Natural Antimicrobials: Strategies & Considerations for Their Use in Food

Jairus David, Ph.D.
Natural Antimicrobial Program
Research & Innovation, ConAgra Foods, Inc.
Omaha, Nebraska 68102

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1. Preservatives
2. Antimicrobials
3. Using Antimicrobials in Food - A Food Industry Perspective
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Preservatives
Preservatives

Antimicrobials  Antioxidants  Antibrowning

Food Additives, 2nd Edn.
Preservatives

Antimicrobials
- To Check or Prevent the Growth of Microorganisms - Spoilage & Food Safety
  - Sorbate, Benzoate, Propionate

Antioxidants
- To Prevent Lipid and/or Vitamin or Color Oxidation in Foods
  - BHA, BHT, Citric acid

Antibrowning
- To Prevent Both Enzymatic & Non-Enzymatic Browning in Foods
  - Vitamins C & E, Citric acid
Preservatives

- **INDIRECT**: Added by Vendor
- **DIRECT**: Added by Food Manufacturer
- End User Must **Label** Both Indirect & Direct Preservatives
- Not Used for **Masking** Poor Practices and Poor GMPs

- Preservatives
- Antimicrobials
- Antioxidants
- Antioxidants: To Check or Prevent the Growth of Microorganisms - Spoilage & Food Safety
  - To Prevent Lipid and/or Vitamin or Color Oxidation in Foods
  - To Prevent Both Enzymatic & Non-Enzymatic Browning in Foods

- Sorbate, Benzoate, Propionate
- BHA, BHT, TBHQ
- Vitamins C & E, Citric acid
2

Antimicrobials
What & Why - Antimicrobials?

- **Ingredients or Natural Extracts that can**
  - Slows the Growth
  - Kills
  - Lactate/diacetate is an example of antimicrobial used in meats to limit the growth of *Listeria monocytogenes*

- **Business Opportunity to use natural antimicrobials to**
  - Assure/Extend Shelf Life
  - Reduce Pathogen Risk
  - Meet Consumer Demand for Minimally Processed RTE High Quality Foods
  - Replace Synthetic/Chemical Preservatives with Natural Clean Label Antimicrobials
Conversion Process

**Raw Materials**
- Reduce or Eliminate Microorganisms (spoilage & Pathogens)
- Access to Food

**Factory**
- Microbial Inactivation Process (Kill Step)

**Retail Consumer**
- Procedures that prevent growth or Slow down Microbial growth
Where?

- **Raw Materials**: Reduce or Eliminate Microorganisms Access to Food
- **Factory**: Microbial Inactivation Process (Kill Step)
- **Retail Consumer**: Procedures that prevent growth or Slow down Microbial growth (Kill Step or Direct &/ or Indirect)

**Indirect**
- **Direct**
  - Pre-Kill
  - and/or Post-Kill
The Big Picture

Raw Materials
- Farm
- Animal Husbandry
- Fisheries
- Handling
- Decontamination
- Storage/Handling

Factory
- Reduce or Eliminate Microorganisms Access to Food
  - Indirect
- Microbial Inactivation Process
  - Kill Step
    - (Direct: Pre-Kill and/or Post-Kill)

Retail Consumer
- Storage, handling
- Cooking instructions
- Open containers

Procedures that prevent growth or Slow down Microbial growth
  - (Direct & Indirect)
Food Safety  → Public Health Safety
(Data for USA)

• 48 million cases of illness
• 128,000 hospitalizations
• 3000 deaths

CDC, 2011
Global Food Loss

- 80% Production to Retailing
- 20% Consumer

1.3 billion tonnes = 1,300,000,000,000 Kg
2,866,000,000,000 Pounds

CAST, 2016
Council for Agricultural Science & Technology, Ames, Iowa
Global Food Loss

1,3 billion tonnes = 1 300 000 000 000 Kg
2 866 000 000 000 Pounds

= 1 Trillion USD
= Feed 2 Billion People
= 2050
9.2 Billion People

- 80% Production to Retailing
- 20% Consumer
3

The Food Industry Approach for Using Antimicrobials in Foods
Questions We Must Answer

Does it work?

Can I Use it?

