Application of Natural Antimicrobials in Food: Food Industry User Perspective

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FAPC/IFT-OK Research Symposium - Keynote Presentation

Food & Agricultural Products Center

Oklahoma State University, Stillwater, OK 74078

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Food Industry User Perspective

Jairus David
Larry Steenson
& Michael Davidson

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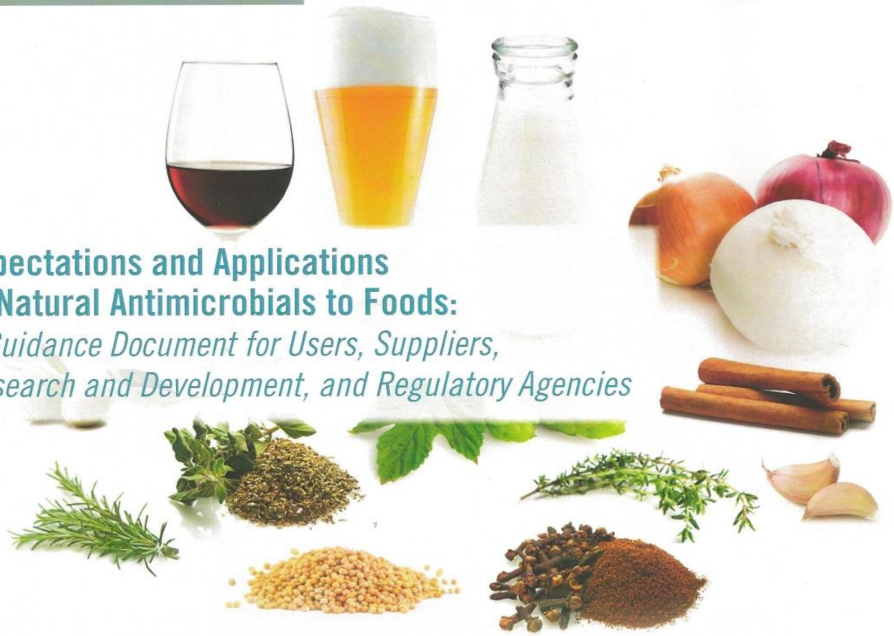

Expectations and Applications of Natural Antimicrobials to Foods:

A Guidance Document for Users, Suppliers, Research and Development, and Regulatory Agencies

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ABSTRACT

Efficient use of natural antimicrobials in food is predicated on the proper implementation of hurdle technology. These substances are meant to increase the robustness of existing food safety or quality assurance programs, not to correct or mask poor practices. The objective of this paper is to outline the important aspects of application of natural antimicrobials to foods, including selection of antimicrobial, determination of target microorganisms, efficacy testing against target microorganisms in vitro and in foods, and issues that must be addressed in the commercial application of the antimicrobial. Because natural antimicrobials are secondary hurdles, expectations of them must be realistic, and considerations should include other aspects, such as effect on sensory and quality attributes of the food, cost (and cost-in-use) of the antimicrobial, and regulatory and labeling considerations, in addition to efficacy against target microorganisms in the food matrix. The "idea-to-launch" business framework and governance is recommended for pairing of a potential antimicrobial with a complex food matrix, along with clearly defined objectives, inputs, outputs, and technical success criteria and business decision criteria. To help quantify the benefits of hurdles, including antimicrobials, we propose use of the "Food Protection Objective" (FPO), which is defined as the acceptable level of microbiological quality and/or safety at the moment of consumption or at the end of shelf life of a food.

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International Association for Food Protection.

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What are Antimicrobials?

- **Naturally Occurring Ingredient or Extract that**
  - → Slows the Growth
  - → Kills

  Pathogens & spoilage organisms

Lactate/diacetate is an example of antimicrobial used in meats to control *Listeria monocytogenes*

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

Manufacturing Process

Food Preservation - PURPOSE

Front Door → Factory → Retail Consumer

Purpose

- **Stabilize the food (Extend Shelf life)**
- **Ensure Food Safety**
- **Preserve Quality**
- Cooking

Raw Material

Conversion Process
-Value-add

Shelf Life
-Fresh - F&V, S
-Ambient
-Frozen
-Refrigerated

Food Preservation - DIMENSIONS

Front Door → Factory → Retail Consumer

Front Door: Reduce or Eliminate Microorganisms Access to Food

Factory: Microbial Inactivation Process

Retail Consumer: Procedures that prevent growth or Slow down Microbial growth

Food Preservation - WHY?

- Farm
- Animal Husbandry
- Fisheries

-Handling, surface decontamination, storage

Front Door → Factory → Retail Consumer

- Storage, handling
- Cooking instructions
- Open containers

Reduce or Eliminate Microorganisms Access to Food

Microbial Inactivation Process

Procedures that prevent growth or Slow down Microbial growth

- **48 million cases of illness**
- **128,000 hospitalizations**
- **3000 deaths**

CDC, 2011

- **31% of the available food supply at the retail and consumer levels was NOT consumed**
- **= $162 billion.** (Buzby et al, 2014, USDA)

Food Preservation - De[tails]

- Farm
- Animal Husbandry
- Fisheries

-Handling, surface decontamination, storage

...Materials → Factory → Retail Con...er

- Storage, handling
- Cooking instructions
- Open containers

- **Quality is Conserved**
- **Safety is Not Compromised**

Red...

Mi...
Access ...

...prevent
...low down
...l growth

Bio-P...

Incoming Ingredient Specifications
-RAC
-Meat
-Powder, Liquid, Solid

DRYING
IRRADIATION
HEAT PASTEURIZATION & CHILLED
FROZEN
Antimicrobials

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...NING
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...EPTIC
...LASH-18

HPP

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...tion
LOW... pH
LOWERI... aW
-Curing
-Drying
TANAKA MODEL
FERMENTATION
MAP
ADDITION OF ANTIMICROBIALS

Food Preservation Continuum – The Context for Use of Antimicrobials

Front Door → Factory → Retail Consumer

Reduce or Eliminate Microorganisms Access to Food

Bio-Burden

Incoming Ingredient Specifications
-RAC
-Meat
-Powder, Liquid, Solid

DRYING
IRRADIATION
HEAT PASTEURIZATION & CHILLED
FROZEN

Microbial Inactivation Process

-Thermal
Sterilization
Pasteurization

-Non-thermal
-Combination

CANNING
HOT-FILL-HOLD/COOL
ASEPTIC
FLASH-18

Procedures that prevent growth or slow down Microbial growth

AMBIENT SHELF STABLE

LOWERING TEMPERATURE
-Frozen
-Refrigeration
LOWERING pH
LOWERING aW
-Curing
-Drying
TANAKA MODEL
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ADDITION OF ANTIMICROBIALS

What are Natural Antimicrobials?

