroxide
- Potassium lactate ($C_3H_5O_3K$)
  - Prepared commercially by the neutralization of lactic acid with potassium hydroxide
- Sodium diacetate ($C_4H_7O_4Na \cdot xH2O$)
  - Produced by reacting equimolar amounts of anhydrous sodium acetate and acetic acid
  - In solution is split off into its constituents, and liberates 39-41% acetic acid and 58-60% sodium acetate.
- Sodium or potassium acetate (CH_3COONa/K)
  - Prepared by the neutralization of acetic acid by either sodium or potassium hydroxide

Antimicrobial mode of action for organic acid salts

- Disruption of cell metabolism sufficient to result in a static response (no growth)
  - Accumulation of acid anions within the cell
  - Intracellular accumulation of anions is driven by external anion concentration and the internal:external pH gradient

- Buffered vinegar
  - Enhance fresh meat and poultry shelf life
  - Clean label option labeled as Vinegar

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Buffered vinegar has proven to be an effective technology to lower the growth rate of spoilage bacteria in fresh chicken. Sensory panel testing confirms that no difference is imparted to the eating quality of the chicken. In-pack delivery of the solution is the most cost effective method for use.

Adapted from Desai, et al., 2014.

Dye test to demonstrate coverage over product after treatment with 1% solution

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Buffered vinegar affects microbial growth in fresh chicken

Desai, et al., 2014.

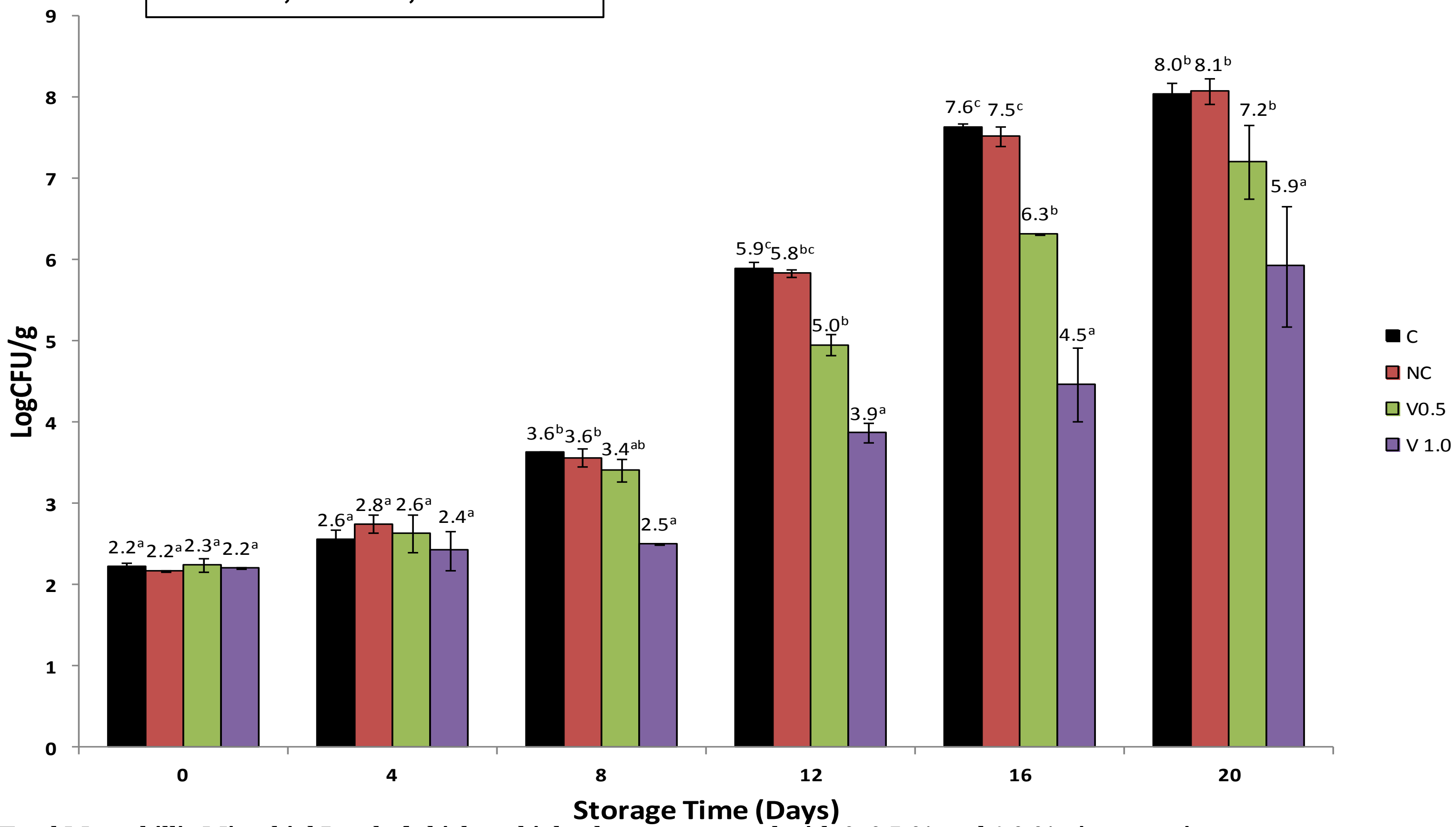
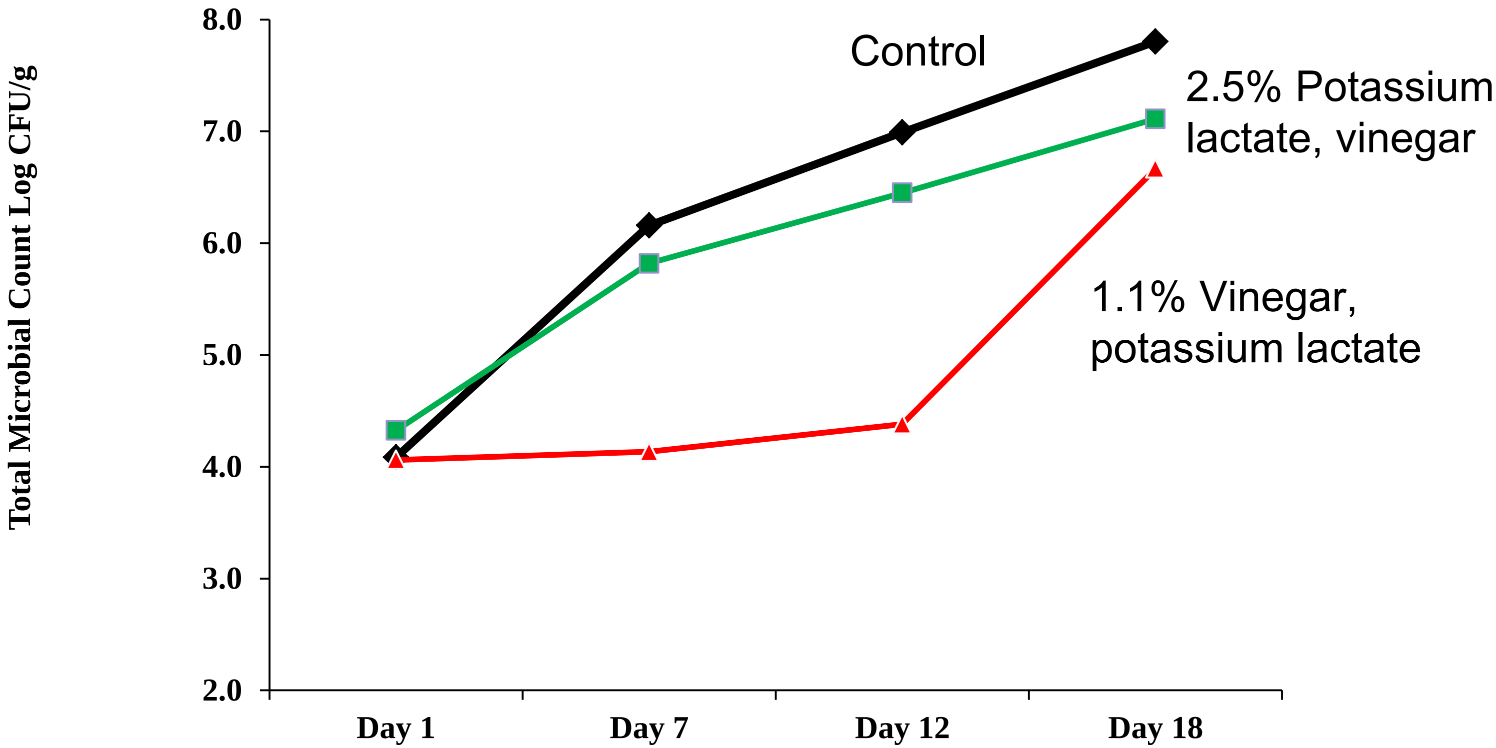


