Iowa State University

From the SelectedWorks of Rodrigo Tarté

April 28, 2015

Food Safety Ingredients in Meat Products

Rodrigo Tarté, Ph.D., *Iowa State University*

This work is licensed under a Creative Commons CC_BY-ND International License.

Available at: https://works.bepress.com/rodrigo_tarte/14/

SELECTEDWORKS™

Food Safety Ingredients in Meat Products

Rodrigo Tarté, Ph.D.

Assistant Professor

Meat Science and Technology

Department of Animal Science

Iowa State University

Ames, Iowa, USA

rtarte@iastate.edu

Brazilian Association of Animal Protein

Associação Brasileira de Proteína Animal

São Paulo, SP, Brazil — 28 April 2015

About Iowa

Iowa in U.S. Agriculture

- #1 Pig and Hog Inventory and Value
- #1 Commercial Hog Slaughter
- #1 Live Animals and Meat Export Value
- #1 Soybean Production and Export Value
- #1 Corn for Grain Production
- #1 Feed Grains and Export Value
- #1 Egg Production
- #2 Red Meat Production
- #4 Cattle on Feed

http://www.ans.iastate.edu/section/meat/

Antimicrobials

- Substances that inactivate or inhibit the growth of microorganisms (bacteria, yeasts, molds, viruses)
- Used for two primary reasons:
  - Food Safety
    - Prevent the outgrowth of disease-causing microorganisms
  - Shelf-life Guarantee
    - Ensure microorganisms that cause food to spoil do not overcome the product before a desired period of time

General Considerations for Use

- Antimicrobial's properties
  - pKa, concentration/use level, solubility, antimicrobial spectrum
- Environmental conditions
  - pH, a_w, temperature, food composition
- Application method
  - Rinse, spray, dip, internal application
- Synergism with other antimicrobials
  - Use of single antimicrobial may not be very effective
  - "Hurdle" effect
- Cost-in-use
  - Price x use level
- Safety
  - Environmental and employee

General Considerations for Use, cont.

- Effect on food product organoleptic attributes
  - Flavor, texture, color
- Labeling requirements
- Consumer/customer acceptance

Antimicrobials

- Salt
- Phosphates
- Nitrite
- Organic Acids and Salts
- Parabens
- Medium- and Long-Chain Fatty Acids and Esters
- Chlorine Compounds
- Quaternary Ammonium Compounds
- Ozone
- Peroxides and Peroxyacids
- Antagonistic Cultures
- Bacteriocins
- Lactoferrin
- Lysozyme
- Plant Extracts and Essential Oils
- Other

Salt (sodium chloride)

- Quite possibly the oldest known preservative
- Antimicrobial effect primarily involves cellular dehydration via osmosis
- Synergistic with other antimicrobial ingredients, such as benzoate, sorbate, nitrite, phosphates, spices, liquid smoke
- As salt is decreased or removed (as when reducing sodium), its antimicrobial properties must be carefully considered and compensated for.
- Potassium chloride has similar antimicrobial properties

Phosphates

- Primary use in meats is for water-holding, texture modification and yield improvement
- Polyvalent anions → bind cations
- Deprive microorganisms of divalent cations and free water
- More effective against G+ bacteria and molds
- Not as effective against G- bacteria
- Effectiveness affected by water hardness
- Trisodium phosphate (TSP) (pH 10–12) is approved in U.S. for decontamination of poultry carcasses and parts

Nitrite

- Available in sodium or potassium nitrite
- Effective against *Clostridium botulinum*, and other bacteria, including Listeria monocytogenes and Salmonella
- Antimicrobial activity enhanced by acidic pH, presence of salt, low temperature and anaerobiosis
- Acts in synergy with other antimicrobials, such as lactate and diacetate
- It has been estimated that at least 70-80 ppm is needed for adequate antilisterial activity (Glass et al., 2008)