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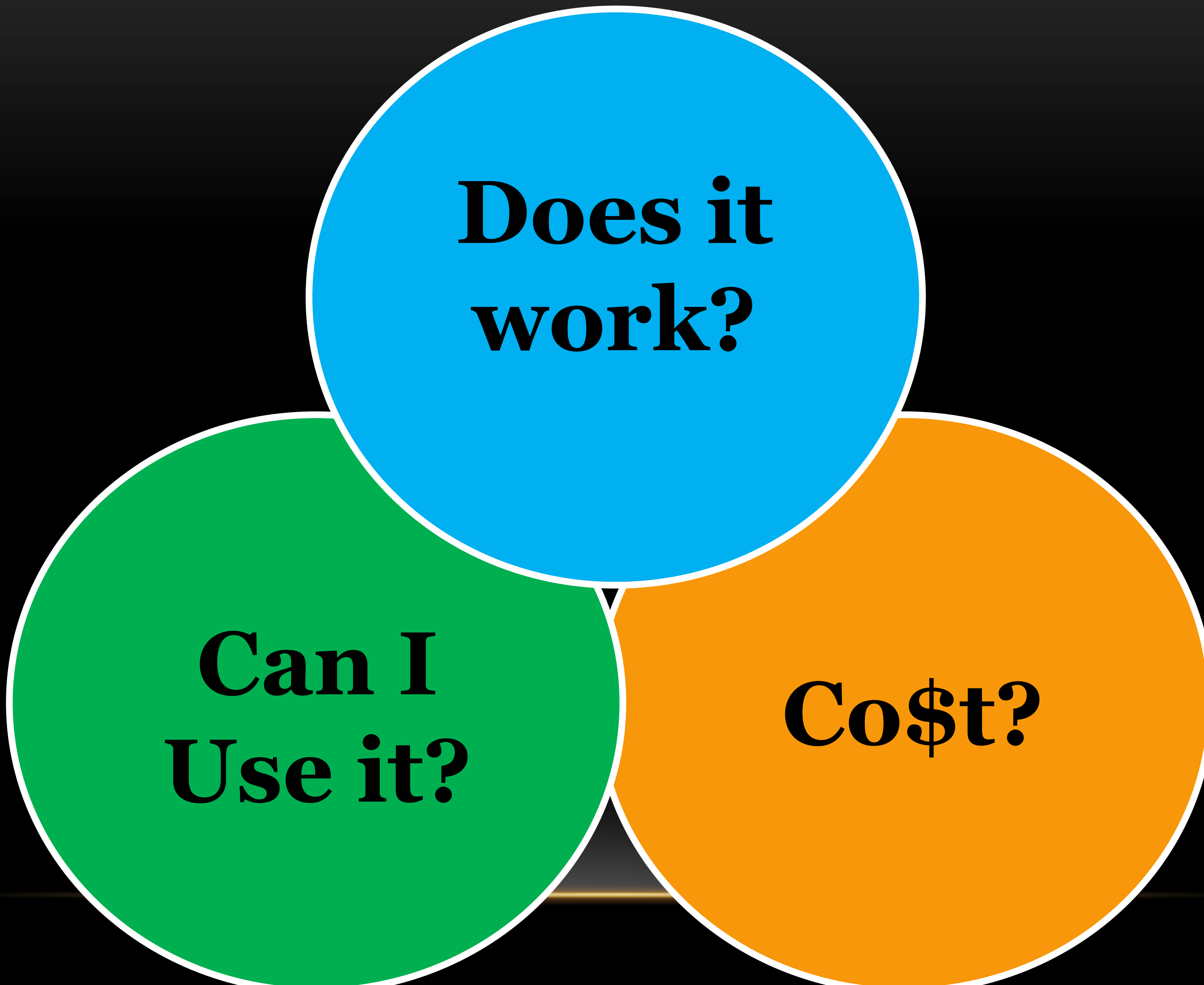
  - Replace Synthetic Preservatives with Natural Clean Label Antimicrobials

Questions We Must Answer



Natural Antimicrobials

Does it work?

- Efficacy in Food
- Sensory Impact
- Regulatory limit

≠

Can I Use it?

- Clean Label
- GRAS/Tox Data
- Use-Patents

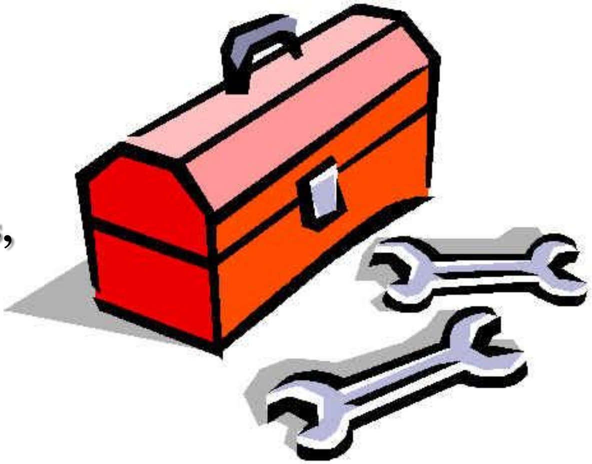
Cost-in-Use?

- Upcharge/Case
- Capital Cost

There is No Silver Bullet

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

1. **Natural ingredients**
   Celery Juice Powder, Cherry Powder, Rosemary Extract, Plant Essential Oils
2. **Fermentates**
   Natural & Clean Label: Cultured Cane Sugar, Cultured Sugar with Vinegar, Cultured Wheat Starch
3. **Bacteriocins**
   Nisaplin; non yet for Gram negative bacteria
4. **Live cultures**
   Lactic acid bacteria, Pediococcus, and yeast spray

Antimicrobial Toolbox

NATURAL

CLEAN LABEL

Classical Chemical Preservatives

Organic Acids & Salts

- **Sorbate**
- **Benzoate**
- **Lactate**
- **Diacetate**
- **Citrate**
- **Nitrate/Nitrite**
- (NaCl)
- (Organic acids)

Bacteriocins

- **Nisin**
- Pediocin
- **Natamycin**
- (Bisin)

