Milk Packaging

Types of packaging material and their functionality, how they protect (or not) milk, innovations packaging for milk

Dr. Claire Sand
July 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/SOCIETY**
- Enable safe package reuse
- Reduce consumer contamination from repeat use
- Expand time for safe product use
- Enable storage
- Portions
- Sustainability

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Claire Sand - Packaging
Packaging Solutions

BRAND/MANUFACTURER

• Manufacturing agility
• Reduce microbial contamination

RETAILER/ CONSUMER

• Provide barrier to deliver needed shelf life
• Sustainability
• Enable distribution & retail handling
• Enhanced value and interface
• Align with demographic shifts
• Safety
Select Roles of Packaging for Milk

- Provide a barrier
- Enable Manufacturing agility
- Enhance consumer interface
- Incorporate sustainability
- Enable Distribution and handling
- Enable safety
Provide a barrier
Functions of packaging barrier for milk

- Reduce lipid oxidation
- Reduce Riboflavin and Vitamin A loss
  - Light barrier
    - Reduce exposure to sunlight, fluorescent LED
  - Oxygen barrier
- Retain water
  - Provide water barrier
Ways to achieve a barrier

• Material and polymer selection
• Polymer modification
  • Copolymers
  • Coextrusions/laminations/coatings
  • Tortuosity
  • Antimicrobials
  • Pigments
Milk barriers - OTR

• OTR and reality
  • Temperature
  • Gradient
  • As rxn progresses
  • What barrier is needed
OTR

- Common OTRs
  - PET - 0.22 cc/m²dayatm
  - HDPE - 2.6
  - PP - 11
  - LDPE - 20
  - Paper/polymer - variable
  - Combinations paper-metal-polymer - ~0
Light barrier
Light barriers

• HDPE and PET with Additives:
  • Carbon black layer
  • 1.3-6.3% TiO2
• Shrink sleeves
LED provides an opportunity

- LED results in less degradation

“Products in PET exposed to LED lighting, with the higher light intensity of 1,460 lx, had higher acceptability for aftertaste (6.0 and higher) than did milk packaged in HDPE (except light-protected HDPE) under LED light.”

“LED light intensity (4,000 lx) resulted in less nutrient degradation in 1% milk than fluorescent light (2,200 lx) after 24 h of light exposure.”
<table>
<thead>
<tr>
<th></th>
<th>Mean Hedonic Scores (n=154)</th>
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<tbody>
<tr>
<td>Translucent-F</td>
<td>6.1&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Translucent-LED</td>
<td>6.3&lt;sup&gt;ab&lt;/sup&gt;</td>
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<tr>
<td>Light-Protected LED</td>
<td>6.5&lt;sup&gt;b&lt;/sup&gt;</td>
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![Bar chart showing count frequency for different packaging types.](chart.png)
### Mean Hedonic Scores (n=157)

<table>
<thead>
<tr>
<th>Type</th>
<th>Score</th>
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<tbody>
<tr>
<td>Clear-F</td>
<td>5.7</td>
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<tr>
<td>Clear-LED</td>
<td>6.6</td>
</tr>
<tr>
<td>Light-Protected LED</td>
<td>6.6</td>
</tr>
</tbody>
</table>

**Notes:**
- Clear-F: 5.7
- Clear-LED: 6.6
- Light-Protected LED: 6.6
Flavor: Just About Right

- Study 1: Not Enough
- Study 2: Not Enough

LED

- Response (%)
- Light-Protected PET
- White PET (6.5% TiO2)
- Clear PET
- Light-Protected HDPE (4.5% TiO2)
- White HDPE (11.3% TiO2)
- Yellow HDPE
- Translucent HDPE

Fluorescent

- Response (%)
- Clear PET
- Translucent HDPE
PET
Altering polymers

- Copolymers
- Coextrusions/laminations/coatings
- Tortuosity
- Antimicrobials
- Pigments
Plastics Extrusion

[Diagram of plastics extrusion process]
Cast Plastic Film/Sheet Extrusion Line
Blown Plastic Film Extrusion Line
1. Parison ready

