STATE OF THE ART OF ACTIVE/INTELLIGENT FOOD PACKAGING

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OVERVIEW

- Definitions
- Active packaging
  - Moisture
  - Oxygen
  - Ethylene
  - Microbiological
- Intelligent packaging
  - Temperature
  - Location
  - Microbiological status
CONCLUSIONS

- Developmental
  - Many good laboratory results
  - Relatively little commercial application
    - Cost
    - Accuracy
    - Adverse secondary effects
- Commercialization has been relatively slow
  - Purge, moisture control
  - Oxygen removal
  - Time temperature integrators
  - Location/identification
CONCLUSIONS

- Potential for future
  - Combine moisture control with antimicrobials
  - Inventory monitoring
  - Interaction of package with home and food service appliances
  - Temperature data
  - Reduced oxygen to prolong biochemical shelf life
  - Stimulates enhanced barrier packaging
NEEDS FOR FUTURE

- Improved communication among academic, industry and others involved
- A single independent objective resource to objectively evaluate developing technologies
- Closer targeting of longer term commercial needs
ACTIVE PACKAGING

- Active packaging is sensing followed by the overt manipulation of the environment in the package to better retain food content microbiological or biochemical quality
  - Purge absorbers
  - Microwave susceptors
  - Oxygen scavengers
  - Oxygen additions
  - Moisture absorbers or emitters
  - Odor absorbers or emitters
  - Anti or counter microbials
  - And other controllers of active variables
INTELLIGENT PACKAGING

- An intelligent package senses change and communicates that information to can provide benefits (such as more convenience, better safety, or higher quality) if used.
- Examples
  - Time-temperature, etc. indicators can imply/signal user the quality of the packaged product
  - Biosensor in theory can inform the user of the presence or growth of microorganisms, spoilage and even pathogenicity in the package
  - Bar or PDF code can help to provide better reheating and/or cooking
  - Ripeness
  - Nutritional attributes
  - Gas concentrations in modified atmosphere packages
ACTIVE PACKAGING

- Moisture control
  - Desiccants for dry food
    - Internal
    - Multiphase plastic for both pre and post opening activity
  - Humidity controllers
    - For high moisture foods, e.g. cut fruit, vegetables
    - To retard moisture loss
    - To retard excess moisture in headspace and interstices where microorganisms can grow
- Integrate moisture control with other active packaging functionalities
  - e.g., antimicrobials, pH controllers, oxygen removers
Active Packaging

- Purge absorption
  - To remove liquid squeezed or leaking from fresh products such as meat, poultry and fruit
- Unsightly
- Medium for microbiological growth
- Odor generating
- Leaks into consumer environment: source of major consumer complaints

- Controlled by pulp or polymers
Active Packaging

- Purge absorption
  - Can be enhanced by active additives
    - Antimicrobials
    - pH reducers
    - Carbon dioxide generators
  - The largest commercial application of active packaging although not always classified as active packaging
Purge Absorbers - Pulp
Maxwell-Chase Polymeric Purge Absorbers
CONTROLLED PURGE FRUIT PACKAGE
ACTIVE PACKAGING

- Moisture control
  - Desiccants for dry food
- Internal adjuncts
  - Porous sachets or perforated plastic cartridges
  - Mostly for pharmaceuticals for long term preservation
- Incorporate into plastic package
  - Plastic is partial moisture barrier
  - Multiphase plastic for both pre and post opening activity
    - Largely for multi-use drugs/testing devices
MINIPAX® SORBENT PACKETS

MiniPax® Sorbent silica gel packets are formed of heat sealed Tyvek® spunbonded polyolefin.
Active Packaging

Humidity controllers

☐ For high moisture foods, e.g. cut fruit, vegetables
☐ To control in-package relative humidity
☐ To retard moisture loss
☐ To retard excess moisture in headspace and interstices where microorganisms can grow
☐ Infrequently used
ACTIVE PACKAGING: OXYGEN REMOVERS

- Oxygen scavengers
  - To remove oxygen and retard oxidative reactions
  - As sachets in headspace
    - Jerky
    - Pepperoni
    - Pasta
    - Bakery goods
  - As labels – with less quantity of active component
  - Incorporated into package materials
    - Plastic beer bottles
    - Pasta
    - Retortable pouches and trays
OXYGEN SCAVENGERS