Live Cultures

- **Lactic Starter Culture**
- **Pediococcus**
- Probiotics
- **Yeast Spray**

Fermentates

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

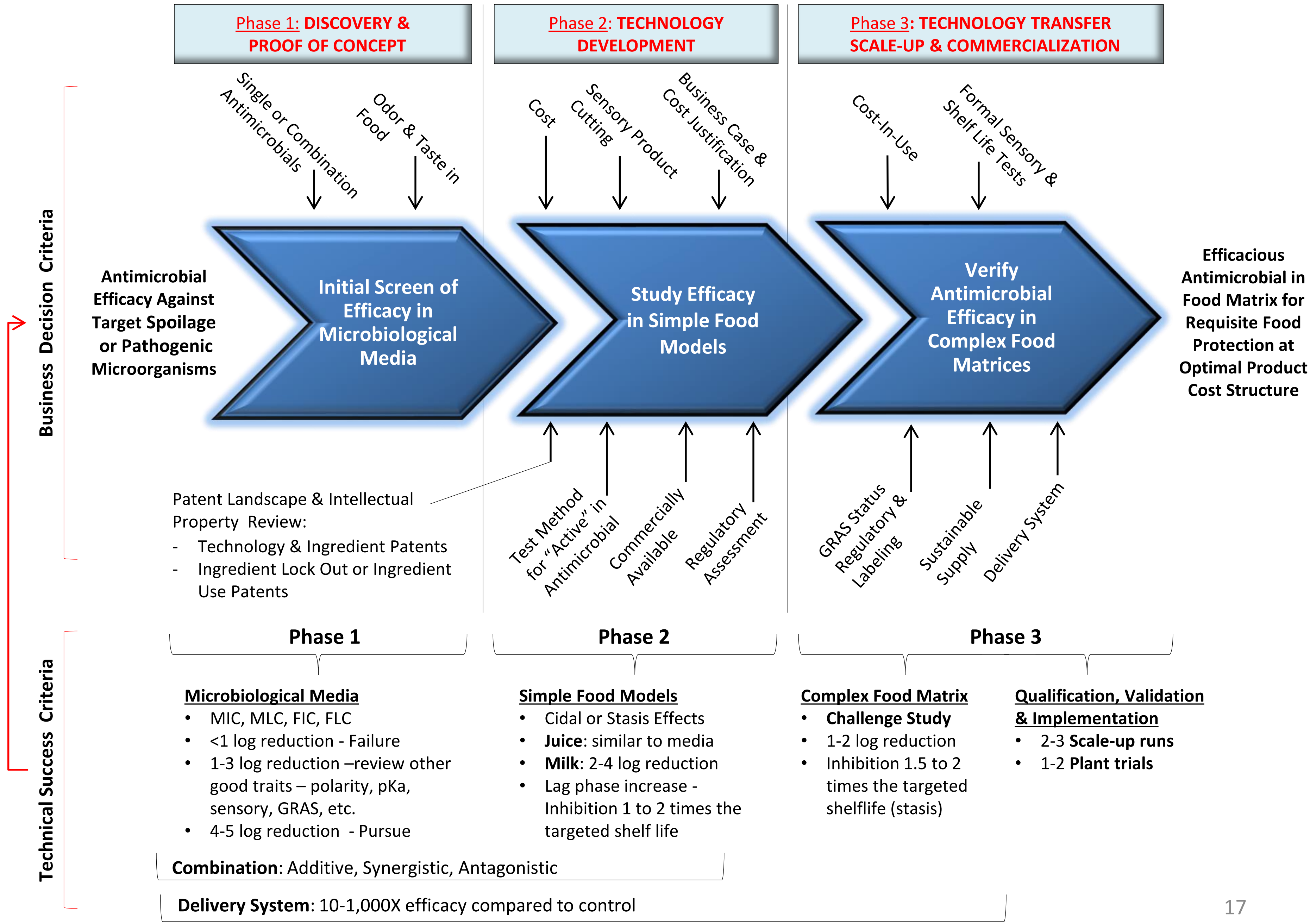
Natural Ingredients

Plant & Animal Extracts

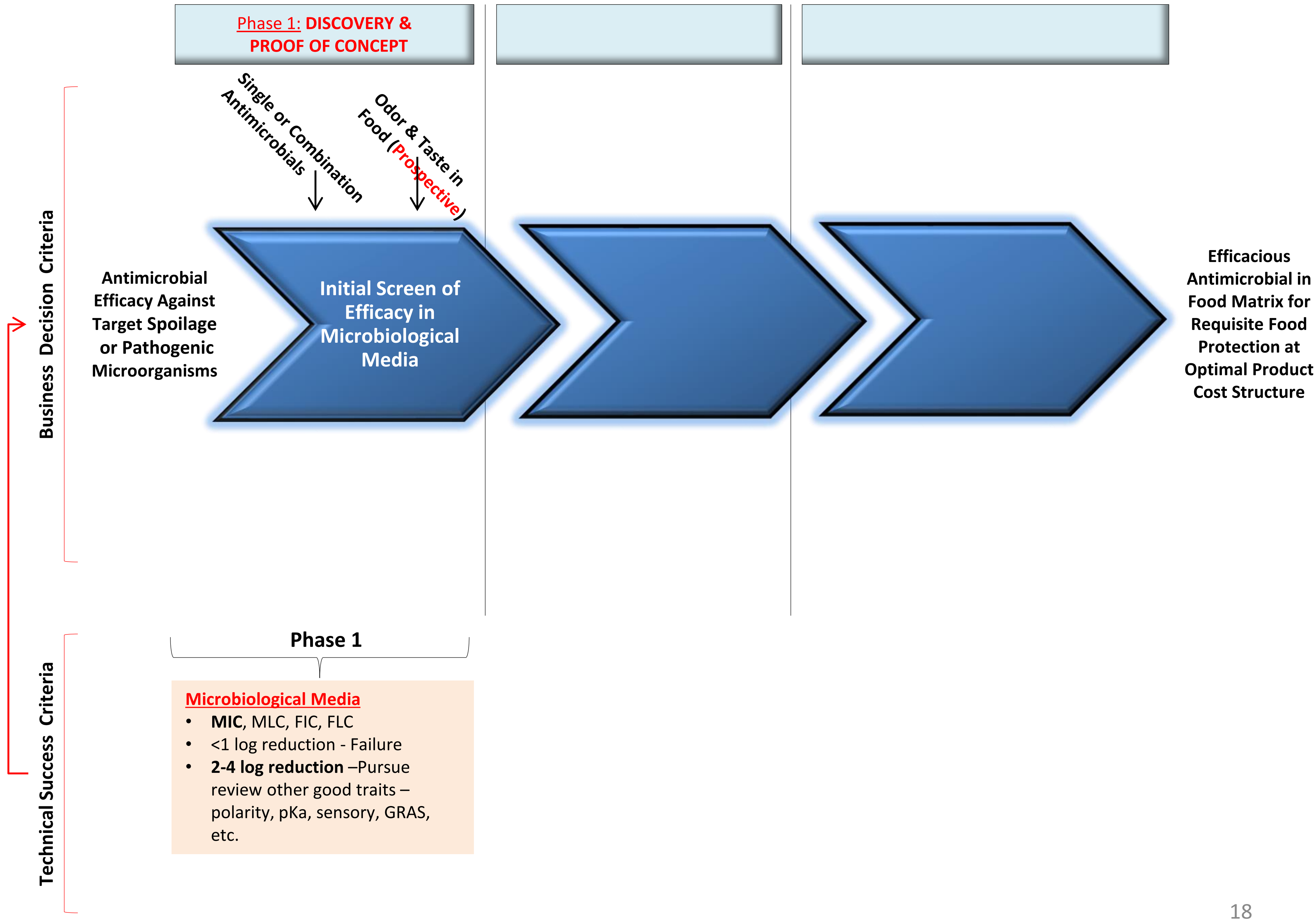
- **Celery extract**
- **Cherry Powder**
- **Rosemary**
- **Vinegar**
- Essential Oils (WMEO)
- Phyto-Phenols
- Bioflavonoids
- Lysozyme