2. Mold closes over parison


4. Bottle removed and trimmed.
Coextrusions/laminations/coatings

• Adding further oxygen barriers
  • EVOH
  • PVDC
  • Nylon
• SiOx
• Metallizing
Add Tortuosity

Polymer-Clay composites

Fig. 4, Alexandre & Dubois, Mater. Sci. Eng.. 28(2000) 1-63
Employ Antimicrobials or oxygen scavengers

within a structure

through headspace

as a coating
Coatings work best

- Nisin coated vs incorporated to the polymer matrix

(Mangalassary & Cooksey, unpublished data)
Antimicrobial Options

Regulatory

- FDA
  - Most are GRAS
- EU
  - Defined amounts allowed
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 Food Safety Food Quality Categories Tested Packaging Materials Tested FDA EU FAO/WHO Manufacturers Economic Social Issues Technology Innovation

**Nisin**
- Listeria (with Lyszyme); E. coli (with EDTA); Salmonella
- Not assessed
- Meat, cheese, seafood, perishable, processed food
- Cellulose and SPI, zein, WPI, LDPF, cellulose, paper, chitosan
- GRAS
- E234; Restrictions to cheeses, yoghurts, puddings
- Approved
- Numerous
- Costs are not standard and are based on desired result; concern with resistance promotes use of other bacteriocins in tandem
- Increased resistance possible; considered natural
- Abundance of studies due to nisin’s commercial availability
- Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution

**Pediocin**
- Listeria
- S. aureus and B. cereus
- Processed meat (ham, bologna, smoked fish)
- Zan, WPI, Paper board with AP; PE, Pectin/PLA composite Cellophane
- GRAS
- Not approved
- Minimal
- Concern with resistance promotes use of other bacteriocins in tandem
- Increased resistance possible; considered natural
- Limited studies
- Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution

**Lacticin**
- Clostridia and Listeria
- S. aureus, Bacillus, Lactococcus, Lactobacillus
- Cottage cheese, cheese, milk, orange juice, egg, water, ham, turkey breast, smoked salmon
- Zan, WPI, Paper board with AP; PE, Pectin/PLA composite Cellophane
- GRAS
- Not approved
- Approved by 50+ countries
- Laboratories
- Concern with resistance promotes use of other bacteriocins in tandem
- Increased resistance possible; considered natural
- Limited understanding beyond use as additive
- Use bacteriocins synergistically; bioengineering for increased efficacy; refine coating distribution

**Chitosan**
- E. coli
- S. Aureus, P. fragi, B. subtilis
- Seafood
- PVA, PE, carrier of other antimicrobials
- GRAS
- Not approved
- Multiple
- Innovations and use in water quality and fuel cells may lower prices or increase demand to increase prices
- Non-toxic, biodegradable, and biocompatible
- Abundance of research; variability of results due to natural origin
- Combining with other antimicrobials to increase spectrum; identify optimum molecular weight and polymatization

**Lyszyme**
- Listeria; E. coli (with lactoferrin or EDTA)
- S. aureus, P. fragi, B. subtilis, E. plastratum
- Tuna, sushi, raw and processed meat
- Cellulose, paper, zein, SPI, PVP, CH4, immobilization
- GRAS
- E1105; approved for cheese and beer
- Numerous chemical companies
- Need to combine with lactoferrin or EDTA to inhibit E.coli
- Considered natural
- Abundance of research; variability of results due to natural origin
- To attain both Listeria and E. coli inactivity, determine optimum EDTA or lactoferrin concentration

**Lactoperoxidase**
- Listeria, E. coli
- Yeasts, Molds
- Salmon and roasted turkey, milk, cheese, vegetables
- WPI, alginate
- GRAS
- No approved
- Recommended when adequate coating unavailable in dairy
- Numerous chemical companies
- Whey derivation lowers cost
- Adocacy by FAO has increased awareness
- Efficacy a function of LPS, chlorocyanite, and H2O2
- Activation by H2O2

**Plant Extracts**
- E. coli (Oregano); Listeria (Nemem)
- S. aureus (Grapefruit seed; Listeria (Nemem)
- WPI, SPI, lactoferrin, casein
- GRAS
- Approved
- Approved
- Numerous
- Costly due to extraction
- Taste preferences inhibit use; no labeling issues
- Not applied beyond laboratory stages
- Natural/organic platform; improving efficacy