Organic Acids and Salts

- Short-chain organic acids
- Weak acids
- Antimicrobial activity is pH-dependent
- Antimicrobial activity increases as environmental pH approaches pK_a
  - When pH = pK_a, half of the acid molecules are dissociated
  - At pH<pK_a, more of the acid is undissociated (and thus more effective)
- In undissociated state, organic acids enter cell, dissociate and decrease cytoplasmic pH. In effort to maintain homeostasis, cellular ATP is depleted
- Organic acids are lipophilic and therefore difficult to solubilize in water phase; therefore they are more commonly added in their salt forms

Organic Acids and Salts

Organic acids commonly used in meat products

Organic acid	MW	pK_a
Acetic	60.50	4.75
Propionic	74.08	4.88
Lactic	90.08	3.08
Phosphoric	98.00	2.21
Sorbic	112.13	4.80
Fumaric	116.70	3.03
Benzoic	122.12	4.19
Malic	134.09	3.40
Caprylic (octanoic)	144.21	4.89
Citric	192.12	3.14

Source: Simpson, C. A., & Sofos, J. N. (2009). Antimicrobial ingredients. In R. Tarté (Ed.), *Ingredients in meat products: Properties, functionality, and applications* (pp. 301–377). New York: Springer Science + Business Media.

Organic Acids and Salts

- Combinations of organic acids (or with other antimicrobials) can sometimes be more effective than a single one
- Commercial applications:
  - Decontamination of fresh meat or carcasses
  - Processed meats
- Lactate (usage ≈ 2–3%), sometimes in combination with diacetate, has been used effectively in processed meats for many years
- Recently benzoate and propionate have gained popularity due to their lower cost-in-use (usage ≈ 0.2–0.3%)

Parabens

- Inactivate membrane functions by disrupting membrane lipids
- Susceptibility
  - Fungi > G+ bacteria > G- bacteria
- Effectiveness increases as chain length increases
  - Heptyl > butyl > propyl > ethyl > methyl
- Activity is dependent on pH, time, temperature, substrate
- Most effective at near neutral pH
- Potassium salts are more soluble
- Not permitted in meat products in the U.S., but are used in other countries

Medium- and Long-Chain Fatty Acids and Esters

- Work by disrupting cell membrane
- More commonly used in sanitation programs
- Medium-chain fatty acids → 8–14 carbons
  - Caprylic (8:0), capric (10:0), lauric (12:0)
- Long-chain fatty acids → ≥ 16 carbons
  - Palmitic (16:0), stearic (18:0), oleic (18:1), linoleic (18:2), linolenic (18:3)
- Esterified by replacing H atom of acid group with an alcohol or sugar group
- As a family, their antimicrobial spectrum varies, and they respond differently to environmental conditions
- In general more effective at pH ≤ 4.6

Medium- and Long-Chain Fatty Acids and Esters

- Applications
  - Octanoic (caprylic) acid approved in U.S. for beef carcass decontamination and as antimicrobial in RTE meat & poultry products
  - Lauramide arginine ethyl ester (LAE) as surface treatment for fresh meat and poultry cuts as well as RTE products
  - Monolaurin has demonstrated activity against *L. monocytogenes,* especially at low temperature and pH

Chlorine Compounds

- Effective against G+ and G- bacteria, fungi and viruses
- Biofilm-forming bacteria are less susceptible
- Effectiveness reduced by alkaline pH, low temperatures, organic matter and water hardness
- Several chlorine compounds approved in U.S. for decontamination of poultry and meat carcasses and parts, including carcass chiller water
  - Chlorine gas (Cl_2), chlorine dioxide (ClO_2), acidified sodium chlorite ($NaClO_2$), sodium hypochlorite ($NaClO$), calcium hypochlorite ($Ca(ClO)_2$), hypochlorous acid ($HClO$)