The "Hate List"

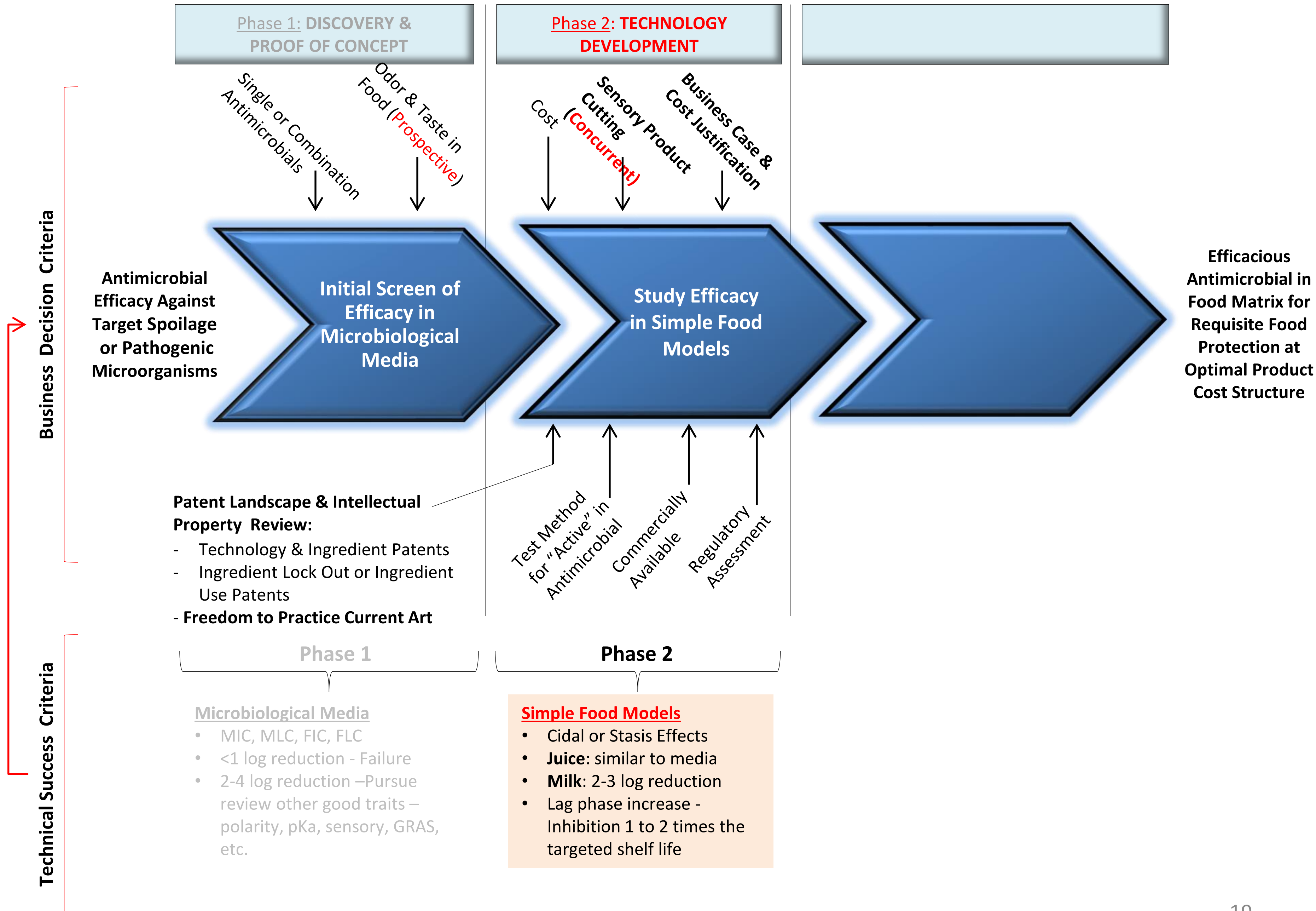
STAGE GATE for Achieving Due Diligence



Process for Achieving Due Diligence – PHASE 1



Process for Achieving Due Diligence – PHASE 2



Future Prospects

1. Stronger Partnership: University-Vendor-User
2. Bacteriocins for Gram negative Bacteria
3. Effective preservative in the pH range of 5-7
4. Standardization of Efficacy Determination
5. Delivery system
6. Influence on Natural Microflora

Antimicrobial Toolbox – PRICE LIST

NATURAL

Classical Chemical Preservatives

CLEAN & LABEL

Organic Acids & Salts	Bacteriocins	Live Cultures	Fermentates	Natural Ingredients
• **Sorbate** • **Benzoate** • **Lactate** • **Diacetate** • **Citrate** • **Nitrate/Nitrite** • (NaCl) • (Organic acids)	• **Nisin** • Pediocin • **Natamycin** • (Bisin)	• **Lactic Starter Culture** • **Pediococcus** • Probiotics • **Yeast Spray**	• **Cultured Cane Sugar** • **Cultured Sugar with Vinegar** • **Cultured Dairy** • **Cultured Wheat Starch**	**Plant & Animal Extracts** • **Celery extract** • **Cherry Powder** • **Rosemary** • **Vinegar** • Essential Oils (WMEO) • Phyto-Phenols • Bioflavonoids • Lysozyme

Chemical: 0.01 to 1 cent/lb of finished product

Natural: 2 to 8-10 cents/lb of finished product

Q: If an ingredient is $10.00/lb. If your use level is 1% in finished product.