**Metal Ions**
- E. coli; Listeria (Titanium), Zinc, Silver, Copper; Salmonella (Zinc and nisin)
- S. aureus
- Meat, sliced fruit, eggs, orange juice
- Glass, metal, polymers, chitosan, zein, cellulose
- Defined amounts
- Defined amounts
- Defined amounts
- Numerous
- Silver most costly
- Consumer familiarity; Environmental and increased resistance; Limit migration into food is paramount
- Nanoparticles most effective due to small surface area
- Medical research applicable to food packaging

**Surface Treatments**
- E. coli
- Antifungal
- Meat, produce
- Paperboard, polymers
- by-products would need approval
- by-products would need approval
- Internal
- Variable
- Resultant additives require acceptance
- Skill set within converters
- Adapt processes from medical packaging; plasma activation; GRAS by products

**Acids, Salts, Anhydrides**
- Listeria and E. coli (Sorbic Acid); Listeria (Lactic acid and EDTA)
- Yeasts, Molds
- Meat, produce
- Coatings on various substrates
- Most are GRAS
- Defined amounts allowed
- Defined amounts allowed
- Numerous
- Variable
- Consumer familiarity
- Processes of inactivation are well known
- Refined efficacy

**Chlorine Dioxide**
- Listeria, Salmonella
- Not Evaluated
- Produce
- Known permeability to ClO2
- Considered a treatment
- E602 under consideration
- Numerous
- Systems in place lowers cost
- Color issues; Connected to household disinfectant
- Technology well known
- Explore ability to recharge system
Select Roles of Packaging for Milk

- Provide a barrier
- Enable Manufacturing agility
- Enhance consumer interface
- **Incorporate** sustainability
- Enable Distribution and handling
- Enable safety
Incorporate sustainability
Packaging sustainability-Competitive advantage

• Interviews from CEOs state:
  • 98 % believe that sustainability issues will be critical to the future success of their business
  • 92 % believe that companies should integrate sustainability through their supply chain; only 59% believe that their company has done so
  • 51 % cite the complexity of implementation as the most significant barrier to embedding sustainability
Packaging & Sustainability - Packaging waste increases with income

[Bar chart showing packaging waste by income level:]

- High-Income Countries:
  - Paper: 36%
  - Organic: 28%
  - Plastics: 9%
  - Metals: 8%
  - Glass: 7%
  - Other: 12%

- Middle-Income Countries:
  - Paper: 15%
  - Organic: 11%
  - Plastics: 15%
  - Metals: 11%
  - Glass: 3%
  - Other: 2%

- Low-Income Countries:
  - Paper: 41%
  - Organic: 47%
  - Plastics: 4%
  - Metals: 1%
  - Glass: 2%
  - Other: 11%
Sustainability is seeking a favored option
Packaging & Sustainability - Companies react in different ways

► Dannon reduced packaging waste by eliminating the plastic cap over the peel-back foil seals on yogurt cups
  ► 3.6 million pounds of plastic/year
  ► Copied others in industry
► SunChips
  ► Compostable bag
  ► Limited compost facilities
  ► Noisy
Measuring Package Sustainability

1. LCAs
2. COMPASS
3. Carbon Foot Print
4. Tesco and Wal-Mart Scorecards
Packaging LCAs

Packaging Life Cycle

Imports & Other Materials → Converters → Brand Owners/Product Mfrs → Distribution/Warehousing

Material Mfrs → Converters

Resource Extraction → Converters

Exports → Recyclers

Recyclers → Composting, Inciner./WTE, Landfill, Litter/Open Burning

BUSINESS-TO-BUSINESS FLOWS

POST CONSUMER FLOWS

Consumers → Retailers
Packaging-LCA of Frozen and Canned Green Beans
Sustainable food packaging

• Provides packaging to protect food for total reduction of resource (energy, nutrients, etc) waste
• The future value chain links the post consumer value of packaging with raw materials
  • This moderates research to focus on raw material production—the largest energy use in packaging
  • Packaging processes are being refined to use less water and energy
  • 28% of US consumers are LOHAS
• Packaging’s role is unique due to the short use of the packaging
• Packaging is also unique in that it is global since packages are made and disposed worldwide vs products being consumed or used as durable goods
  • Packaging research leads the way for regeneration of manufactured goods
    • Example—reusable packaging before reusable computers