Figure 1: Total Mesophillic Microbial Load of chicken thighs that were treated with 0, 0.5 % and 1.0 % vinegar prior to packaging in carbon dioxide and stored (2-4 °C) for up to 20 days. C=control with 1.0 % DI water; NC=negative control; V0.5= 0.5 % vinegar, V1.0= 1.0% vinegar. Means with unlike superscripts within each storage time are different (*P* < 0.05).

Total aerobic plate counts for refrigerated shelf life display of fresh pork sausage with vinegar and lactate salts



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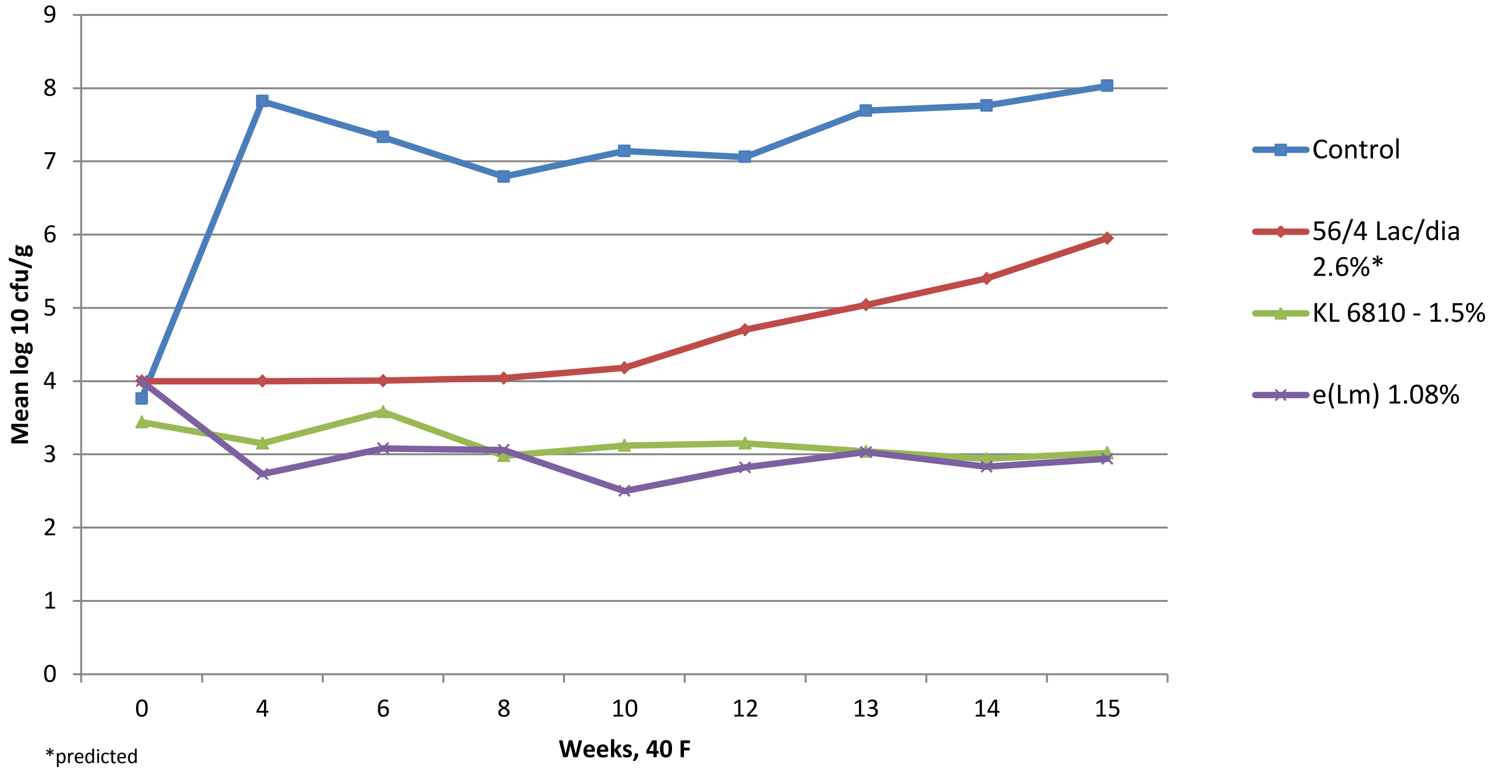
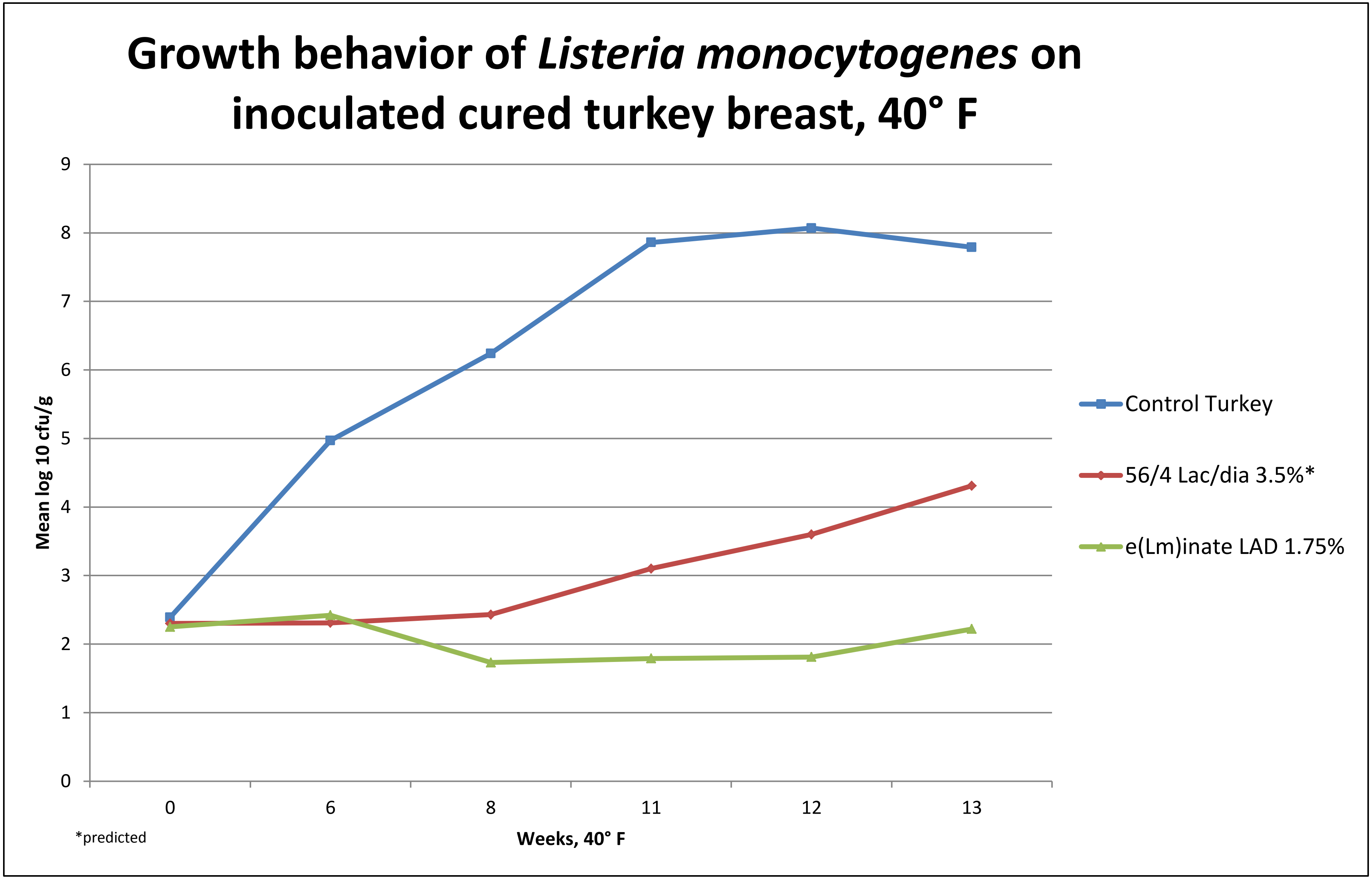
Growth behavior of Listeria monocytogenes on inoculated chicken/pork frankfurters, 40° F