A: Then the cost-in-use will be 10 cent/lb of finished product

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

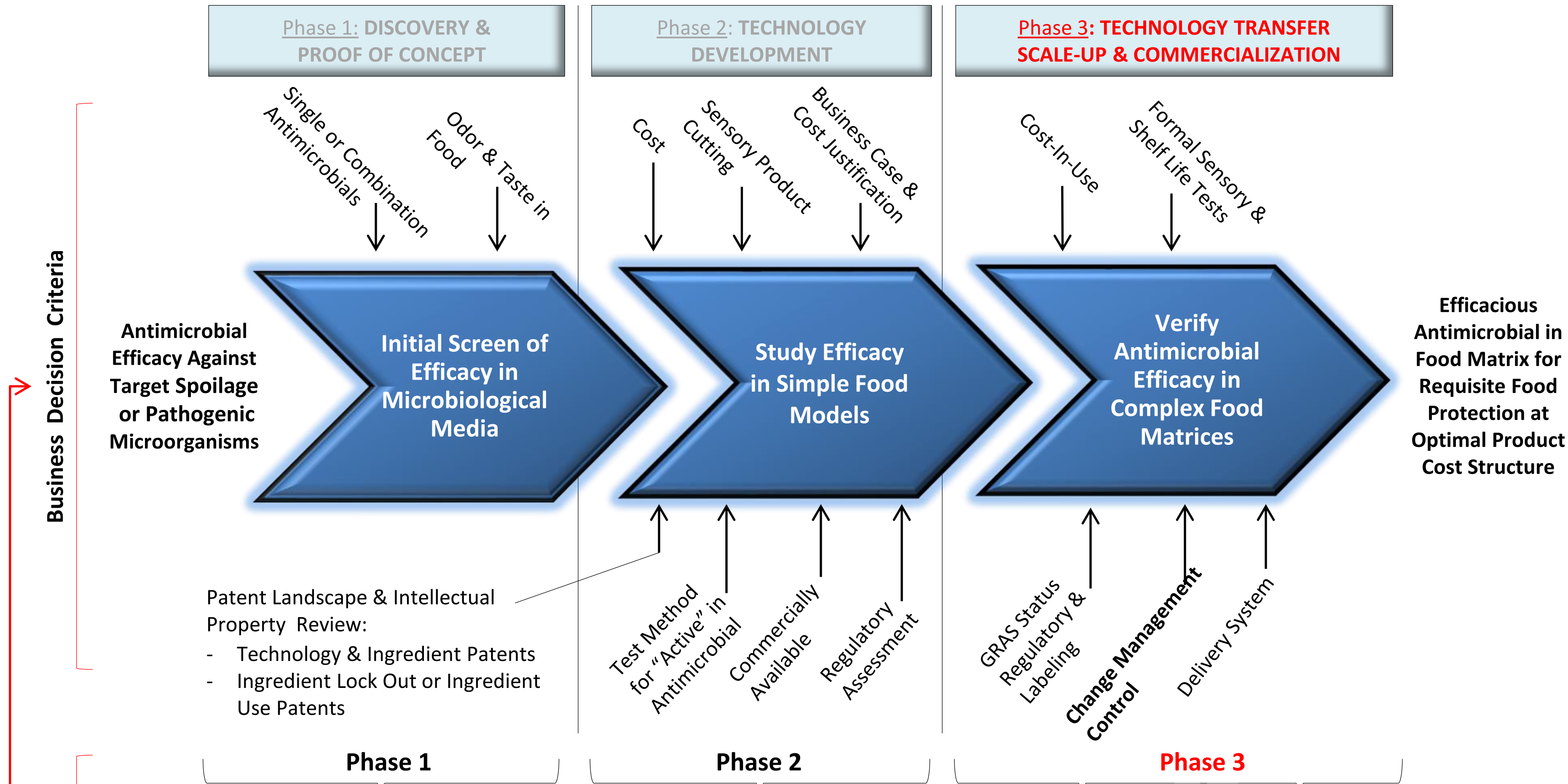
- **Natural Clean Label Antimicrobial**

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

Process for Achieving Due Diligence – PHASE 3



Technical Success Criteria

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

Target Food Matrix

- **Challenge Study**
- 1-2 log reduction
- Inhibition 1.5 to 2 times the targeted shelflife (stasis)

Qualification, Validation & Implementation

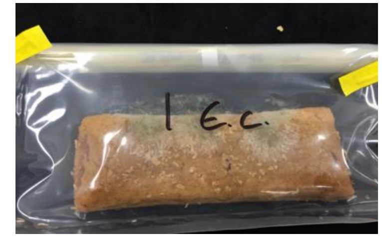
- **1-2 Pilot Plant** Scale-up runs
- 1-2 **Plant trials**

Combination: Additive, Synergistic, Antagonistic

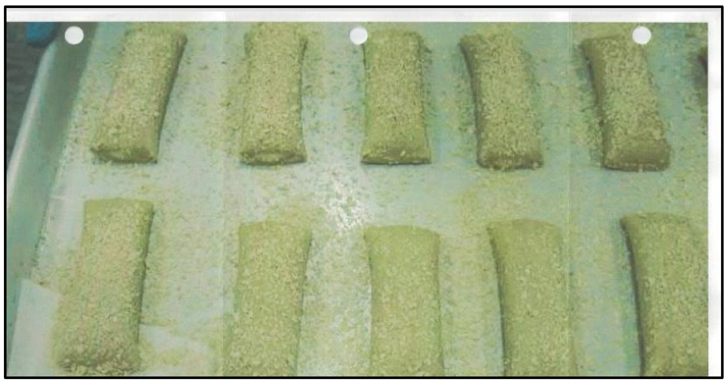
Delivery System: 10-1,000X efficacy compared to control

