Hurdle Technology & Formulating for Longer Shelf-life

April 30, 2019

Jerry Erdmann
Principal Scientist – Food Protection
DuPont Nutrition and Biosciences
Agenda

Setting Expectation – Cleaner Label AM

How to be Successful

- Factors Influencing Growth
- Hurdle Technology
- Holistic Approach to Food Safety and Quality
- Shelf-life and Challenge Studies
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM are not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental contamination
- Shelf-life and spoilage challenge studies
Restaurants responding to clean label

- **Subway** – removing all artificial colors, flavors and preservatives

- **Chipotle** – removing all GMO ingredients and targeting the removal of all artificial preservatives

- **Panera** – issued “no-no list” of 150 artificial additives removed from menu items

- **Papa John’s** – removing additives such as MSG, BHA, BHT

- **Pizza Hut** – removing all artificial colors and flavors immediately and multi-year effort to reduce sodium

- **Taco Bell** – removing all artificial colors, flavors, artificial preservatives and additives

Source: www.entrepreneur.com
What is Clean Label?

For food manufacturers, it’s a balance between the degree of cleanliness they can afford and the market they can work in......

CLEAN LABEL INGREDIENT SPECTRUM

ORIGINAL
Product in its standard state with legacy ingredients like corn syrup, sorbate, gelatine, etc.

ALTERNATIVE
Begin reducing number of ingredients, begin to replace legacy ingredients

CLEAN
Start making specific claims, address “no” lists

CLEANER
Incorporate most restrictive alternatives like non-GM, organic and natural

CLEANEST
Product in its most traditional state (i.e. only grains, flour, oil, sugar, water, salt, etc.)

TRADE-OFFS
+/- Impact On The Ingredients Deck & Product claims
+/- Price, Cost-In-Use
+/- Sensory Attributes & Consumer Acceptance
+/- Product Shelf Life
+/- Manufacturing & Processing Tolerance

1/17/2012
Finding the Sweet Spot

- Flavor
- Sweet Spot
- Effect
- Cost

Deactivate by clicking

Finding the Sweet Spot

Sweet
Spot

Cost

Effect

Deactivate by clicking
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM - not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental contamination
- Shelf-life and spoilage challenge studies
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM - not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental contamination
- Shelf-life and spoilage challenge studies
Culture Preservation Formats

Product Fermentation → Protective Cultures → Fermentate Addition → Purified Metabolites

- Sour Cream
- Buttermilk
- Yogurt
- Adjunct Culture
- Whole Fraction Fermentates
- Nisin
- Natamycin
Microbial Whole Fraction Fermentates

These substances are naturally occurring antimicrobials which by themselves or in combination are highly effective against spoilage and pathogenic microorganisms.
Fermentates

Fermentates

FERMENTATES

PURIFIED METABOLITES

- R-COO-
- R-COO-
- R-COO

• Cultured Dextrose
• Cultured Whey
• Cultured Non Fat Dry Milk
• Cultured Sugar
• Cultured Wheat Starch

• Nisin
• Natamycin
• Lacticin
• Pediocin
• Sakacin
• Microcin

Purification
Plant Extracts Activity

• Composition Depends on:
  - Climate, environmental conditions, time of harvest
  - Commonly named oils from different plant species
  - Extraction method
  - Part of the plant extracted
  - Assay methods

Source: Sara Burt - Essential oils: their antibacterial properties and potential applications in foods – a review
Right Tool: Understanding the Mode of Failure

- Gram + Bacteria
- Gram − Bacteria
- Yeast & Mold
- Purified Metabolite
- Fermentate
- Protective Cultures
- Blends
- Natural Extracts
- Enzymes
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM - not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental Contamination
- Shelf-life and spoilage challenge studies
**Hurdle Technology:** The leveraging of multiple hurdles to compound control over microbial outgrowth and improve safety and stability of the food product.