Cost?
Questions We Must Answer

Does it work?
- Efficacy in Food
- Sensory Impact
- Regulatory limit

Can I Use it?
- Clean Label
- GRAS/Tox Data
- Ingredient Patents & Food Use-Patents

Cost-in-Use?
- Upcharge/Case
- Capital Cost
Need to Pair!

**FOOD**
- Savory-Sweet-Neutral Foods
- pH & pKa Classification: <5.0, 5.8-6.2, >7
- Partition Coefficient – Formulation, Fat, Proteins, Gums, CMC, TiO2
- aW
- Adding Natural Antimicrobial does not make the entire product natural

**Antimicrobials**
- Narrow Spectrum
- Gram +ve Bacteria - Vegetative vs. Spores
- Gram –ve
- Yeast & Mold
- Acid & Preservative (Sorbate) Resistant Yeasts

Adding Natural Antimicrobial does not make the entire product natural.
Back to Basics
(Regulatory Definitions)

Antimicrobials
• FDA (21 CFR 170.3 (0) (2))
• USDA FSIS (9 CFR 430.1)

Natural Antimicrobials
• FDA – No Definition yet, Proposed Rule & Comment Period
• USDA - 21 CFR 101.22 ((1982) (Vinegar & Lemon Juice)

Clean Label
• FDA & USDA – Not defined

Defined by Retailers & Restaurants (Whole Foods or Trader Joe’s, Panera Bread)
• = Natural ingredients
• = Common Names
• = Fewer Ingredients
• ≠ Chemicals
• = “Free-from”
• = 3 No’s
Voice of Customer (VOC)

• About ½ do not know about preservatives
• Most Consumers accept that preservatives are necessary
• Around ½ of consumers claim they would pay more for natural preservatives in most food products
• Consumers liked natural or clean label, but did not want to pay higher price at the retail (POS)

Natural Preservatives – A Consumer Perspective
Food Ingredients European Conference, 2013

Clean Label Rules, But Confusion Reigns
Elizabeth Sloan, Food Technology, September, 2015
My Antimicrobial Toolbox

"NATURAL"

Classical Chemical Preservatives

Organic Acids & Salts
- Sorbate
- Benzoate
- Propionate
- Lactate
- Diacetate
- Citrate
- Nitrate/Nitrite

Bacteriocins
- Nisin
- Pediocin
- Natamycin (Bisin?)

Live Cultures
- Lactic Starter Culture
- Pediococcus
- Probiotics
- Yeast Spray
- Bacteriophage (Processing Aid)

Fermentates
- Cultured Cane Sugar
- Cultured Sugar with Vinegar
- Cultured Dairy
- Cultured Wheat Starch

Natural Ingredients
- Plant & Animal Extracts
  - Celery extract
  - Cherry Powder
  - Rosemary
  - Vinegar
  - Essential Oils
  - Phyto-Phenols
  - Bioflavonoids
  - Lysozyme

"CLEAN LABEL"

Organic Acids & Salts
- Sorbate
- Benzoate
- Propionate
- Lactate
- Diacetate
- Citrate
- Nitrate/Nitrite

These are perfectly safe!!!!

- HPP (No Labeling needed)
**STAGE GATE for Achieving Due Diligence**

**Phase 1: DISCOVERY & PROOF OF CONCEPT**
- **Antimicrobial Efficacy Against Target Spoilage or Pathogenic Microorganisms**
- **Initial Screen of Efficacy in Microbiological Media**
  - Patent Landscape & Intellectual Property Review:
    - Technology & Ingredient Patents
    - Ingredient Lock Out or Ingredient Use Patents
- **Microbiological Media**
  - MIC, MLC, FIC, FLC
  - <1 log reduction - Failure
  - 1-3 log reduction – review other good traits – polarity, pKa, sensory, GRAS, etc.
  - 4-5 log reduction - Pursue
- **Simple Food Models**
  - Cidal or Stasis Effects
  - **Juice:** similar to media
  - **Milk:** 2-4 log reduction
  - Lag phase increase - Inhibition 1 to 2 times the targeted shelf life
- **Delivery System:** Additive, Synergistic, Antagonistic

**Phase 2: TECHNOLOGY DEVELOPMENT**
- **Study Efficacy in Simple Food Models**
  - Test Method for “Active” in Antimicrobial
  - Cost
  - Sensory Product Cutting
  - Commercially Available
  - Regulatory Assessment
- **Technical Success Criteria**
  - Delivery System: 10-1,000X efficacy compared to control

