Tactical Packaging Challenges & Solutions for Seafood

Dr. Claire Sand
February, 2017
Packaging Challenges

**MANUFACTURER**
- Reduce contamination during product fill
- Assess initial microbial load
- Reduce initial microbial load
- Enable HACCP, etc
- Address chilled worker conditions

**DISTRIBUTOR/RETAILER**
- Enable stock rotation
- Time & Temp monitoring system
- Oxygen level monitoring system
- Control temperature
- Reduce microbial load at POS

**CONSUMER**
- Refrigerate to Freezer
- Heat/Cook in Package
- Enable safe package reuse
- Reduce consumer contamin from repeat use
- Expand time for safe product use
- Enable freezer storage
Challenges Isolated Into 4 Key Areas

- Maintain Texture, Flavor, Color, and Nutrients
- Ensure Low Microbial Growth
- Add Value to Consumers
- Add Value to Retailers
Available Packaging Solutions

MANUFACTURER

- Decrease filling time by reducing number of packaging components
- Enable more rapid filling
- Rapid product sealing
- Use antimicrobial packaging

RETAILER/ CONSUMER

- Edible water vapor barrier
- Enable package sterilization
- Serving size separators within package
- Enhanced product interface
- Refine freezer storage options
Packaging solutions isolated into 4 key areas

- Antimicrobial packaging
- Communicate safety-intelligent packaging
- Edible packaging
- Value Chain needed to meet goals
Antimicrobial Packaging
Increasing Need for Antimicrobial Packaging

Market need for Antimicrobial is increasing due to increase in:

1. Resistance of microbes to standard processing technologies
2. Food safety outbreaks
   - Foodborne disease reaches 30% of the population
   - Vibrio increased 115% since 2006
3. Need for controlled temperature conditions to inhibit microbial growth
4. Global food distribution in various stages of processing
5. Increase in consumer interest in fresh and multicomponent prepared meals
6. Inability of MAP/CAP technology to accommodate lack of controls in distribution, processing, product
7. Growing urban population in need of food they can not produce
8. High potential for cross contamination
   - Processing facilities often manufacturer more than one product
   - Distribution systems between products are often linked
3 ways to convey Antimicrobial activity from the package

- within a structure
- as a coating
- through headspace
3 Ways to Convey Antimicrobial Activity From the Package

• For coatings and degradable polymers that contain Antimicrobials, all the Antimicrobial activity is imparted into food

• For Antimicrobials within polymers and in indirect contact with the food, the final amount of Antimicrobials within the food is a function of the ratio of $S_{\text{polymer}}$ to $S_{\text{food}}$
Antimicrobials

ORGANIC ACIDS
• Benzoic acid and benzoates
• Sorbic acid and sorbates
• Acetic acid
• Propionic acids and propionates
• Lysozyme

SOME OTHERS
• Chlorine dioxide
• Triclosan
• Silver zeolite, nitrate
• Bacteriophages
• Maillard reaction end products

BACTERIOCINS
• Nisin
• Pediocin

POLYMERS
• Chitosan

NATURAL EXTRACTS
• Cinnamaldehyde
• Eugenol
• Allyl isothiocyanate
• Green tea extract
• Various extracts
Antimicrobial Options

Regulatory

- FDA
  - Most are GRAS
- EU
  - Defined amounts allowed
Antimicrobial Packaging Bases

- Base materials: cellulose and SPI, zein, WPI, LDPE, Cellophane, paper, chitosan
- Format: coating/flexible; encapsulated within structures; coated on substrates
- Constraints: seal area, migration rates are product dependent
Nisin

• Nisin in conjunction with:
  • Lysozyme resulted in a reduction of E. coli
  • EDTA resulted in a reduction of Listeria and E. Coli
  • Grapeseed/Green tea extract resulted in a reduction of Listeria
• Chilled lobster (listeria), salmon (listeria)
Nisin - Regulatory