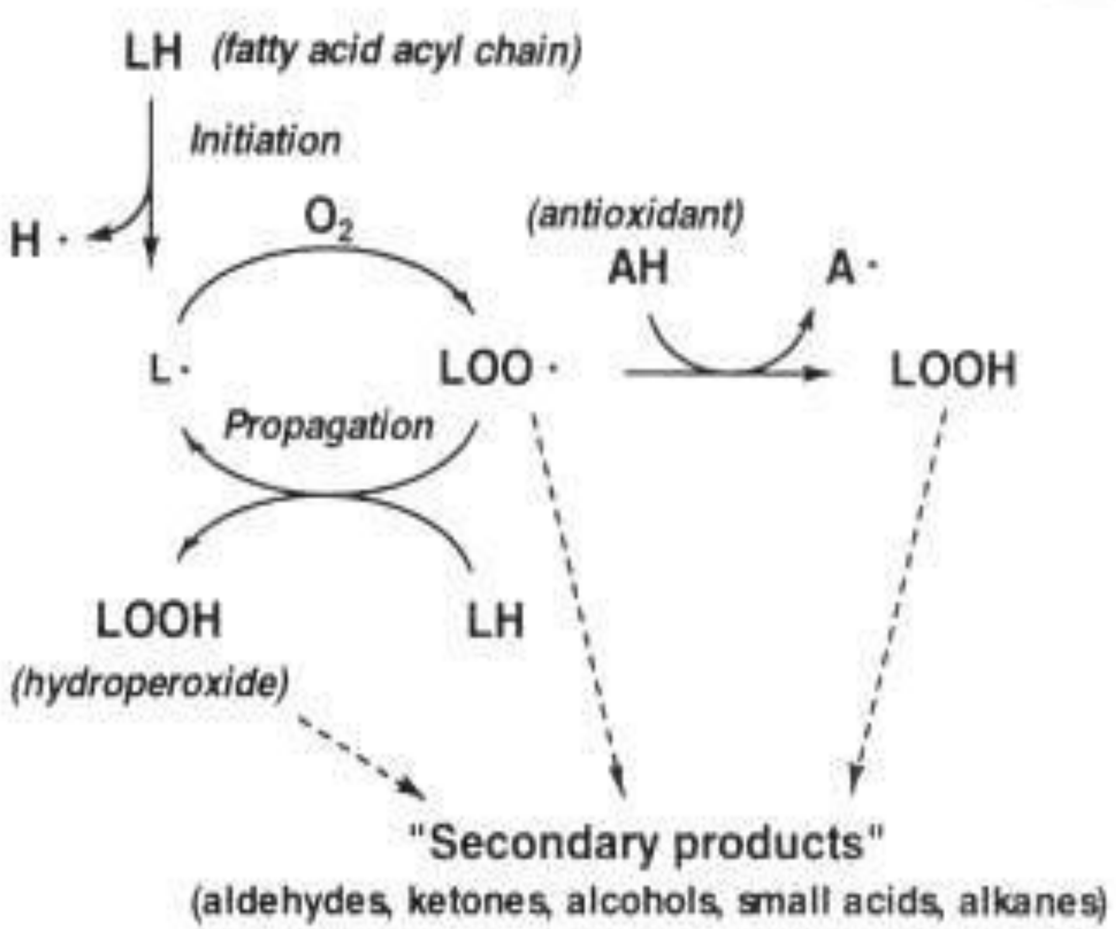
e(*Lm*)inate™ KL 6810 – 68% potassium lactate/10% sodium diacetate
e(Lm)inate LAD – 23% potassium lactate, 23% potassium acetate, 14% sodium diacetate