**Phase 3: TECHNOLOGY TRANSFER SCALE-UP & COMMERCIALIZATION**
- **Verify Antimicrobial Efficacy in Complex Food Matrices**
  - GRAS Status
  - Regulatory & Labeling
  - Sustainable Supply
  - Delivery System
  - Formal Sensory & Shelf Life Tests
- **Complex Food Matrix**
  - **Challenge Study**
  - 1-2 log reduction
  - Inhibition 1.5 to 2 times the targeted shelf life (stasis)
- **Qualification, Validation & Implementation**
  - 2-3 Scale-up runs
  - 1-2 Plant trials
- **Efficacious Antimicrobial in Food Matrix for Requisite Food Protection at Optimal Product Cost Structure**
Expectations and Applications of Natural Antimicrobials to Foods: A Guidance Document for Users, Suppliers, Research and Development, and Regulatory Agencies

Process for Achieving Due Diligence – PHASE 1

**Phase 1: DISCOVERY & PROOF OF CONCEPT**

- **Single or Combination Antimicrobials**
- **Odor & Taste in Food (Prospective)**

Antimicrobial Efficacy Against Target Spoilage or Pathogenic Microorganisms

**Initial Screen of Efficacy in Microbiological Media**

**Microbiological Media**
- MIC, MLC, FIC, FLC
- ≤1 log reduction - Failure
- **2-4 log reduction** – Pursue other good traits – polarity, pKa, sensory, GRAS, etc.

Efficacious Antimicrobial in Food Matrix for Requisite Food Protection at Optimal Product Cost Structure
**Process for Achieving Due Diligence – PHASE 2**

**Phase 1: DISCOVERY & PROOF OF CONCEPT**
- Odor & Taste in Food (Prospective)
- Single or Combination Antimicrobials

**Antimicrobial Efficacy Against Target Spoilage or Pathogenic Microorganisms**

**Initial Screen of Efficacy in Microbiological Media**

**Technical Success Criteria**
- Microbiological Media
  - MIC, MLC, FIC, FLC
  - <1 log reduction - Failure
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**Phase 2: TECHNOLOGY DEVELOPMENT**
- Sensory Product Cutting (Concurrent)
- Business Case & Cost Justification
- Test Method for “Active” in Antimicrobial
- Commercially Available
- Regulatory Assessment

**Business Decision Criteria**
- Process for Achieving Due Diligence – PHASE 2

**Patent Landscape & Intellectual Property Review:**
- Technology & Ingredient Patents
- Ingredient Lock Out or Ingredient Use Patents
- Freedom to Practice Current Art

**Simple Food Models**
- Cidal or Stasis Effects
- Juice: similar to media
- Milk: 2-3 log reduction
- Lag phase increase - Inhibition 1 to 2 times the targeted shelf life

**Efficacious Antimicrobial in Food Matrix for Requisite Food Protection at Optimal Product Cost Structure**
Process for Achieving Due Diligence – PHASE 3

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  - **Juice**: similar to media
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  - Lag phase increase - Inhibition 1 to 2 times the targeted shelf life
- **Combination**: Additive, Synergistic, Antagonistic
- **Delivery System**: 10-1,000X efficacy compared to control

Phase 2: TECHNOLOGY DEVELOPMENT
- **Study Efficacy in Simple Food Models**
- **Testing Method**
  - for “Active” in Antimicrobial Available
  - Sensory Product
  - Business Case & Cost Justification
- **Cost**

Phase 3: TECHNOLOGY TRANSFER SCALE-UP & COMMERCIALIZATION
- **Verify Antimicrobial Efficacy in Complex Food Matrices**
- **Target Food Matrix**
  - **Challenge Study**
  - 1-2 log reduction
  - Inhibition 1.5 to 2 times the targeted shelflife (stasis)
- **Qualification, Validation & Implementation**
  - 1-2 Pilot Plant Scale-up runs
  - 1-2 Plant trials
- **Patent Landscape & Intellectual Property Review**
  - Technology & Ingredient Patents
  - Ingredient Lock Out or Ingredient Use Patents
- **Formal Sensory & Shelf Life Tests**
- **Cost-In-Use**
- **Change Management**
- **Delivery System**
Example 1: Cost-in-Use