• EU
  • E234 (EEC 1983); EU commission number 215-807-5
  • Restrictions to cheese, eggs, puddings
• FDA GRAS status (1988)
• China
  • GB2760-86 (1990)
  • Canned food, plant protein, dairy, meat, prepared meat, cooked meat beverages, condiments, cereals products, convenience rice products, cooked seafood
• Global
  • Harmonized System (HS) code 29419090
  • Only bacteriocin approved by the World Health Organization (WHO, 1969)
Pediocin

• Shellfish
• Food safety: Listeria focused spectrum
  • Food quality: *S. aureus* and *B. cereus*
• Lack of approval by EU and WHO/FAO limits research
Chitosan

- 3 log cycles decay are typical
- Chitosan Discrepancies in reported Antimicrobial activity are due to:
  - Variability (in molecular weight and degree of polymerization) associated with naturally derived products
  - Reduces the motility of the chitosan and their interaction with microbes due to required cross-linking and/or heat to form
- Abundance of research on combinations of chitosan and other antimicrobials
  - Cinnamaldehyde (Enterobacteriaceae, L. Sakei)
  - Oregano (Listeria, E Coli)
  - Silver ions (Listeria, E Coli)
  - Nisin (E Coli, S, aureus, B cereus)
  - Chitosan/vermiculite nanocomposites
- FDA approved
Lysozyme

- Tuna, sushi

- Regulatory
  - Need for combining with EDTA or lactoferrin to inhibit E. coli increases regulatory issues and cost
  - Lysozyme
    - FDA GRAS
    - EU number 1105
    - Egg white derivation is potential allergen
  - EDTA
    - FDA GRAS
    - EU number 385
    - Unprocessed shellfish, processed fish and shellfish
Kinetics: Acceptable Limits of Antimicrobial Use

• Governed by CFR 21 and updated in the Federal Register
• How much of an Antimicrobials can be used is determined by the:
  • Acceptable Daily Intake (ADI) of the Antimicrobials
  • Estimated Daily Intake (EDI) if Antimicrobials
• Kinetics of direct and indirect contact
  • Often maximum adsorption of Antimicrobials is assumed to allow for temperature abuse and to account for uncontrollable factors
• If no data for a substance is present, research to determine the ADI must be conducted
• So, most Antimicrobials research and development is done with approved substances
# Factors Effecting Efficacy of Antimicrobials

## 1. FOOD PROCESSING CONDITIONS
- Food pH, and stability after pH changes
- Inactivation by food enzymes
- Interaction with food additives/ingredients

## 2. FOOD SHELF LIFE FACTORS
- Food storage temperature
- Limited stability during food shelf life

## 3. MICROBIAL FACTORS
- Microbial load
- Microbial diversity and the target bacteria
- Microbial interactions in the food system
- Physiological stage (growing, resting, starving or viable)

## 4. BARRIERS
- Protection by physico-chemical barriers (microcolonies, biofilms, slime)
- Barriers enrobing Antimicrobials

## 5. DEVELOPMENT OF RESISTANCE/ADAPTATION
- Predicted to be an issue of concern
Antimicrobial Packaging Recommendations -1

• Focus efforts on use of Antimicrobial coatings or within a degrading film to:
  • Optimize required amount of Antimicrobial
  • Blend antimicrobials
    • Reuterin-Bacteriostatic activity against *L. monocytogenes, S. aureus, E. coli* in combination with nisin and lactoperoxidase
    • HPP with nisin with lysozyme, lactoferricin, and a synthetic lysozyme-derived peptide increases efficacy
    • Unique bacteriocins can be generated by either mutating bacteriocin-encoding genes or by fusing genes from different bacterial species
      • Mutating of ring A within nisin results in enhanced Antimicrobial activity
Antimicrobial Packaging Recommendations -1