Growth behavior of *Listeria monocytogenes* on inoculated cured turkey breast, 40° F
Mean log 10 cfu/g
0
1
2
3
4
5
6
7
8
9
0
6
8
11
12
13
Weeks, 40° F
*predicted
Control Turkey
56/4 Lac/dia 3.5%*
e(Lm)inate LAD 1.75%

Rancidity

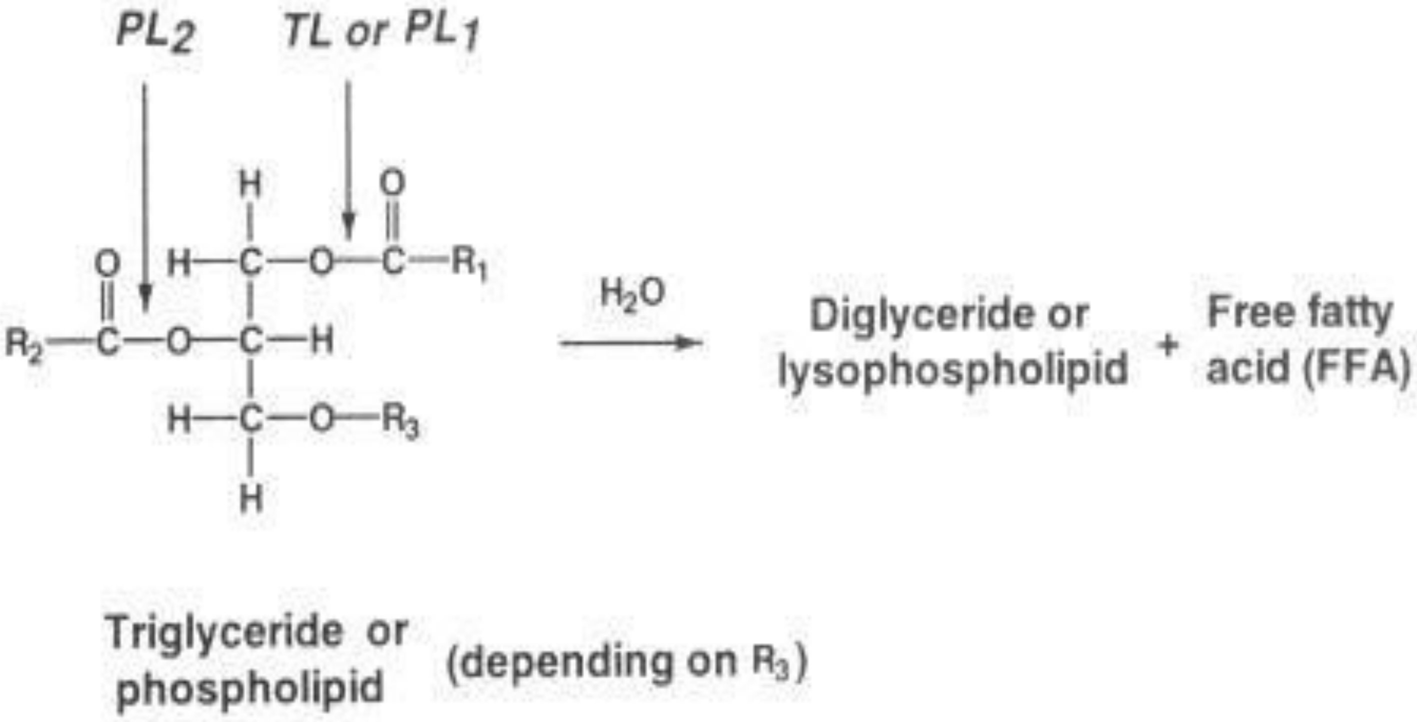
- Two reactions in lipids promote quality deterioration resulting from rancid odors and flavors:
  - Hydrolysis
  - Oxidation
- Meat with high fat (oil) content are more susceptible to fat deterioration
- Free fatty acids may produce a “soapy” flavor

Oxidation



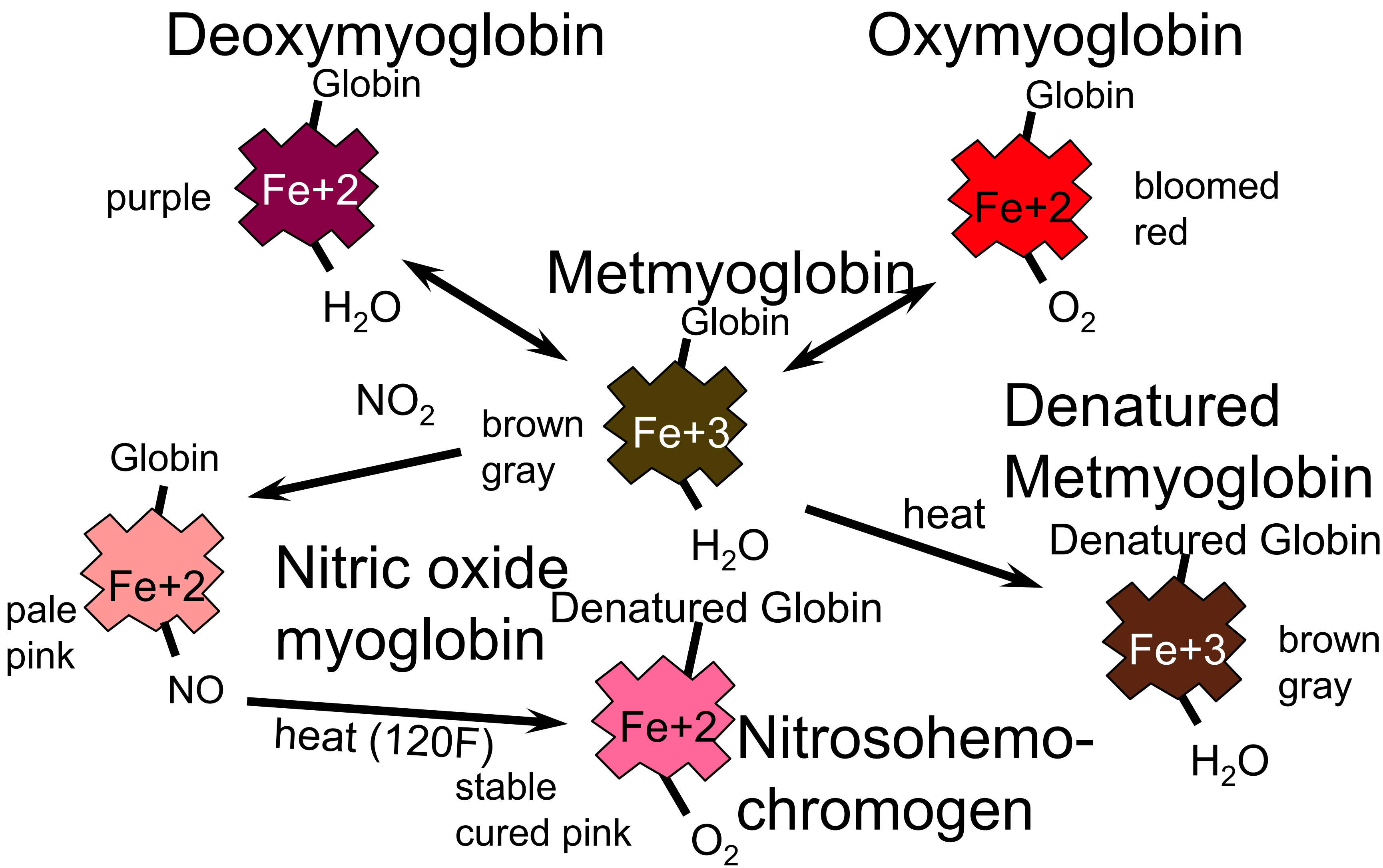
Source: FAO Document Repository (www.fao.org)