Example 2: Unintended Consequence

Eurotium chevalieri on CY20S agar plate



E. Chevalieri growth on a model cereal bar



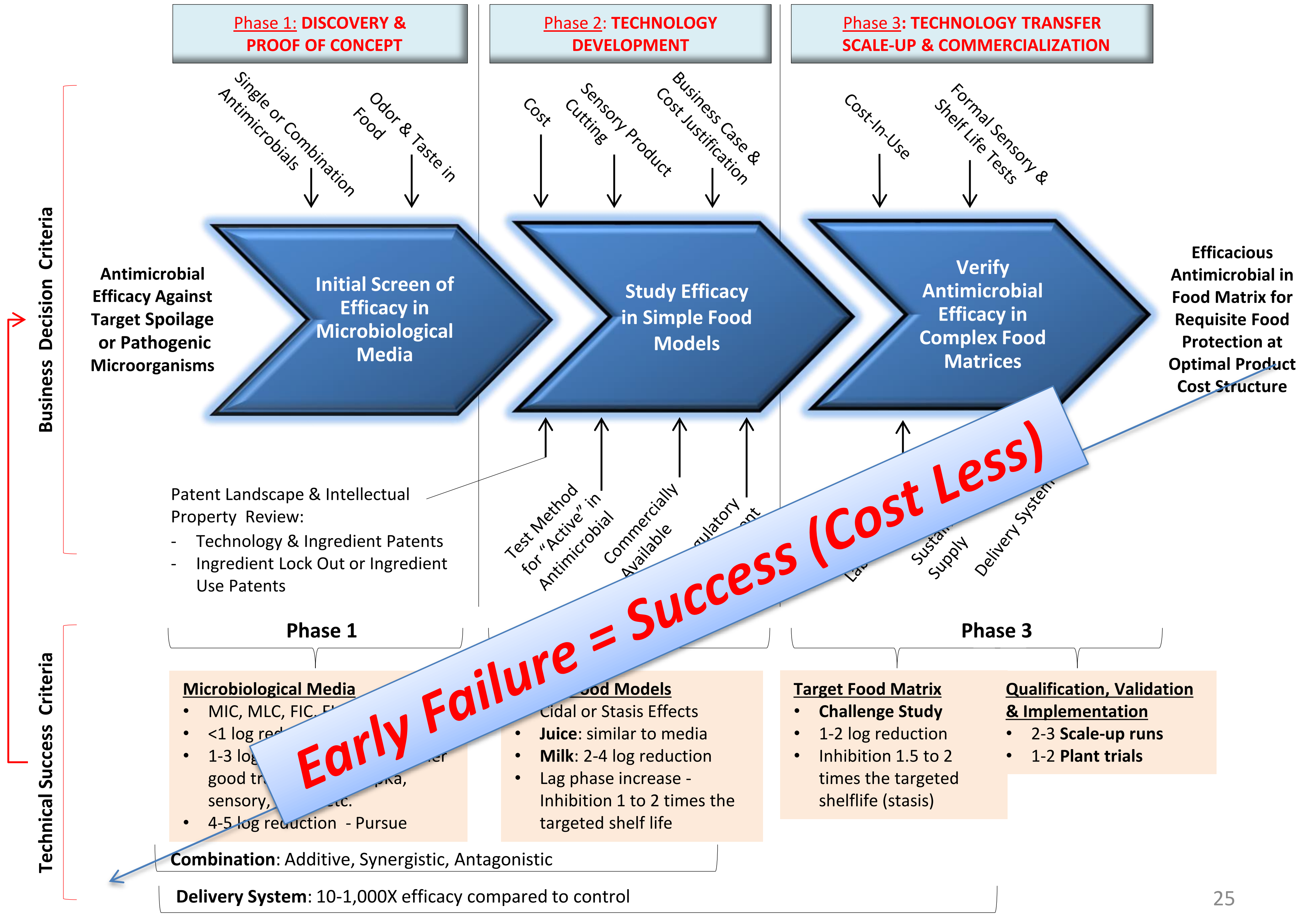
CONTROL

Syneresis of fruit core

Bake Test

Added antimicrobial should work with the current process parameters & formulation

STAGE GATE for Achieving Due Diligence



Food Preservation - Details

- Farm
- Animal Husbandry
- Fisheries

-Handling, surface decontamination, storage

Materials

Factory

Retail

Consumer

- Storage, handling
- Cooking instructions
- Open containers

- **Quality is Conserved**
- **Safety is Not Compromised**

prevent

low down

growth

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Micro

Access to

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NG TEMPERATURE

Incoming Ingredient Specifications

-RAC

-Meat

-Powder, Liquid, Solid

DRYING

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KEY TAKEAWAYS

- Consumer want natural or naturally derived antimicrobials vs chemical preservatives
- Food Industry Answer: Antimicrobial Tool Box for Pairing with Foods
- Steps for Adding Natural Antimicrobials to Foods – NOT SIMPLE
- Call for Continued Partnerships – University-Vendor- Food Industry

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Food Industry User Perspective: Jairus David, Ph.D.
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Appendix

Case Study: Model Fresh Sausage

AEM
Journals.ASM.org

Microbial Successions Are Associated with Changes in Chemical Profiles of a Model Refrigerated Fresh Pork Sausage during an 80-Day Shelf Life Study

Andrew K. Benson,[a] Jairus R. D. David,[b] Stefanie Evans Gilbreth,[b] Gordon Smith,[b] Joseph Nietfeldt,[a] Ryan Legge,[a] Jaehyoung Kim,[a] Rohita Sinha,[a] Christopher E. Duncan,[b] Junjie Ma,[a] Indarpal Singh[b]
Department of Food Science and Technology, University of Nebraska, Lincoln, Nebraska, USA[a]; ConAgra Foods, Inc., Omaha, Nebraska, USA[b]

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ConAgra Foods

University of Nebraska Lincoln

Fresh sausage product
Spice blend
Antimicrobials

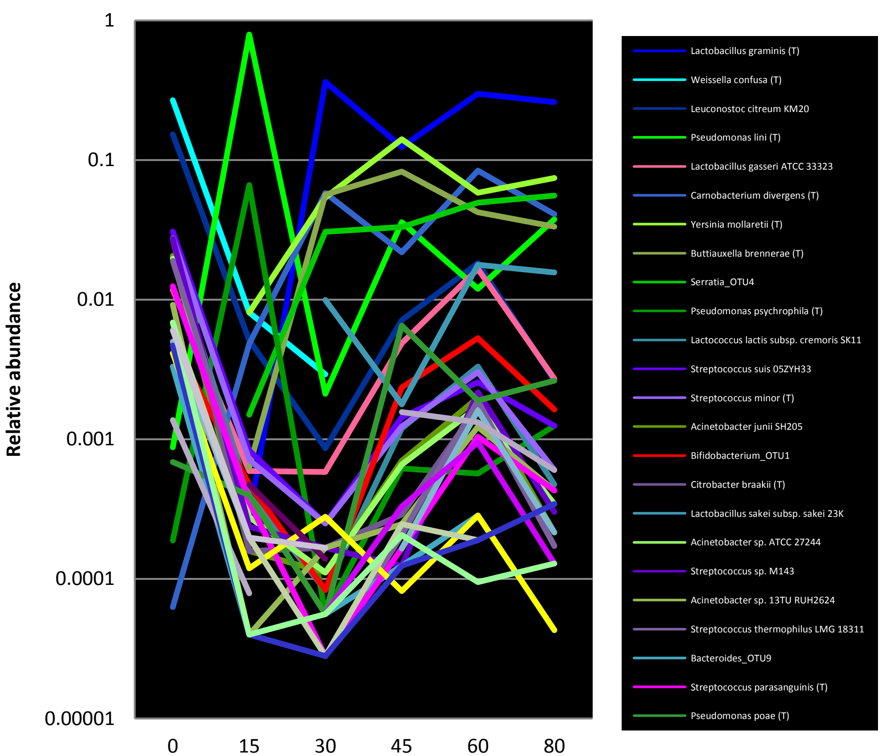
→

1. Traditional microbiological methods
2. Sniff testing –Meat Science
3. Microbiome analysis (16S)
4. Chemistry (eNose array)