• Nisin coated vs incorporated to the polymer matrix

(Mangalassary & Cooksey, unpublished data)
Antimicrobial Packaging Recommendations-2

- Ensure consistent amount of Antimicrobial
- Avoid reliance of multifaceted kinetics that prevent predictions
  - Nisin from 2-layer films (EC/HPMC) desorbed in 0.5 h
  - Nisin from 2-layer films (EC/HPMC/EC) desorbed in 20 h
- Controlled release of the Antimicrobial is necessary to extend the shelf life
  - Done with nanotechnology
  - Rapid release causes fast antimicrobial “consumption” in a short period of time
  - Slow release may enable spoilage reactions on the food surface
Antimicrobial Packaging Recommendations-2

• Natamycin migration from polyvinylidichloride lacquer coating

(Hanusova et al., 2010)
Antimicrobial Packaging
Recommendations-2

Use nanocomposite films

- Antibacterial activity of gelatin based nanocomposite film against *E. coli* (b) and *L. monocytogenes* (c) 

(Kanmani & Rhim, 2014)
<table>
<thead>
<tr>
<th>Microorganisms</th>
<th>Food Safety Microbes</th>
<th>Categories Tested</th>
<th>Packaging Materials Tested</th>
<th>FDA Approval</th>
<th>WHO Approval</th>
<th>Manufacturers</th>
<th>Economic Parameters</th>
<th>Social Issues</th>
<th>Technology Parameters</th>
<th>Innovation Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Staphylococcus aureus</em>, <em>Lactobacillus</em></td>
<td>Not assessed</td>
<td>Meat, cheese, seafood, perishable processed food</td>
<td>Cellulose and SPI, zein, WPI, LDPE, cellulose, paper, chitosan</td>
<td>Approved</td>
<td>Yes</td>
<td>Numerous</td>
<td>Costs are not standard and are based on desired result; concern with resistance promoting use of other bacteriocins in tandem</td>
<td>Increased resistance possible; considered natural</td>
<td>Abundance of studies due to Asin’s commercial availability</td>
<td>Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution</td>
</tr>
<tr>
<td><em>Pediococcus</em></td>
<td>Not assessed</td>
<td>Processed meat (ham, bologna, smoked fish)</td>
<td>WPI coated PP, Cellulose</td>
<td>Not approved</td>
<td>No</td>
<td>Minimal</td>
<td>Concern with resistance promoting use of other bacteriocins in tandem</td>
<td>Increased resistance possible; considered natural</td>
<td>Limited studies</td>
<td>Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution</td>
</tr>
<tr>
<td><em>Listeria</em></td>
<td>Not assessed</td>
<td>Cottage cheese, cheese, milk, orange juice, egg, water, ham, turkey breast, smoked salmon</td>
<td>Zn, WPI, Paper beard with API, PE, Pectin/PLA composite Cellulose</td>
<td>Not approved</td>
<td>Approved by 50+ countries</td>
<td>Laboratories</td>
<td>Concern with resistance promoting use of other bacteriocins in tandem</td>
<td>Increased resistance possible; considered natural</td>
<td>Limited understanding beyond use as additive</td>
<td>Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>Not assessed</td>
<td>Seafood</td>
<td>PVA, PE, carrier of other antimicrobials</td>
<td>Not approved</td>
<td>No</td>
<td>Multiple</td>
<td>Innovations and use in water quality and fuel cells may lower prices or increase demand to increase prices</td>
<td>Non-toxic, biodegradable, and biocompatible</td>
<td>Abundance of research; variability of results due to natural origin</td>