**Key:** The antimicrobial is just one aspect of the overall preservative system.
Factors Influencing Growth - Example
Approximate Minimum Water Activity (Aw) for Microbial Growth

<table>
<thead>
<tr>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Limit of Microbial Growth</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osmophillic Yeast</td>
<td>C.botulinum</td>
<td>Pseudomonads</td>
<td>Staph aureus</td>
<td>Bacillus Cereus, L. Mono &amp; Lactic Acid Bacteria</td>
<td>E. coli</td>
<td>Salmonella</td>
<td>Spoilage Molds</td>
<td>Spoilage Yeast</td>
<td>Xerophillic Molds</td>
</tr>
</tbody>
</table>

*Risks still may need to be evaluated in areas where no microbial growth is expected
# Factors Influencing Growth - Example

**Approximate Minimum pH Values for Microbial Outgrowth**

<table>
<thead>
<tr>
<th>pH</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral pH</td>
<td>Egg whites</td>
<td>Milk</td>
<td>S. aureus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidic pH</td>
<td>Cheese</td>
<td>Bread</td>
<td>C. botulinum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Food Micro Concepts: Growth Phase

**Key:** Preservative systems could potentially play a static or cidal role in controlling microorganisms over the shelf-life.

**Key:** Cidal tends to describe the effectiveness of a processing or chemical treatment to kill microorganisms.

---

**Key:** Preservative systems could potentially play a static or cidal role in controlling microorganisms over the shelf-life. Cidal tends to describe the effectiveness of a processing or chemical treatment to kill microorganisms.
Holistic Approach for Safety and Quality

- Raw Materials – Reduce the Incoming Micro Load
  - Spices – Treated
  - Vegetables – Washed /IQF
  - Meat – Cooked/HPP/Fermented
  - Other Raw Agricultural Commodities – Flour, eggs
  - Cultured products

- Processing
  - Process Flow – How the product is put together
  - Processing – Thermal and HPP
  - Packaging – MAP or Vacuum
  - Order of Addition – Hydration and Distribution

- Environment

- Finished Products
**Order of Addition**

**DO**

- **Hydrate** any antimicrobials in water, vinegar, lemon juice early in production
- **Optimize** the dosage and the addition to the process (earlier is generally better...)
- **Ensure** antimicrobial is evenly distributed throughout the product
- **Order of Addition** may need to be customized to meet your needs

**AVOID**

- Add antimicrobials **directly** into an oil
- **Sprinkling** the antimicrobial on top of the product at the end of production
- **Excessive** heating
- **Assumption of no pH change**
Holistic Approach for Safety and Quality

- Raw Materials
- Processing
- Environment
  - Environment Monitoring
  - Air Quality
  - Sanitation – Validation
  - Line Run Times

- Finished Products
  - Intrinsic and Extrinsic Parameters – Aw, pH, MAP
  - Robustness of the Product – Hurdles, Strength of Emulsion
  - Single vs. Multi Use
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM - not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental contamination
- Shelf-life and spoilage challenge studies
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend

- Clean label AM - not 1:1 replacements for chemicals preservatives

- Clean label AM are more targeted – Select the “Right” Tool

- Clean label AM require more attention to detail

- Clean label AM have different sensory and CIU profiles

- Environmental contamination

- Shelf-life and spoilage challenge studies
Clean Label Antimicrobials – What you need to know?

- Growing customer demand/trend
- Clean label AM - not 1:1 replacements for chemicals preservatives
- Clean label AM are more targeted – Select the “Right” Tool
- Clean label AM require more attention to detail
- Clean label AM have different sensory and CIU profiles
- Environmental contamination

- Shelf-life and spoilage challenge studies
SPOILAGE Shelf-Life vs. SPOILAGE Challenge Studies

STEP #1: Understanding Shelf Life Evaluations

- Defining clear expectations and objectives on the front end
  - What is your target shelf life?
  - What is the testing schedule and length?
  - What determines spoilage (micro levels)?
  - What type of organism(s) spoil your product?
  - What should we test for in a shelf life study?
SPOILAGE Shelf-Life

Step #2 – Assumptions

- Final product formula produced in a plant environment with the same potential for contamination
- Consistent initial micro loads
- Formulation differences were minimized as much as possible
- Packaged in commercial containers
- Held at storage temperatures that mimic typical handling
Spoilage Shelf-life

Step 3: What Does The Shelf-Life Data Tell Us?

Questions/Learnings

- What organisms could potentially spoil your product?
- How micro stable is your current formulation under normal conditions?
- How micro stable is your formulation without preservatives or antimicrobials?