Bottom line:
50-100x more expensive for use of Natural Antimicrobial Clean Label version compared to Chemical version, for same structure-function

Basis: 300-400 gram product, 60 ppm nitrite

- **Natural Clean Label Antimicrobial**
  Cost per pound of Cultured Celery Juice Powder: $25.63
  Cost-in-use would be approx 1.2 g to deliver 60ppm nitrite. This would result in approx **6-7 cents** in cost per 300-400 g

- **Approved Chemical Antimicrobial**
  Cost per pound for nitrite is **$0.60**
  Cost-in-use approx 0.43 g to deliver 60 ppm nitrite. This would result in approx $0.00057 (**0.06 cent**) in cost per 400 g
Example 2: Unintended Consequence

*Eurotium chevalieri* on CY20S agar plate

*E. Chevalieri* growth on a model cereal bar

CONTROL

Syneresis of fruit core

**Added antimicrobial should work with the current process parameters & formulation**
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Phase 1: DISCOVERY & PROOF OF CONCEPT
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- Odor & Taste in Food

Phase 2: TECHNOLOGY DEVELOPMENT
- Cost
- Sensory Product
- Business Case & Cost Justification

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- Cost-In-Use
- Formal Sensory & Shelf Life Tests

Efficacious Antimicrobial in Food Matrix for Requisite Food Protection at Optimal Product Cost Structure

Business Decision Criteria
- STAGE GATE for Achieving Due Diligence
- Delivery System: Additive, Synergistic, Antagonistic
- 10-1,000X efficacy compared to control
Think......

Does it work?

Can I Use it?

Cost?
Recap

Does it work?
- Efficacy in Food
- Sensory Impact
- Regulatory limit ≠

Can I Use it?
- Clean Label
- GRAS/Tox Data
- Ingredient Patents & Food Use-Patents

Cost-in-Use?
- Upcharge/Case
- Capital Cost
The Big Picture

Raw Materials
- Farm
- Animal Husbandry
- Fisheries
  - Handling
  - Decontamination
  - Storage

Factory
- Microbial Inactivation Process
  - (Kill Step)
  - (Direct: Pre-Kill and/or Post-Kill)

Retail Consumer
- Storage, handling
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Reduce or Eliminate Microorganisms Access to Food
  - Indirect

Procedures that prevent growth or Slow down Microbial growth
  - (Direct & Indirect)
Case for Continual Use of Preservatives

Global Food Loss

- 80% Production to Retailing
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USA Public Health Safety

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1,3 billion tonnes =
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So, What Did We Learn?
**KEY TAKEAWAYS**

- Preservatives are good
- Consumers Want Natural/ Clean Label Preservatives
- Food Industry is Continuing to Develop Antimicrobial Tool Box
- Steps for Adding Antimicrobials to Foods— NOT SIMPLE
- Natural & Clean Label Not Defined by Regulators
FUTURE PROSPECTS

- Stronger Partnership: University-Vendor-Food Industry User-Regulatory Agencies-Consumer
- Antimicrobials for Fresh-like “Minimally Processed Foods”
- Bacteriocins for Gram negative Bacteria
- Effective preservative in the pH range 5-7
IFT Annual Meeting, July 16-19, 2016, Chicago,

Organizers:
Jairus David, Senior Principal Research Scientist, ConAgra Foods, Inc.
Dr. P. Michael Davidson, Institute Professor, University of Tennessee

Speakers

Jairus David, Senior Principal Research Scientist, ConAgra Foods
Dr. Lu Ann Williams, Director of Innovation, Innova Market Insights
Dr. Patrick Lesueur, Global Open Innovations Director, Unilever Innovation
Dr. Jennifer McEntire, Vice President of Science Operations, Grocery Manufacturer’s Association, Washington, DC
Dr. Mickey Parish, Senior Advisor for Microbiology, US Food and Drug Administration, Washington, DC
Dr. P. Michael Davidson, Institute Professor, Department of Food Science and Technology, University of Tennessee

Achieving a “Clean Label” While Maintaining the Quality and Safety of Your Product, Is It Possible? Part 1 & 2