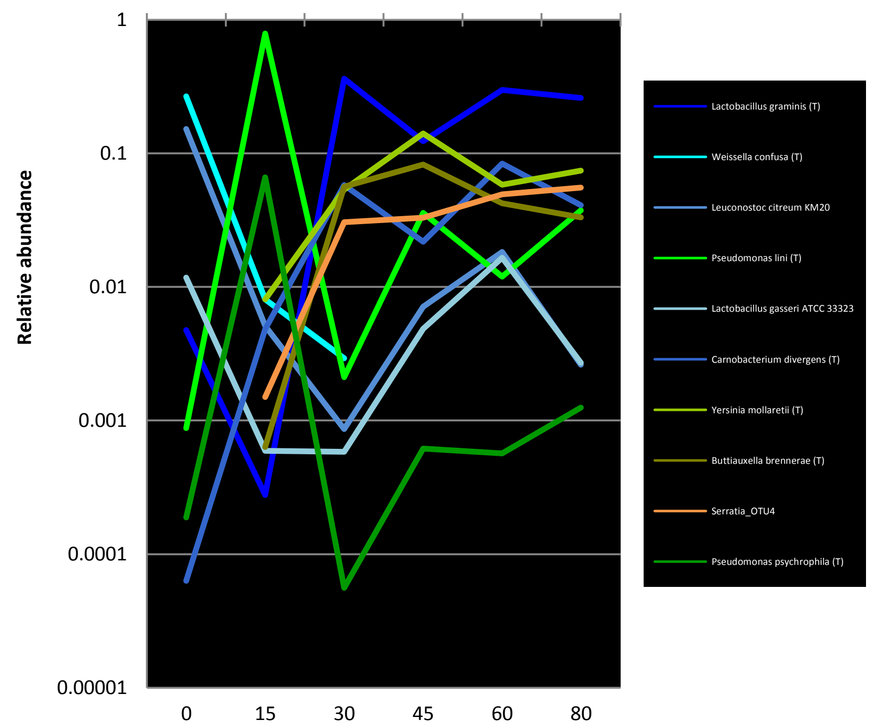
1. Big Disconnect between plate data and sensory spoilage
2. Ecological successions detected by NGS
   a. Three major successions
   b. Not observable by traditional micro
3. Shelf-life extenders eliminated successions, favored growth of single species
4. Source-tracking of species to spice blends, and not meat
5. Correlation analysis from eNose array identified 3 candidate taxa