When is a micro challenge study necessary? 
A, B, C, D, or It Depends?
STEP #4: Understanding Challenge Study Evaluations

- Defining clear expectations and objectives on the front end
- What is the mode of failure/concern on this product?
- How is the product packaged?
- How is the product going to be inoculated?
- What level of inoculum should be used?
- Analytical parameter of the product?
- How will the inoculum be prepared?
- What is the storage temperature?
- Length of the study?
- Testing schedule and frequency?
Selecting Challenge Study Organisms
Order of Relevance

Organisms Isolated from spoiled product(s).
• How micro-stable is your product without any antimicrobial and/or preservative system?
• Has your commercially product spoiled in the past? What caused the spoilage?
  1. Formulation issue(s) (e.g. pH, emulsion issues, etc.)
  2. Processing issue(s) (e.g. heat treatment, excess condensation, etc.)
  3. Introduction of new contaminants or environmentally adapted organisms.

Organisms Isolated from raw ingredients
• Do your raw ingredients increase the risk of spoilage in your products?
• Starting with clean raw ingredients adds an extra hurdle into your process.

Potential environmental contaminants
• Non-food contact vs. food contact surfaces – what’s the difference in risk?
• Potential hang up points may be the best place to start your search – why?

Industry standard organisms and/or organisms from literature
• Are these organisms relevant?
Commonly Isolated Spoilage Yeasts
Low pH Dressing and Sauces

Most Frequently Isolated Spoilage Yeasts (Low pH Products)

- **Saccharomyces cervisiae**: 63.70%
- **Pichia anomola**: 7%
- **Dabaryomyces etchellsii**: 6%
- **Zygosaccharomyces bailii**: 6%
- **Candida parapsilosis**: 6%
- **Issatchenkiea orientalis**: 5%
- **Pichia membranafaciens**: 4.73%
- **Other species**: 3.95%
- **Other species**: 3.95%
- **Other species**: 3.95%

“During product research and development, it is advisable to conduct challenge tests in which various product formulations are inoculated with representative spoilage microorganisms. It is preferable to use cultures of spoilage microbes that have been recently isolated from spoiled containers or similar products, rather than cultures that have been carried in the laboratory for many years or obtained from a reference culture collection” (1)
Spoilage Challenge Study
Balancing Risk and Relevance

**Recommended Inoculum Levels**

“The combined inoculum level should provide a relatively low level of microbes in the test samples, on the order of $10^2 - 10^3$ microbes/g. This controlled low level of inoculum is higher than that which would usually occur during normal production so that it provides a sufficient challenge to the food. It is also low enough to avoid the creation of microenvironments in which clusters of spoilage microorganisms could overwhelm the preservative factors present in the food and grow to levels capable of spoiling the product.” (1)

SPOILAGE Challenge Study

Step #5 – Assumptions

- Final product formula produced in a plant
- Minimize formulation differences
- Packaged in commercial containers
- Pre-determined parameters that may be slightly abusive
- Relevant organisms and inoculation levels
- Necessary controls will be in place
Spoilage Challenge Study

Step #6 – What does a spoilage challenge study tell you?

How robust is your solution?

<table>
<thead>
<tr>
<th>Control (no antimicrobial)</th>
<th>Chemical Preservatives</th>
<th>Clean Label Antimicrobial</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFU/g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Spoilage level

Target Shelf Life

Total Counts

Deactivate by clicking Spoilage Challenge Study Step #6 – What does a spoilage challenge study tell you?

How robust is your solution?
Challenge Study Results

None of the treatments made it to the end of the shelf life. What does this tell us?

Challenge studies indicate the robustness of your solution under a pre-determined set of conditions.
Summary
Steps to obtain longer shelf-life

✓ Know who / what you’re up against, i.e. the specific organisms.
✓ How many are there? (e.g. initial vs. end of shelf life micro loads)
✓ Find the “Right” tool for the job
✓ Application of the “Right’ tool
✓ Leveraging the intrinsic and extrinsic parameter to develop a robust antimicrobial system (i.e. develop product hurdles)
✓ Utilizing a holistic approach to food safety and quality
✓ Performing relevant product validation
✓ Remember there are **NO** silver bullets for food safety or shelf life extension.
Bringing Value to the Food Industry

- Cleaner Label
- Increased Shelf-life
- Expanded Distribution
- Increased Brand Exposure
- Value Creation
- Brand Protection
- Improved Product Quality
- Reduced Returns/Risk
- Improved Brand Image
- Value Creation