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Sustainable food packaging

• Packaging’s role in the value chain can link raw materials with post consumer environment

• Progress mirrors the future
  • Example - EU’s APEAL industry initiatives provide image of potential in packaging
  • Example-KLM
  • Example-Migros exceeded Switzerland’s PET recycling goal

• Future role in value chain is collaborative

• Global powerhouses (WWF, CERES, Forum for Future) are engaged
Polymer derivation, biodegradation, recycling

PCL
PBAT
PBS

Starch based,
PLA, PHA,
Chitosan

PE, PP, PET,
PS, PVC

bPET, bPE,
PTF, PEF

PCL = Poly (ε-caprolactone)
PBAT = Poly(butylene adipate-co-terephthalate)
PBS = Polybutylene succinate
PE = Polyethylene
bPE = Bioderived Polyethylene
PP = Polypropylene
PS = Polystyrene
PET = Polyethylene terephthalate
bPET = Bioderived Polyethylene terephthalate
PVC = Polyvinylchloride
PLA = Polylactic Acid (Polylaktate)
PHA = Polyhydroxalkanoate
PTF = Polytetrinethylene furandicarboxylate
PEF = Polyethylene furanoate

Adapted from G. Robertson
Biomaterials - Definitions

• Biopolymer: organic material where source of the carbon is from biological resources (not-fossil resources)
• Biodegradable: Biodegradable polymers with approved biodegradability (according to EN 13432)
• Compostable: *ill defined*
Green PE and PET

- **Sugarcane**
  The sugarcane crop metabolizes the CO₂ to produce sucrose (85 t/ha; 14% sugars + 26% biomass)

- **Ethanol CH₃-CH₂OH**
  At the distillery, the sugar juice is fermented and distilled to produce ethanol

- **Ethylene CH₂=CH₂**
  Through the dehydration, the ethanol is transformed in ethylene

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- **Recycling**
  The green polyethylene is 100% recyclable (Mechanical / Incineration)

- **Carbon capture**
  The green polyethylene is transformed in final products in the same unities already existents

- **Green PE [CH₂=CH₂]**
  The ethylene is polymerized in polyethylene production unities (3 t PE/ha)
More Sustainable choices

7th generation bottle
Consumes about 33% less energy to produce
Carbon Footprint that is 48% lower than plastic
More Sustainable choices

Calcium Carbonate stiffens HDPE
More Sustainable choices
Packaging & Sustainability-Value Chain derived redesign

- Improved design is stackable, eliminates need for crates
- Eliminates need to transport, return and wash crates
- Can fit 224 jugs on a pallet instead of 180
- Reduces distribution costs by ~30%
- Reduces price to consumers by ~$ 10
Packaging & Sustainability-Value Chain derived redesign

- PAPER
- PLASTIC
- BOX
- FILM
- TRAY

*Not recycled in all communities

Check Locally*

how2recycle.info
Sustainability-Value Chain & shared value solutions needed

Total resource optimization-Food and nutrient vs packaging energy & waste

Design for Recovery
• Paper & film-air float separation
• Steel-magnetic separation
• Aluminum-Eddy currents
• PE, PP, PET, PS- NIR and float density

Use of Recycled and Bioderived recyclable polymers
• rHDPE Envision
• rPET
• bPET

Build Composting and Recycling Infrastructure
Select Roles of Packaging for Milk

- Provide a barrier
- Enable Manufacturing agility
- Enhance consumer interface
- Incorporate sustainability
- Enable Distribution and handling
- Enable safety
Enable Manufacturing agility
Agility provides inherent opportunity

New product launches around the world

Global milk consumption increased by 2.4% in 2015 to 251 billion litres

- White milk: 93% of volume, 2% growth
- Flavoured milk: 7% of volume, 7% growth

Growth forecast per year to 2020

West Europe, North America and Latin America hold 35% of global market volume

Recent trends: vitamin-enriched, added protein, child-oriented

52% of global consumption takes place in Asia Pacific

USA
Mexico
Europe
India
Japan
Agility provides inherent opportunity
Agility provides inherent opportunity
Agility provides inherent opportunity