<td>Combining with other antimicrobials to increase spectrum; identify optimum molecular weight and polymerization</td>
</tr>
<tr>
<td><em>Enzymes</em></td>
<td>Not assessed</td>
<td>Tuna, sash, raw and processed meat</td>
<td>Cellulose, paper, zein, SPI, PVO, surface immobilization</td>
<td>Approved</td>
<td>Yes</td>
<td>Numerous chemical companies</td>
<td>Need to combine with lactoferrin or EDTA to inhibit E. coli</td>
<td>Considered natural</td>
<td>Abundance of research; variability of results due to natural origin</td>
<td>To attain both Listeria and E. coli inactivity, determine optimum EDTA or lactoferrin concentration</td>
</tr>
<tr>
<td><em>Pediococcus</em></td>
<td>Not assessed</td>
<td>Yeasts, Molds</td>
<td>Salmon and roasted turkey, milk, cheese, vegetables</td>
<td>WPI, alginate</td>
<td>No approved</td>
<td>Recommmended when adequate cooling unavailable in dairy</td>
<td>Numerous chemical companies</td>
<td>Whey derivation lowers cost</td>
<td>Advocacy by FAO has increased awareness</td>
<td>Efficacy as a function of LPS, bisacodyl, and H2O2</td>
</tr>
<tr>
<td><em>Plant Extracts</em></td>
<td>Not assessed</td>
<td>Plant material (Oregano; <em>L. ream</em>)</td>
<td>SPI, WPI, chitosan, casein</td>
<td>Approved</td>
<td>Approved</td>
<td>Numerous</td>
<td>Costly due to extraction</td>
<td>Taste preferences inhibit use; no labeling issues</td>
<td>Not applied beyond laboratory stages</td>
<td>Natural/organic platform; improving efficacy</td>
</tr>
<tr>
<td><em>Metal ions</em></td>
<td>Not assessed</td>
<td>Meat, sliced fruit, eggs, orange juice</td>
<td>Glass, metal, polymers, chitosan, zein, cellulose</td>
<td>Defined amounts</td>
<td>Defined amounts</td>
<td>Defined amounts</td>
<td>Numerous</td>
<td>Silver most costly</td>
<td>Consumer familiarity; Environmental and increased resistance; Limit migration into food is paramount</td>
<td>Nanoparticles most effective due to shig surface area</td>
</tr>
<tr>
<td><em>Surface Treatments</em></td>
<td>Not assessed</td>
<td>Antifungal</td>
<td>Paperboard, polymers</td>
<td>by-products would need approval</td>
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<td>Internal</td>
<td>Variable</td>
<td>Residual additivities require acceptance</td>
<td>Skill set within converters</td>
</tr>
<tr>
<td><em>Acids, Salts, Arhydrides</em></td>
<td>Not assessed</td>
<td>Yeasts, Molds</td>
<td>Coatings on various substrates</td>
<td>Most are approved</td>
<td>Approved</td>
<td>Approved</td>
<td>Numerous</td>
<td>Variable</td>
<td>Consumer familiarity</td>
<td>Processes of inactivation are well known</td>
</tr>
<tr>
<td><em>Chlorine Dioxide</em></td>
<td>Not assessed</td>
<td>Produce</td>
<td>Known permeability to ClO₂</td>
<td>Considered a Category B52 under consideration</td>
<td>Numerous</td>
<td>Systems in place lowers cost</td>
<td>Color issues, Connected to household disinfectant</td>
<td>Technology well known</td>
<td>Explore ability to recharge system</td>
<td>Innovation Parameters</td>
</tr>
</tbody>
</table>

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**Dr Claire Sand**

Winter 2017

Tactical Packaging Challenges & Solutions for Seafood
Intelligent packaging
Difference Between Active and Intelligent Packaging
Intelligent Packaging

• Focus on:
  • TTI
  • Degradation sensors
  • No-Fraud assurance packaging
  • Responsive packaging
TTIs