Formation of free fatty acids

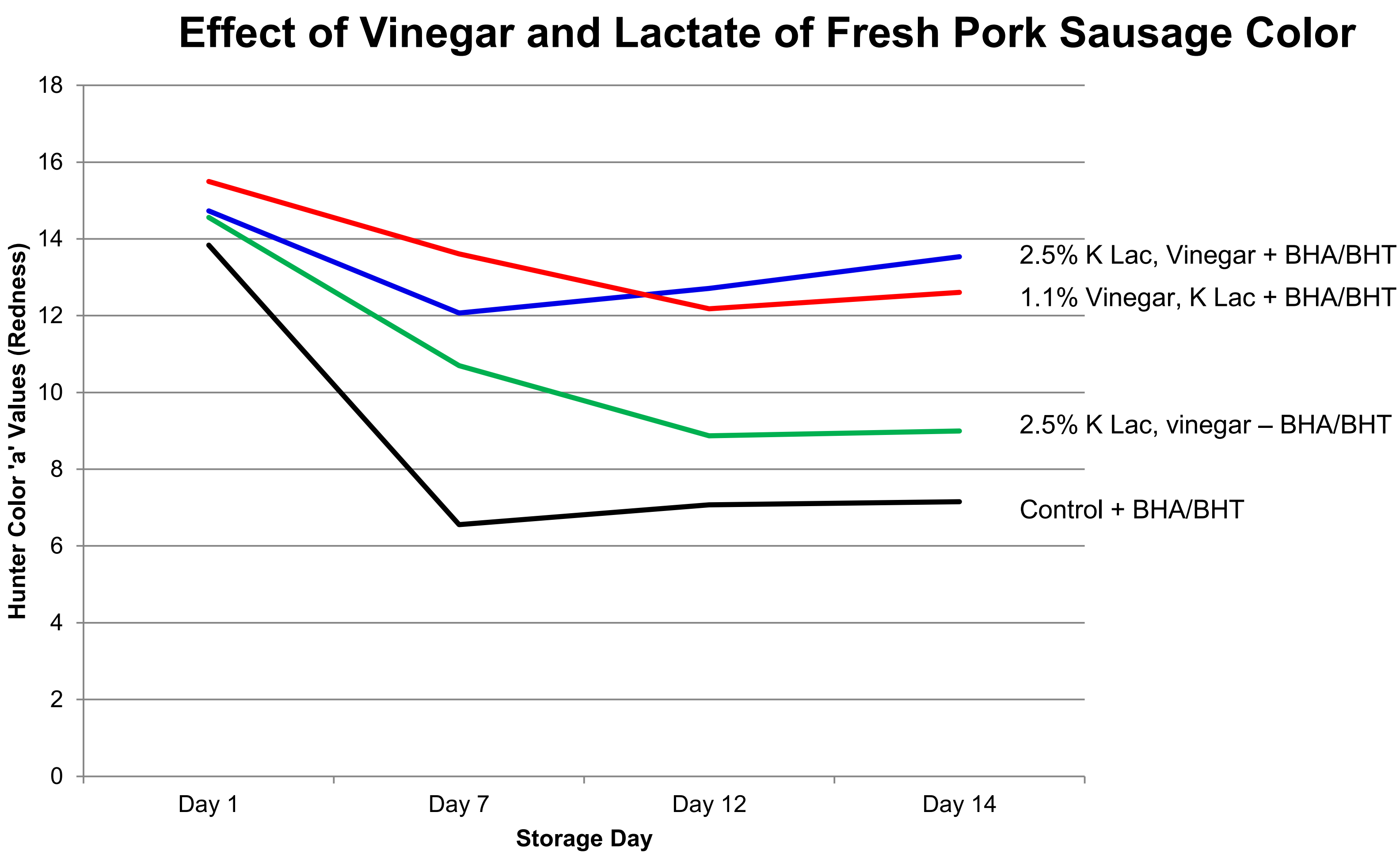


Source: FAO Document Repository (www.fao.org)

Meat Pigment States



Interactions between color stability and microbial growth suppression



Maximizing fresh pork sausage shelf-life

- Fresh pork sausage shelf-life is limited by discoloration, lipid oxidation (rancidity), and microbial growth
- Organic salts and vinegar products inhibit spoilage organism growth and promote pigment stability, prolonging red color life (Crist, et al, 2014).
- Synergies with various natural antioxidants can promote color stability and reduce lipid oxidation (Pham et al., 2013), while synthetic antioxidants are typically most effective on fat oxidation (Dziezak, 1986).

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Fresh sausage color

- Combinations of antioxidants, such as rosemary and green tea extract, can extend color life by one to three days in fresh sausage, whether displayed fresh or when displayed from frozen to slack out in retail cases (Pham, et al. 2013).
- When combined with lactate salts and acetic derivatives, natural antioxidants, promote maximum color stability.