Quaternary Ammonium Compounds

- Also known as QACs or "quats"
- Commonly added to pharmaceutical, personal hygiene and environmental sanitation products
- Amphiphilic molecules that disrupt and damage cell membranes
- Effective against fungi, viruses and bacteria (mostly G+s)
- More effective at higher temperatures
- Effectiveness reduced by organic matter and hard water
- Cetylpyridinium chloride (CPC), a cationic QC, approved in U.S. "to treat the surface of raw poultry carcasses or giblets, or raw poultry parts (skin-on or skinless)"

Ozone

- O_3 – unstable, colorless, gas that occurs naturally
- Created by exposing O_2 to electrical discharges or UV radiation
- Effective against bacteria, fungi, viruses and spores
- Effectiveness reduced by pH, temperature, organic matter and salt (≥ 2.5%)
- Many studies have looked at O_3 use for carcass decontamination
- Effectiveness is debatable; may work better in combination with other antimicrobials
- Strong oxidizer; exposure by humans can cause uncomfortable side effects (irritation of eyes and skin, headaches)
- Approved in U.S. for use in all meat and poultry products in accordance with good manufacturing practices

Peroxides and Peroxyacids

- Primarily hydrogen peroxide (H_2O_2) & peroxyacetic acid (PAA)
- Decomposition of H_2O_2 generates hydroxyl radicals (•OH) that can damage cell membranes and DNA
- PAA acts in similar way
- Effective against bacteria, fungi, viruses and spores
- Effectiveness is enhanced by acidic pH, high temperatures and absence of organic matter
- H_2O_2 may cause bleaching of meat tissue, so PAA might be preferred
- Not as effective as other antimicrobials (e.g., lactate)
- In U.S. both approved for use together in combination with other antimicrobials for decontamination of carcasses and carcass parts, and chiller water

Antagonistic Cultures

- Lactic Acid Bacteria (LAB) typically produce antimicrobials such as:
  - Organic acids, hydrogen peroxide (H_20_2), diacetyl, ethanol, free fatty acids
- Some produce bacteriocins
  - *Lactobacillus sakei*, *L. curvatus*, *L. plantarum*, *L. brevis*, *L. casei*
  - Bacteriocin-producing pediococci
- Bacteriocins
  - Positively-charged peptides that kill gram-positive bacteria by interacting with anionic phospholipids of their cell membranes

Bacteriocins

- Isolated and purified from LAB fermentation
- Advantages
  - Can be used when fermentation conditions are not desired
  - Permit more exact dosification
- Only nisin is approved in meats in the U.S.
- Pediocin and natamycin have also been used in food

Lactoferrin

- Iron-binding transferrin protein
- Commercially obtained from whey protein
- Effective against bacteria, fungi and viruses
- Approved in U.S. for decontamination of beef carcasses and parts

Lysozyme

- Muraminidase enzyme
- Commercially obtained from milk and egg white albumin
- Disrupts cell wall in gram-positive bacteria
- By itself, ineffective against gram-negative bacteria
- Activity can be enhanced by combining with other antimicrobials
- Approved in U.S. in casings and on cooked RTE meat and pultry products

Plant Extracts and Essential Oils

- Efficacy demonstrated in extracts and essential oils obtained from various plants, such as rosemary, oregano, sage, cinnamon, cloves, thyme, allspice, basil coriander, nutmeg
- General susceptibility
  - Fungi > gram + bacteria > gram – bacteria
- Efficacy can be affected by high protein and fat
- Efficacy favored by low a_w, high NaCl, organic acids
- Chemical types:
  - Phenols: eugenol, isoeugenol, carnosol, rosmanol, isorosmanol, rosmarinic acid, borneol
  - Aldehydes: cinnamaldehyde
  - Terpenes: thymol, carvacrol
  - Thiosulfinates: allicin

Others

- Smoke
- Bacteriophages
- Acidified calcium sulfate
  - Demonstrated effectiveness against *L. monocytogenes* in RTE products
- Epsilon-Polylysine
  - Fermentation by-product of *Streptomyces albulus*
- Chitosan
  - Derived from chitin via deacetylation

Muito obrigado

Perguntas?