Data Reduction: Focus on Behavior of The Most Abundant Taxa

Most abundant

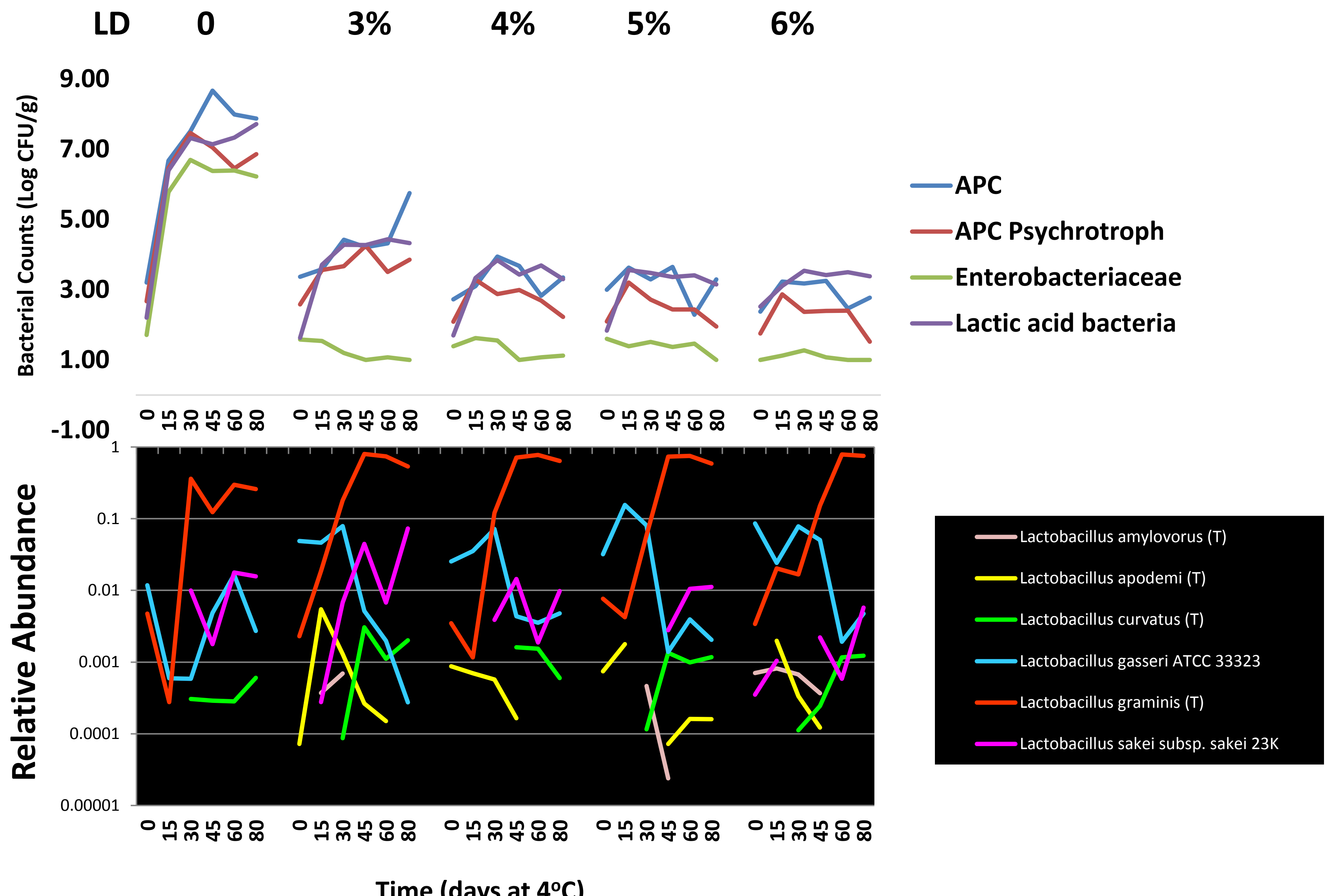


Overall most abundant



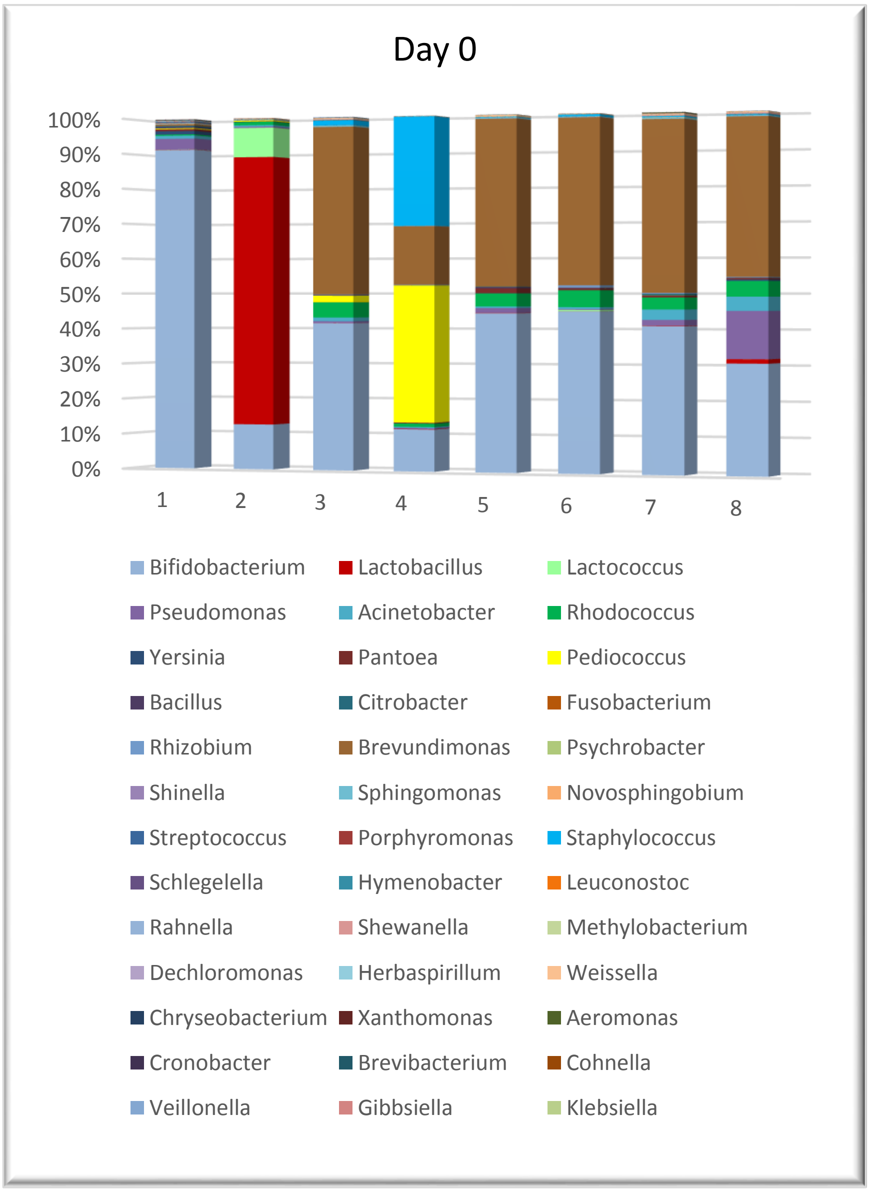
Time (days at 4°C)

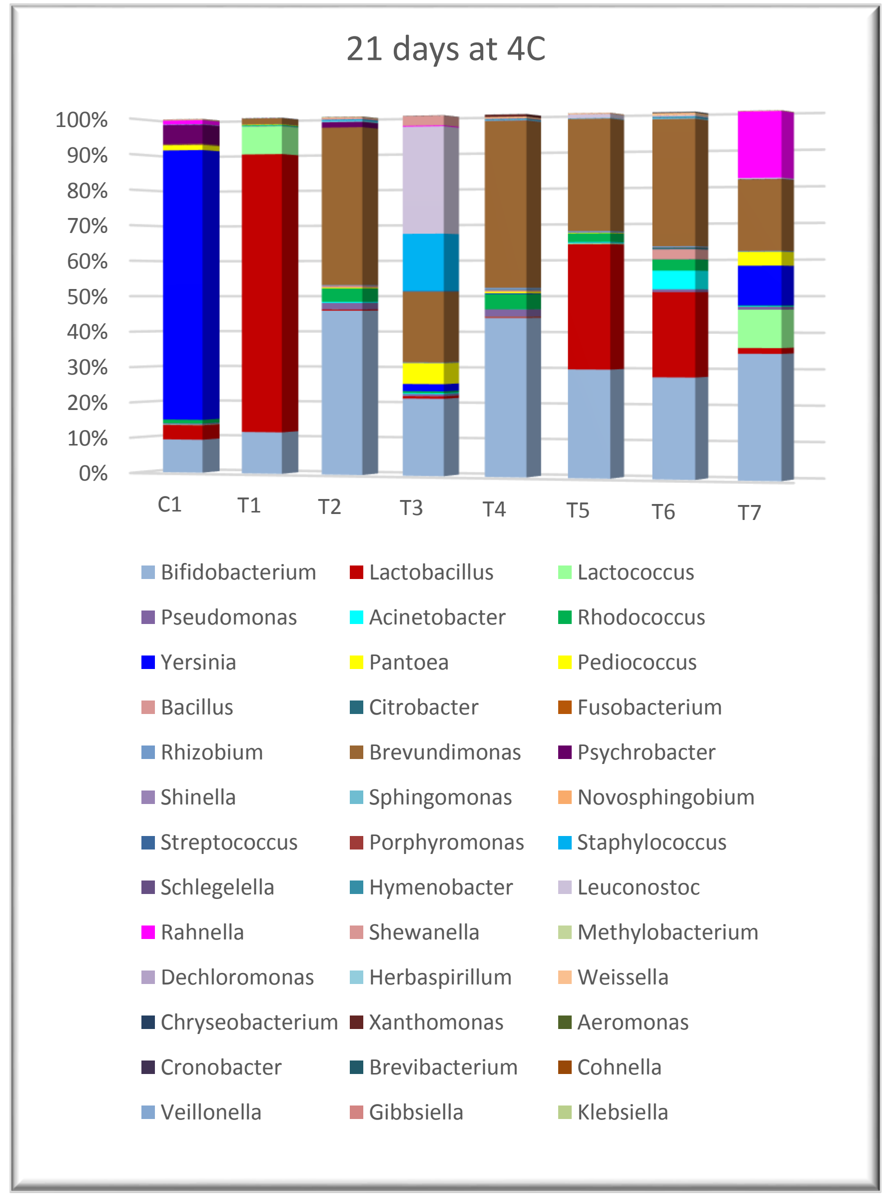
3 Major Successions



Antimicrobials Eliminated 3 Major Successions

Favoring a Single Species of Lactobacillus = Signature Spoilage Microorganism





Phase 3: C1 vs. T1, T2, T4