6 weeks from idea to nationwide launch
Select Roles of Packaging for Milk

- Provide a barrier
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- Enable safety
Enable Distribution and handling
Supply Chain & Value Chain are needed now

Supply Chain finesse has allowed the packaging industry to evolve:

1950-1980s
• Post-war era saw efficiencies grow
• Reduced energy costs associated with distribution led to JIT and ECR

1980s and 1990s
• Supply Chain management
• Global sourcing
• Commoditization
• Strategic alliances
Value Chain evolved to meet diverse competitive goals

1990s
- Drucker’s “knowledge worker”
- Porter’s Value Chain
- Grenier’s organization growth

2000s
- Need more than logistics to be competitive
- TBL - people-profit-planet
- Sweet spots
- Sustainability wave for US which has existed globally
Involve distribution and handling to innovate

Managing for new approach requires the value chain to provide-

• Shared business culture, vision, terminology, and set of practices within the value chain
• Ability to envisage how the parts add up across chain
• Ability to change internal systems
• Activities for the sake of the whole as a cooperative effort
• Dense network of contacts and trust
• Focus on team building activities
Refine and flex distribution and handling

- Packaging can facilitate the distribution via alternative channels (versus traditional models) to meet urban needs
  - A future value chain defined by consumer led value will optimize packaging based on global urban and rural consumers
    - Example: Medical contract packaging & Anderson’s window walls & UHP
  - Optimal packaging technology focuses on post consumer disposal in urban areas (DSD)
  - Consumer specific packaging is growing
    - Kids design Legos and package
  - Packaging research on predictive restocking (beyond RFID) to make consumer and post consumer packaging seamless
Select Roles of Packaging for Milk

Provide a barrier

Enable Manufacturing agility

Incorporate sustainability

Enable Distribution and handling

Enhance consumer interface

Enable safety
Enhance consumer interface
Enhance value for consumers-exploration

- *Exploration* closely links value chain entities with consumers to
  - Tell ‘stories’ about the packages we use to explain
    - Why it is used
    - How it was produced
    - Impact on the environment
    - Welfare of workers involved along the chain
    - Rewards accruing to the primary producers

- Commodity packaging is
  - Not able to compete on these issues
  - Disadvantaged in many premium market segments
Enhance value for consumers-exploration

- Implementation of an exploratory platform for sustainability requires incentives

- Absorb new ideas into organization
  - Reward ideas that address how challenges could be faced
  - Enable quick clearance for external entities
  - Reward long term innovation at the expense of short term innovation

- Realign partners to achieve innovation
  - Reward new arrangements that focus on a long term innovation need
  - Reward concepts that offer opportunities to use value chain
  - Reward value chain teams that make steps toward implementation of new technology/initiative
Intelligent packaging expands brand image potential
Nothing can be
more fresh than
our product that’s
straight from udder!

SUPER
MILK
FRESH FROM UDDER

PREMIUM
PRODUCT
WITH CARE
Breaking through
every barrier

EDUCATE
MORE TALKING
Less info on bottle

FRESH
STRAIGHT
FROM UDDER
More info.

NICHE
BE LOCAL!
ACT LOCAL!
LOCAL LOCAL.
WE RE LOCAL!

PACKAGING
Optimize packaging for different environments

- Electricity
- Urban vs rural
- Consumer group size
- Income
- etc
Align packaging for economic reshuffling

• Packaging can **enable** affordable choices the 4 billion+ consumers at pyramid’s base
• Packaging needs to technically **leapfrog** to provide product protection and a market
• Packaging can **facilitate** manufacturing value added goods versus raw material exports
  • Reveals opportunity to use **historically** indigenous materials (eg: jute)
• Research **potential** in facilitating leapfrogging in technology is high
Align for volatility

- VUCA (volatile, uncertain, complex, ambiguous) society demands agility in packaging
- By focusing on each link’s value, packaging can uniquely offer this agility
  - Packaging’s various finished goods phases enable faster reaction time
    - Example - skin graft packaging & disaster mgmt
  - Packaging’s role is evolving within the value chain
  - Research on increasing responsiveness, core technologies (inks, tertiary packaging, labeling, GFSI, FSMA, REACH) have focused innovation on finished goods flexibility
Select Roles of Packaging for Milk