- Mitsubishi Gas Chemical Ageless; Multisorb Technologies, etc., oxygen absorbers
  - Ferrous oxide in Tyvek spun bonded polyolefin sachets
  - Water vapor activated
  - “Rusted” to ferric oxide by reacting with environmental oxygen
  - In excellent oxygen barrier primary packages, removes residual and entering oxygen
  - Used widely in Japan for dry meats, bakery goods, nuts
  - Not overly successful in North America or Europe
- Ascorbic acid, sulfites, photosensitive dyes, unsaturated hydrocarbons and ligands
- Oxbar™ cobalt catalyzed nylon MXD6 imbedded in the plastic structure
Mitsubishi Ageless® Oxygen Absorber

Comparison Effect of AGELESS

Pizza Crust

After 5 days @ 25°C.

AGELESS packet

Control

After 20 days @ 25°C.

AGELESS packet

Control
MULTISORB OXYGEN ABSORBERS

FreshPax™ Packets and Strips are designed to absorb oxygen inside sealed packaging to less than 0.01%

FreshMax™ Label is designed for adhesion with high value foods where oxygen absorption requirements are at levels below 50 cc.
Oxygen Scavenger Label
OXYGEN SCAVENGERS

- Chevron Phillips OSP oxygen scavenging polymer
  - EMCM: Benzoacrylates
  - No resulting odor from oxidation reaction
  - Basis for current Cryovac OS2000
    - Incorporated in film
    - Lidding on Barilla moist pasta, processed meat trays
  - Ultraviolet energy triggered
  - Claimed capable of reducing oxygen to 4-10 ppm
  - Departing the business
Oxygen Scavengers

- Starshield
  - Crown Cork and Seal
  - Constar
- PET bottles
  - Multilayer preforms
  - PET/5 % Oxbar/PET
  - Oxbar=MXD6 nylon + Cobalt catalyst
  - For beer and juice
- Continental PET Technologies
  - MXD6 nylon + Cobalt catalyst
PET BEER BOTTLE WITH OXYGEN SCAVENGERS
Oxygen Scavengers

- Amcor PET
  - Bind-Ox
  - Amguard multilayer preforms
  - PET bottles
  - Beer and juices
Oxygen Scavengers

- BP Chemicals
  - Amosorb ferrous iron
  - Licensed by Color Matrix
  - PET bottles
    - Monolayer or multilayer

- Bericap
  - One piece bottle closure with multilayer oxygen sulfite scavenger
Oxygen Scavengers

- O-Ox
  - Snappy Apple
  - Claims 5X oxygen removal rate
  - Ferrous iron based concentrate
  - For plastic beer bottles
Oxygen Scavengers

- Honeywell
  - Blend scavenger with nanocomposite to enhance barrier
  - Aegis Ox – OXCE
  - Removes oxygen
  - Restricts oxygen AND carbon dioxide
  - Plastic beer bottle
Oxygen Scavengers

- Actituf
  - Monolayer PET
  - Liquid activated+passive barrier
  - Plastic beer bottles
- Unsaturated hydrocarbon butadiene: produces off odors
- Glucose oxidase
  - Nutraceuticals
  - Can simultaneously produce carbon dioxide as an antimicrobial
Oxygen Scavengers

- Huhtamaki
  - Combine scavenger with EVOH
  - Grey color

- Hsaio Sung – Taiwan
  - O-buster ferrous iron
  - For consumer use
  - Sachets
Oxygen Scavengers

- Ciba
  - Shelfplus
  - Ferrous iron based
  - Now combining with EVAL’s EVOH
    - Bebo Plastik
  - For polypropylene and even polyethylene
    - Semi-rigid containers
    - Retort trays
Oxygen Scavengers

- Mitsui – Japan
  - Wonderkeep
  - Integrate with RFID

- Wipak
  - Combitherm
  - Multilayer of scavenger and EVOH
ADD OXYGEN

☐ To retard respiratory anaerobiosis
  - Responsive to temperature
  - Intellipack™ increases/controls package gas permeability to permit entry of air as a function of temperature

☐ To retard respiratory anaerobic pathogenic microbiological growth

☐ To retard respiration in cut lettuce: > 70% oxygen
  - Oxygen generating chemicals in package structure
  - From Atco, France