TTIs are a refined proven technology

- Remain relevant since temperature governs reaction rates and controls microbial growth

\[ k = Ae^{-E_a/(RT)} \]
TTIs

- **FreshCode**, Varcode and **Tempix**, Tempix
  - fading barcodes

- **CoolVu**
  - aluminum layer thins causing a reaction

- **FreshMeter**
  - turns from blue to gray via benzopyridine photoactivation

- **L5-8 Smart Seafood**
  - irreversible color change from the hydrolysis of triglycerides
Degradation sensors are advancing rapidly
  • Direct connection to food deterioration
  • More sophisticated sensors that convert biochemical
    signals to electrical responses that show remaining shelf
    life from manufacturer to consumer
Degradation Sensors-Mechanisms

- High surface to volume ratio of nanofibrous membranes and electrospun sensors
- Based on surface enhanced Raman spectroscopy (SERS)
  - Measures total volatile basic nitrogen (TVBN)
  - Monitors cysteine loss via hydrogen sulfide
  - Color change indicator that activates as microbial growth increases
- Advances in wireless nanosensor networks (WNSNs)
  - Graphene printing and conductive polymers
    - Enables wireless communication between nanosystems
  - Incorporate antibodies (for detection) within polymer films
Responsive Sensors

- Responsive sensors that detect then act to reduce deteriorative reactions
  - Through the release of CO$_2$, antioxidants or pH change agents
- Tremendous amount of IP in this area
Authenticity Sensors-Overt and Covert

Overt authenticity is refined and solutions exist and line is blended between covert and overt

- **Overt** acts as deterrent and prevention

<table>
<thead>
<tr>
<th>Current solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Timestrip</em> and <em>Novas</em> - time elapsed since opening</td>
</tr>
<tr>
<td>RFID and NFC</td>
</tr>
<tr>
<td>Alien Technology, CAENRFID, Convergence Systems</td>
</tr>
<tr>
<td><em>authentiQ</em>, <em>Sicpa</em>, and <em>VerifyMe</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Older solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber tear</td>
</tr>
<tr>
<td>TE bands</td>
</tr>
</tbody>
</table>
Authenticity Sensors-Overt and Covert

Overt authenticity is refined and solutions exist and line is blended between covert and overt

- **Covert** acts a detection

- **Current solutions**
  - *FluxSecure* - glass coated metal thread embedded in packaging
  - TruTag, Flint Group, Spectra Systems - silicon dioxide based tags
  - *SigNature* - printing plant based DNA as barcodes, watermarks, microdots
  - *Genome Trakr* - DNA based verification methods
  - Alpvision - fingerprint within molded caps and bottles
  - *Unisecure* - imperfection tracking with a 5-megapixel smart phone
Authenticity Sensors
Authenticity Sensors

Intelligent packaging expands brand image potential

Current solutions
- Thermochromatic inks change color and reveal images when the product is at the proper temperature to eat or drink
- NFC *OpenSense* package sensor is tapped with a smartphone
- Polymark fluorescence based detection for sorting food-contact PET
Intelligent Packaging Recommendations

• TTI continue to be the standard
• For optimum safety, focus on degradation sensors in 1-3 years
• Assess branding and authenticity link to balance costs
• For nutritional waste reduction and safety, focus on responsive sensors in 3-5 years
Edible Packaging
Edible Packaging

• Focus on
  • Reduce and not replace synthetic packaging
  • Freezer burn
  • Decreasing water loss in fresh seafood
  • Enhancing product offerings
    • Cook in bag
    • Shaped products
    • Meal kits to align with what retailers are doing
The Need for Water Management

• Freezer burn
  • Interfacial water freezes and thaws and ice crystals grow crushing cells
  • Increased degradation within cells before they burst
  • Texture loss

• Water loss
  • Loss from product
  • Loss from package is ($$$) loss
Edible Packaging as a Water Vapor Barrier

• Alternative to vacuum package
• Edible barriers are a robust solution in consumer freezers
• Many options and can be linked to antimicrobial barriers
Edible Packaging as a Water Vapor Barrier

- Realistic assessment
- Lipids-wax, fatty acids, glycerides
- In a base-proteins, starches, or celluloses derivative
- Confused research
Edible Packaging to Enhance Product Offerings - Cook in a Bag