Rosemary Extract and Green Tea Extract Impacts on Fresh Pork Sausage Color

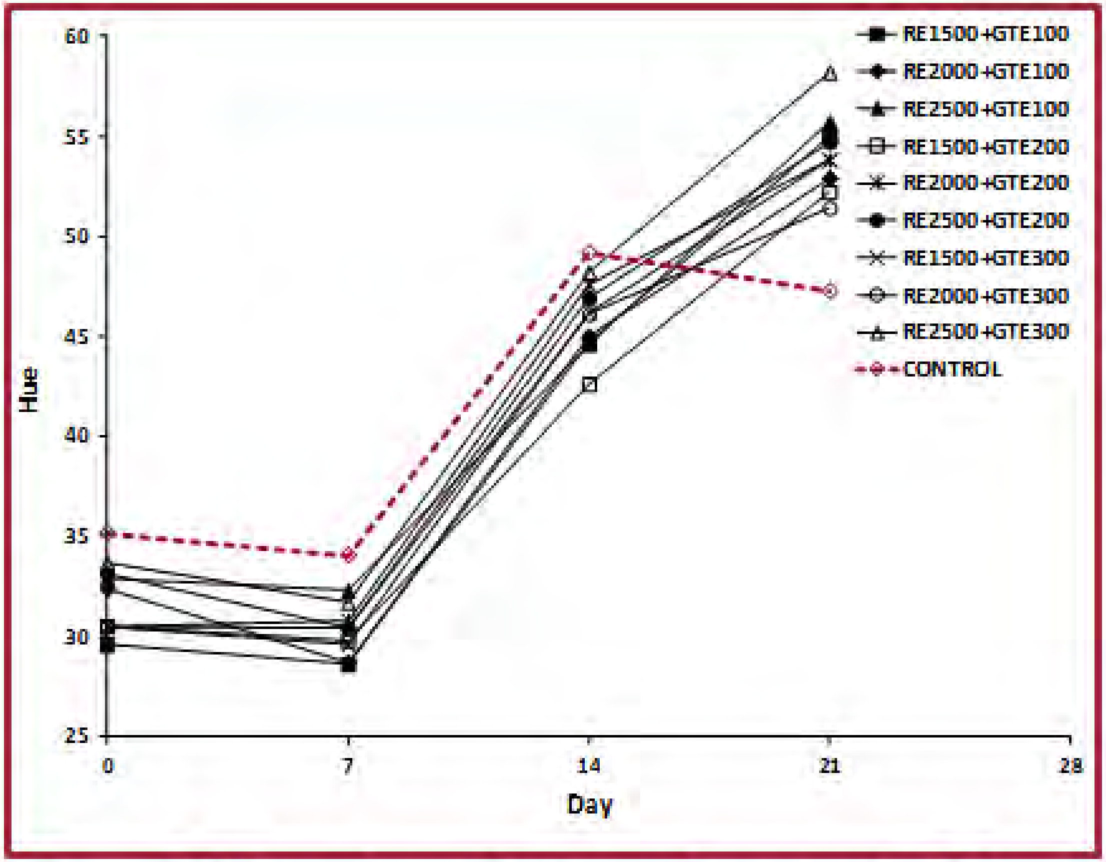

Figure 3. Effect of combinations of rosemary (RE) and green tea (GTE) extracts on the hue (discoloration) values of fresh pork sausage under simulated retail display (3±1°C, 21 d).

Adapted from Pham, et. al., 2013.

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Water

- Water contains organic matter, dissolved solids and minerals that form SCALE in distribution pipes, fixtures, equipment and on surfaces.
- FILMS form on surfaces in contact with water.
- Many cleaning and sanitizing agents leave film RESIDUES.
- Scale, film, residues & other deposits reduce efficiency, performance and longevity of systems and equipment.

Water Hardness

Ingredient water should be treated separately from plant process water

Hardness Level	ppm Calcium
Very Hard	>180
Hard	120-180
Mod Hard	60-120
Soft	0-60

Table: Water Hardness

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Salt – Why do we use it in food products?

- Lowers a_w (ties up moisture)
- Flavor
- Antimicrobial
- Protein extraction (bind, yield, texture)
- Increases ionic strength of meat system
- Increases water holding capacity
- Improves fat binding and emulsification properties

TBA Values of raw pork stored at 4C for 5 days.

Chloride Salt	Ionic Strength	TBA Number	TBA Ratio
NaCl	0.70	8.39a	40
	0.35	4.99c	24
KCl	0.70	4.90c	23
	0.35	3.09e	15
$MgCl_2$	0.70	7.63b	36
	0.35	3.63d	17
Control	0	0.21f	1

Different Superscripts indicate TBA Numbers are different ($P < 0.05$)

TBA Ratio is the ratio of the TBA value to control (no chloride salt)

From Rhee et al., 1992

Purge – an unsightly deterrent to consumer purchasing decisions

Purge Constraints on Processed Meat Shelf-life as a Function of Ingredient Selection

- Two common ingredients can provide extreme variability in performance of moisture management

1. Phosphates
2. Modified food starches

Modified Food Starches

- Moisture management
  - Water binding
  - Purge control
- Freeze thaw stability
- Texture modification
- Various specific cooking temperature ranges

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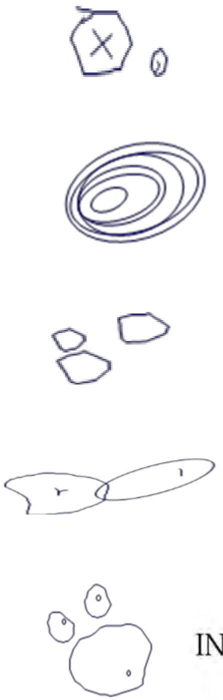
Starches

- Modified food starches are derived from a variety of carbohydrate sources.
- These sources normally include corn, potato, rice, tapioca, and wheat.
- Corn starches for food applications are further classified based two glucose polymers, amylose and amylopectin.

Starch Granule Characteristics

Source	Morphology	Average Diameter (υm)
Corn	Discs	15
Potato	Ellipse	70
Rice	Granules	1-2
Tapioca	Bell Shapes, Discs	20
Wheat	Granules (2 sizes)	5, 30