☐ To “control” oxymyoglobin red color in fresh meat

☐ But does the oxygen reach into pockets and interstices?
CARBON DIOXIDE CONTROL

- Add carbon dioxide from package structure to carbonated beverages to compensate for losses due to insufficient gas barrier
- Add carbon dioxide to increase internal environmental gas to suppress microbiological growth
  - A sub-set of modified atmosphere packaging
  - From plastic package structure
  - From moisture-activated chemicals in sachets, absorbent pads, etc.
- Remove excess carbon dioxide from fast respiring produce using very high gas permeability plastic
  - Asparagus
OTHER ACTIVE PACKAGING CONCEPTS

- Odor scavengers
  - Remove trivial amounts of odor such as from initial lipid or plastic oxidation from package headspace
  - Activated carbon
    - Most effective
    - Best when on interior surface
      - Multiphase plastic
  - Cyclodextrins
  - Molecular sieves
  - Alpha tocopherol (vitamin E)
  - Polyethylene imide aldehyde scavengers
ODOR CONTROL

☐ Aroma additions
  ■ Enhance the product sensory attributes
  ■ May be incorporated into plastic
    ☐ Continuous emission
    ☐ Activated by physical activity
  ■ May be on plastic surface
  ■ May be independent device such as an impregnated straw or closure
  ■ Activate on opening
ETHYLENE ABSORBERS

- Ethylene is respiratory gas from fresh produce – also from engine exhaust fumes
- Excess ethylene accelerates respiration
- Remove ethylene extend shelf life
  - Physical absorption
    - On active surfaces
      - Activated carbon
      - Zeolite
  - Chemical removal with permanganate
    - Effective and commercial – in bulk distribution

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ACTIVE PACKAGING: ANTI-MICROBIAL

- Antimicrobial or countermicrobial
  - Objective is to reduce the rate of growth of spoilage and/or pathogenic microorganisms in the contained food and thus extend the shelf life
  - Technologies under study
    - Silver ion
    - Allyl isothiocyanate
    - Chlorine dioxide
    - Antibiotics
    - Organic acids
    - Ethyl alcohol
    - Natural spices and essential oils
  - None commercial for food packaging in United States

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ANTI-MICROBIALS

- Silver salts
  - Direct contact
  - Slow migration
  - React with organics preferentially
  - Broad spectrum effectiveness
  - Surface effects primarily
  - Few, if any, secondary effects
ANTI-MICROBIALS

- Ethyl alcohol
  - Adsorbed on silica or zeolite
  - Emitted by evaporation
  - Somewhat effective
  - Secondary odor
  - Regulatory restrictions
  - Consumer concern
  - Used in past for soft bakery goods
ANTI-MICROBIALS

- Chlorine dioxide
  - Widely publicized
  - Precursor in package structure
    - Reacts with water to produce ClO₂
    - ClO₂ is vapor and can permeate product
  - Broadly effective against microorganisms, but weak
  - Adverse secondary effects
    - Meat color darkening
    - Green vegetable bleaching
  - Principal advocate no longer in business
ANTI-MICROBIALS

- Allyl Isothiocyanate (AIT)
  - Active component in wasabi, horseradish, mustard
  - Broad spectrum anti-microbial, antimycotic
  - Strong secondary odor effects
  - Possible amelioration by vanillin

- Other essential oils
  - Clove, carvacrol, thymol, cinnamon, etc.
  - Diacetyl
AND MORE ACTIVITY FOR THE FUTURE

☐ Heat the contents on demand: self heating
☐ Chill the contents on demand: self chilling
☐ Both of the above have been commercial
  ■ At a cost
  ☐ Money
  ☐ Space
☐ Sense the temperature and control the content temperature
  ■ To compensate for the deficient distribution system (cold chain)
Self Heating Packaging
Self Heating Packaging

- Calcium oxide + water exothermic reaction
  - Magnesium oxide + water exothermic reaction
- For coffee) cans
  - Polypropylene barrier
  - Wolfgang Puck
  - Retorted
  - 6-8 minute heating time after activation
- Military rations
- On the go meals
- Heating device occupies large space volume
Self Heating Coffee Can
Self-Cooling Packaging

- Evaporation of external compound removes heat from contents
  - Freon – not environmentally sound
  - Carbon dioxide – pressurized
  - Water evaporated and adsorbed on surfaces –
    - Functional and commercial for beer kegs
    - Reversible
ACTIVE PACKAGING: MICROWAVE BROWNING