Enable venting since product is better protected

1. Perforations
   • (horizontal or in a “patch”) that are coated/laminated; but, to allow air/steam to escape through holes

2. Laser scored
   • top layer that is coated/laminated; but, to allow air/steam to escape through laser cuts that expand when heated
   • steam generated from within the package bursts through the scoring and automatically ventilates the package

3. Channels that vent air/steam through fin seal area
   • Consumer slit bag to vent before microwaving

4. Tray in colander
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Edible Packaging to Enhance Product Offerings - Shapes

- Upscale frozen/fresh *Surimi* seafood
- Impart texture
- Lower fat content by reducing oil uptake
- Bite size
- Decrease product waste
Edible Packaging to Enhance Product Offerings - Meal Kits

• Keep water within separate foods with reduced synthetic packaging
Edible Packaging to Enhance Product Offerings - Meal Kits

- Reduce retailer labor and provide improved food safety
Edible Moisture Barriers
Recommendations-1

• Assess viability

Figure 8 Promises and limits of edible moisture barriers (adapted from Bourlieu et al., 2007).
Edible Barriers Recommendations-2

• Water vapor barriers
  • Apply research and test based on direction of prior work
  • Develop proprietary solutions

Edible Moisture Barriers: How to Assess of their Potential and Limits in Food Products Shelf-Life Extension?

C. Bourlieu, V. Guillard, B. Vallès-Pamiès, S. Guilbert & N. Gontard

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To link to this article: http://dx.doi.org/10.1080/10408390802145724
Value Chain is Needed to Meet Goals
Value Chain Actions

- Ensure Agility
- Build Trust
- Incent
- Develop with partners
Ensure Agility

- Ensure agility in meeting need for package change
- Because food industry processes are not aligned to implement packaging solutions, agility to work a different way is needed
  - Realign cost:benefit within value chain members
    - Development time and costs shared within value chain
    - Develop solutions jointly vs “serving up” solutions
  - Employ startup (mentality/physically) without internal/external barriers
  - Gain tacit knowledge
  - Identify core advisory team experts to guide team
Build Trust to increase shelf life:

• Trust to enable shifting the role to a packaging responsibility is needed
• Need to build trust that ___ can provide extra measure of food safety, or key attribute
  • Process transparency
    • Align goal with food safety HACCP, FSMA, GFSI, etc processes
  • Incorporate transparency to build tacit knowledge
Perform Stress Test

• To assess partner response
• To align to improve functionality
• Increased microbial load, product abused, seasonal variation in value chain
• Explore viability of safety guarantee
  • Need to be involved with integration into HACCP, FSMA, GFSI, etc process and required post pack conditions
Incorporate Incentives

• Since food safety and reducing waste is normally the role of the food processor, incentives to enable shifting the role to packaging is needed
• Need to provide incentives to work as a partner in food safety and waste reduction
  • Assess motivation for CPG to work on ___
    • Timing
    • Reduce costs
    • Chance to truly innovate
• Design reward system based on conversion process
  • Connect with retailer on needs/signage
  • Align rewards to conversion process
• Design reward system based ___ process efficacy
  • Storage of ___ packaging material
  • Packing of product with packaging material
Develop Core Competency with Partners

• Develop core competency with partners in the value chain
• Need to stretch value chain to incorporate more members
  • Researchers in ____ arena jointly funded-consortiums, foundations, universities
• Assess distribution controls
• Explore impact on retail if shelf life extended
• Make consumer connections
• Assess sustainability in holistic manner (reuse, regeneration, recycling, reduce)
  • Nutritional waste
  • Package waste
Questions?

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CEO, Packaging Technology & Research, LLC
Adjunct Professor, Michigan State University

Food science and packaging expertise:
• Coaching
• Consulting
• Technology
• Strategy

www.PackagingTechnologyandResearch.com