- Provide a barrier
- Enable Manufacturing agility
- Enhance consumer interface
- Incorporate sustainability
- Enable Distribution and handling
- Enable safety
Enable Safety
## Value Chain packaging solutions to food safety are focused

<table>
<thead>
<tr>
<th>Causes/Categories</th>
<th>Category Z</th>
<th>Category Y</th>
<th>Category X</th>
<th>Category W</th>
<th>Category V</th>
<th>Category U</th>
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| Pkg. Prop.        |            |            |            |            |            |            |            |            |
| Water resistance  |            |            |            |            |            |            |            |            |
| MVTR              |            |            |            |            |            |            |            |            |
| Antimicrobial     |            |            |            |            |            |            |            |            |

| Packaging and Handling |            |            |            |            |            |            |            |            |
| Reduce impact of contam. ingredients |            |            |            |            |            |            |            |            |
| Reduce contamin. during product fill |            |            |            |            |            |            |            |            |
| Assess initial microbial load |            |            |            |            |            |            |            |            |
| Reduce initial microbial load |            |            |            |            |            |            |            |            |
| Reduce cross contamin. |            |            |            |            |            |            |            |            |
| Enable processing of some ingredients |            |            |            |            |            |            |            |            |
| Enable HACCP      |            |            |            |            |            |            |            |            |

| Distribution & Retail |            |            |            |            |            |            |            |            |
| Address chilled worker conditions |            |            |            |            |            |            |            |            |
| Time & Temp monitoring system |            |            |            |            |            |            |            |            |
| Oxygen level monitoring system |            |            |            |            |            |            |            |            |
| Control temperature |            |            |            |            |            |            |            |            |
| Measure microbial load at POS |            |            |            |            |            |            |            |            |

| Consumer Use       |            |            |            |            |            |            |            |            |
| Enable safe package reuse |            |            |            |            |            |            |            |            |
| Reduce consumer contamin. from repeat use |            |            |            |            |            |            |            |            |
| Expand time for safe product use |            |            |            |            |            |            |            |            |
| Enable oven/MW monitoring |            |            |            |            |            |            |            |            |
| Address eating hygiene through packaging |            |            |            |            |            |            |            |            |
| Enable freezer storage |            |            |            |            |            |            |            |            |

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## Value Chain packaging solutions focus innovation

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<th>Needs/Categories</th>
<th>Package Properties Technology Solutions for Category X</th>
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<td>Chemical</td>
<td>Grease resistance</td>
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<td>Water resistance</td>
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<td>Define exact OTRs and MVTRs</td>
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<tr>
<td>Time &amp; Temp monitoring system</td>
<td>Oxygen level monitoring system</td>
<td></td>
</tr>
<tr>
<td>Control temperature</td>
<td>Measure microbial load at POS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consumer</th>
<th>Needs/Categories</th>
<th>Consumer Technology Solutions for Category X</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Enable safe package reuse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expand time for safe product use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enable oven/MW monitoring</td>
<td></td>
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</tbody>
</table>
Intelligent packaging can improve safety

- Focus on:
  - TTI
  - Degradation sensors
  - No-Fraud assurance packaging
  - Responsive packaging
TTIs are a refined proven technology

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

\[ k = Ae^{-E_a/(RT)} \]
Intelligent packaging-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-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
Common sensors

- 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-status

- TTIs 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
Select Roles of Packaging for Milk

- Provide a barrier
- Enable Manufacturing agility
- Enhance consumer interface
- Incorporate sustainability
- Enable Distribution and handling
- Enable safety
Milk Packaging - some takeaways

- LED (low intensity) and PET, with a better O2 barrier, offer opportunity for increased shelf life
- Sustainable packaging choices and milk shelf life need alignment
- Distribution and handling improvements are possible
- Increased manufacturing agility opens doors
- Enhanced consumer interface reduces commoditization
- Intelligent packaging offers brand and safety benefits
- Value chain solutions are essential
Food science and packaging expertise
• Coaching
• Consulting
• Technology
• Strategy

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