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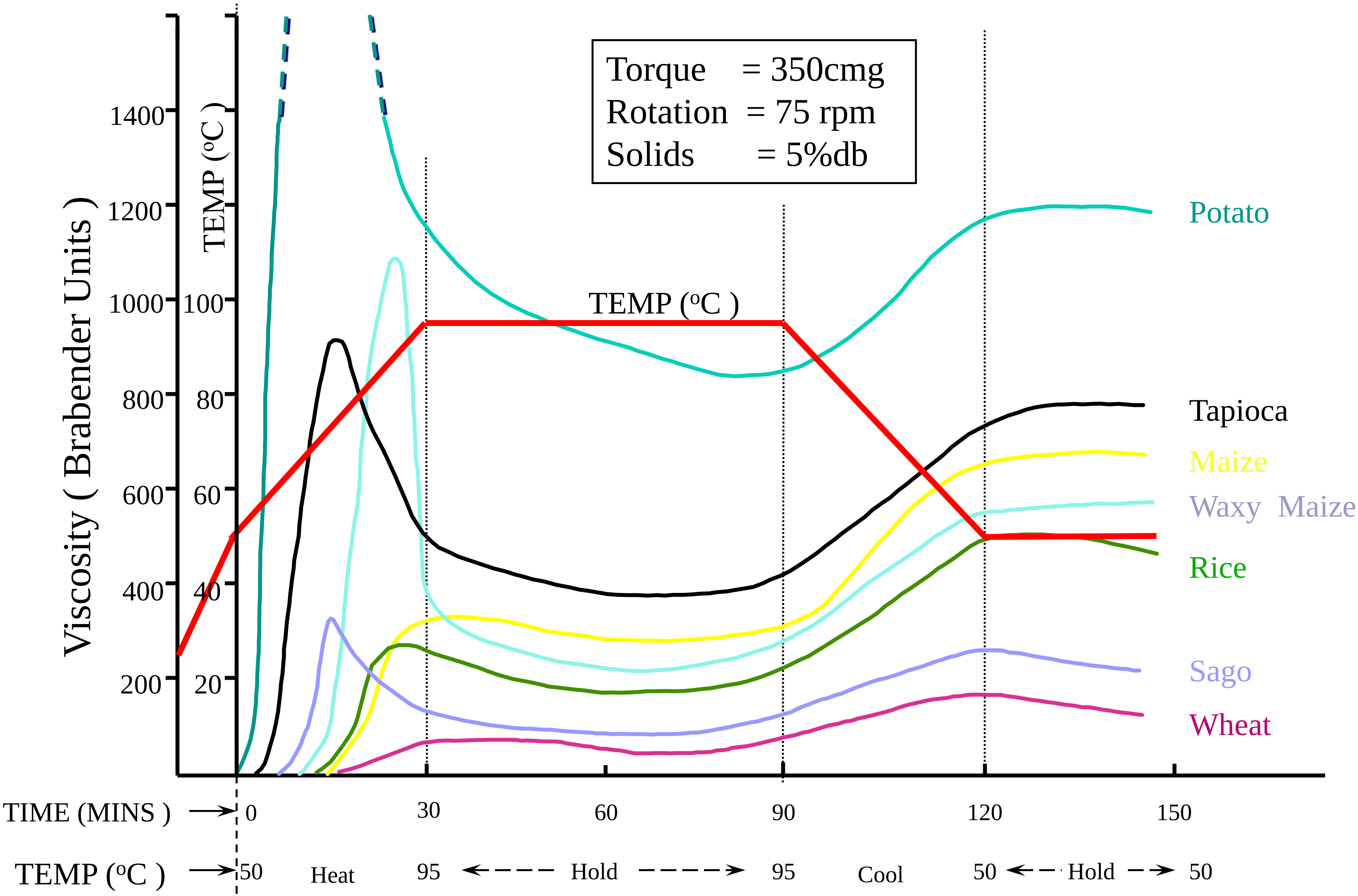
Selection of a Modified Food Starch

- Hydration temperature
- Temperature of peak viscosity
- Stabilized to control purge
- Cost
- Carbohydrate source

Brabender Viscosity Profiles



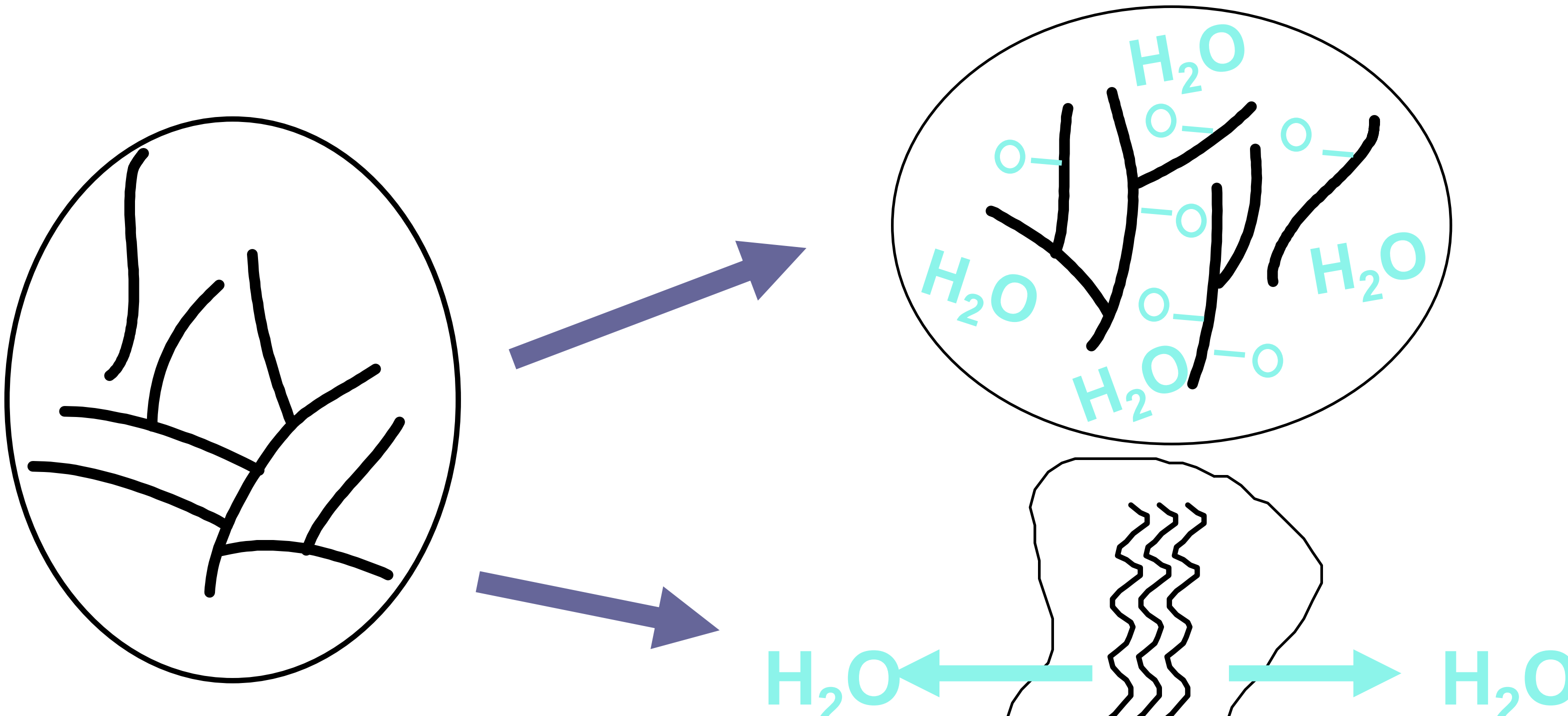
Modified Food Starches

- Cook-up and Instant Starches
  - Cook-up starches require heat to gel (bind water)
  - Instant starch swell in cold water
- Modified food starches provide excellent freeze/thaw properties
- Starches have minimal impact on color and flavor

Stabilized, Modified Food Starches

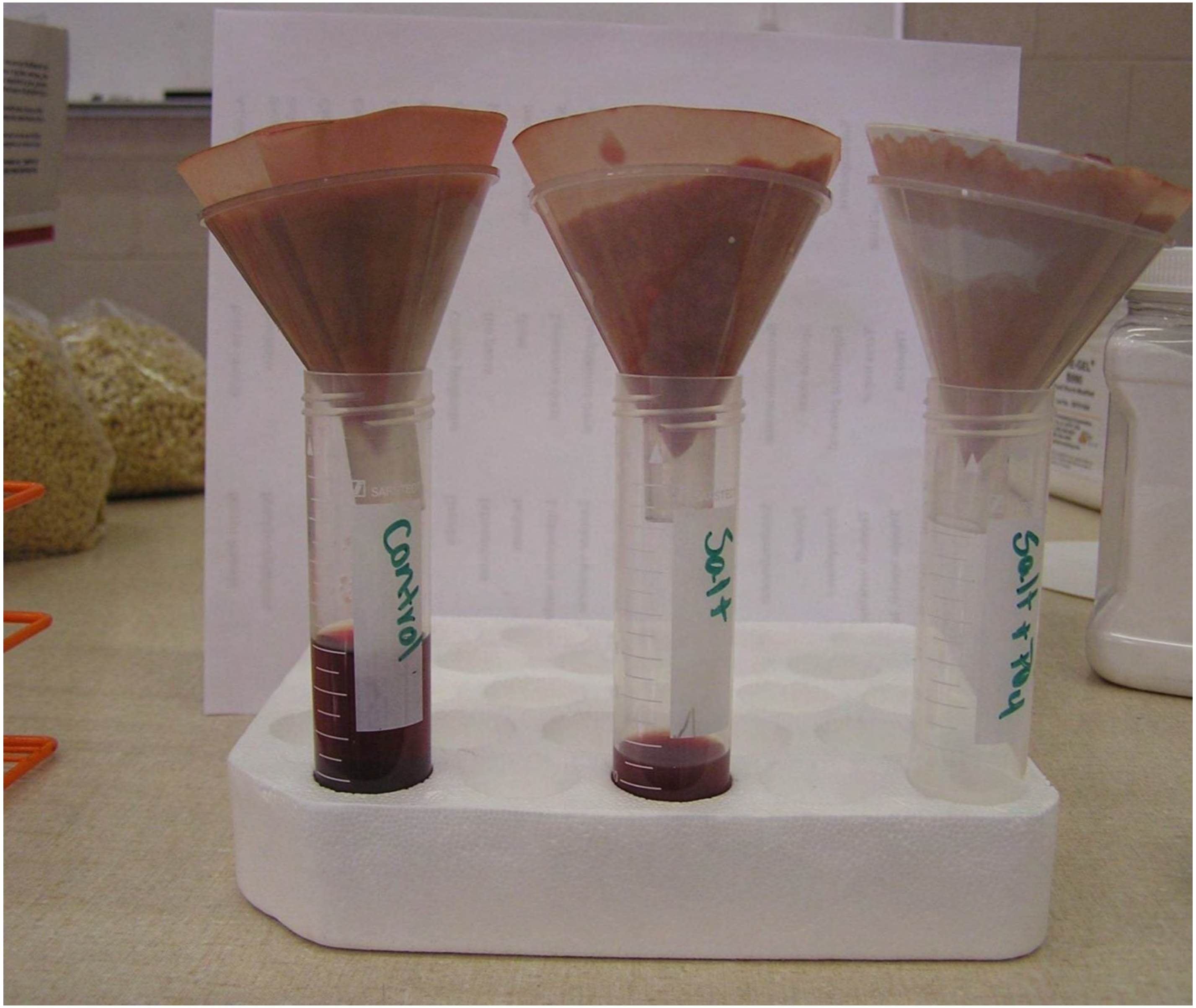
- Cross-Linking
  - Covalently links starch molecules to produce granules with increased resistance to processing stress.
- Substitution
  - Addition of chemical groups that will inhibit starch retrogradation

Effect of Substitution



Selecting a properly substituted starch with a pasting temperature within the thermal processing parameters of the meat product is key to purge control and prevention of retrogradation.

Effects of phosphate on WHC



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Phosphate Manufacturing

- Phosphate rock
- Phosphorous
- Phosphoric acid
- Sodium or potassium phosphate

(source: Israel, Egypt, USA)

- Solubility and salt tolerance
  - drum drying < spray drying < agglomeration

Phosphate Usage Rationale

- Phosphates are unique in that they improve the functionality of the meat proteins
- Phosphates:
  - Improve water holding capacity
  - Improve oxidative stability
  - Increase protein extraction
  - Improve cured color stability
  - Improve texture

Phosphate Properties

Property	Mechanism
Anti-oxidant	Chelating metal ions prevents their participation in oxidation reactions
Emulsification	Stabilizes emulsions by increasing protein extraction efficiency and relaxation of the actomyosin protein matrix to more efficiently encapsulate fat droplets
Texture	More efficient protein extraction
Protein extraction	Improves salt soluble protein extraction by adding ionic strength and like charges to relax and open up meat protein structures
pH	Alkaline phosphate products increase pH and thus improve water holding capacity. Many of these phosphates have pH ranges from 7.5 to 12.0 in 1% solutions and increase pH values of the meat system
Buffering capacity	Phosphates (especially monophosphates) add buffering capacity to meat systems and therefore help the system resist changes when acids (or bases) are added to the system

Phosphate Chain Length Properties

Chain Length Designation	Chain Length	Primary Properties
Mono (ortho) – phosphate	1	Buffering capacity
Di (pyro) – phosphate	2	Dissociation of actin and myosin, chelates magnesium
Tripolyphosphate	3	Chelates calcium, improves water holding capacity predominant component of phosphate blends,
Hexametaphosphate	6 +	Improves solubility, chelates calcium

Phosphate Usage Guidelines

- Restricted ingredient (5,000 ppm – 0.5% of the formula weight)
- Cooked sausage products → pyrophosphate component
- Low/moderate pH → faster cured color development and stability
- Agglomerate products / polyphosphate content → improved salt tolerance and solubility

Factors That Influence Natural Meat Flavors

- Cooking methodology
- End point cooking temperature
- Proximate composition
  - Fat
  - Moisture
- Sweetener content (Maillard reaction)
- Species

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How is flavor a shelf-life limitation?

- Technologies for microbial and oxidation suppression have allowed very long shelf life ranges for processed meats.
- Products with high moisture cooking such as steam, boil, or cook-in-bag do not generate significant flavor compounds.
- Roasting, grilling, frying, and pressure cooking develop high amounts of heterocyclic compounds and Maillard reaction products associated with meat flavors (Melton, 1999).

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Loss of Flavor Limits Shelf-life

- Products such as cook in bag deli turkey and roast beef lose their inherent meaty flavors over time and may become undesirable long before microbial or oxidative processes render the product unsalable.
- Trends toward cleaner labels and lower sodium are also contributing factors.
  - Removal of MSG, HVP’s, 5’-nucleotides
  - Reduced salt levels
- Clean label, species specific natural flavors are ideal for these applications
  - Oil soluble flavors are quite stable and are typically low inclusion levels (< 0.25%).
  - Water soluble flavors are easier to incorporate, but may not have the impact of oil soluble flavor.

Recap

- Balanced formulas, ingredient selection, packaging, and processing conditions play a major role in the color, flavor, and moisture management that can limit shelf life before microbial spoilage renders processed meat products unsaleable.

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No Amount of Technology Will Replace Common Sense and Good Manufacturing Practices

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