- Packaging devices to achieve surface browning and crusting in rapid heating microwave oven environment
- Limited technical ability
- Limited market success
  - Bakery goods
  - Finger foods
  - Popcorn popping adjunct
Susceptors

Susceptor materials consisting of a metallized coating at optical density of around 0.25.
SHIELDING WITH REFLECTORS

Without Shielding
(Over-exposure of the edges)

With Shielding
(Reflector shields the edges and redirect the power to the center)
MICROWAVEABLE PIZZA WITH SUSCEPTOR, SHIELDING AND FOCUSING
INTELLIGENT PACKAGING

- If you can measure a variable, you can probably control it
- Location Indicators
  - The current classical application for Radio Frequency Indentification (RFID)
  - For distribution inventory control
    - Site
    - Time
    - Quantity
Intelligent Packaging

- Oxygen scavenging with integrated monitoring
- Ethylene scavenging with integrated monitoring
- Microwave ready
- Thermochromic inks
- Barrier plus integrated monitoring
- Self-heating/cooling plus monitoring
INTELLIGENT PACKAGING: TEMPERATURE EXPERIENCE

- Temperature indicators
  - Time temperature integrators
    - Commercial and in use
    - Significance of TTI data re: shelf life, quality, etc.
    - Required for military rations and some pharmaceuticals
  - Cost
- Maximum temperature, i.e., threshold, indicators
  - Commercial and in use
  - Mostly for heating
  - Some for refrigerated, frozen foods, ice cream
CURRENT COMMERCIAL TTI PRODUCTS

- LifeLines Fresh-Check
  - Based on polymerization reaction
- 3M Monitor Mark
  - Based on dye diffusion
- Vitsab® TTI (Cox Technologies)
  - Based on enzymatic lipase color change
Lifelines’ Fresh Check indicators are color-changing, self-adhesive labels which respond to cumulative exposure to temperature. The indicator center irreversibly darkens, faster at higher temperatures. Price ranges from US $0.025 – 0.035 each.
Upon exposure to temperatures above the threshold, the activated indicator's window irreversibly turns blue.
The MonitorMark time temperature indicator contains a porous wick indicator track strip, one end of which is positioned over a reservoir pad containing a blue dyed chemical with a desired melt point.
Vitsab Single Dot Label (TTI)

Central raised portion (pouches)
pre-activation = 0.080"
pree-activation = 0.060"

0.08” label thickness
(including adhesive layer)

Single dot Vitsab’s CheckPoint™ brand labels: (1) distribution temperature monitoring of cartons or pallets of product, and (2) distribution or consumer package unit.
INTELLIGENT PACKAGING

- Food preservation
  - Senses the age, quality level of the food and signals
  - Signals on exterior of food storage area
  - Has been demonstrated in laboratory
  - Usually a secondary measurement
    - Measures time/temperature
    - Signals based on history
  - Publicized as mechanism to incorporate tighter temperature controls into distribution channels
SHELF LIFE SENSING

- Developmental
  - RFID remote sensor
  - Chipless with internal paper battery
  - Smart active label – SAL – with chip
  - Can be added to logistic sensor
  - Sense time temperature
  - Send signal to reader
  - Display time temperature record or integral
Food: Microbiological Growth/Spoilage Indicators

- Rapid microbiological indicators do not exist in real commercial world
- Rapid microbiological spoilage sensors do not exist in commerce
- Rapid microbiological pathogen indicators do not exist in commercial world
- Consumer smell, observations and judgment are today the best signals of food spoilage or hazard.
  - Do instrumental, etc. sensors truly reflect spoilage?
- Alternative is tedious laboratory analysis
BIOSENSORS

- Biomolecular recognition
  - Antigen-antibody
  - Phage capture
    - Spores
    - Bacteria
    - Higher capture rate than antibodies
  - Both highly specific
BIOSENSORS

Sensor platforms
- Acoustic wave
  - Thickness shear quartz resonator
  - Microcantilevers
    - Laser measured
- Flexure plate wave devices
  - Piezoelectric actuated
- Piezoelectric polymer devices
- Microelectric-mechanical-magnetostrictive devices
- All require on-board power and connection to RFID
BIOSENSORS

- Sensor platforms
  - Surface plasmon
  - Magnetostrictive
    - Integrated with antibody/phage layer
    - Oscillation
    - Produces magnetic field signal
Food: Microbiological Growth/Spoilage Indicators

- The former Cox Technologies
  - Respond to amine and sulfide volatiles from spoilage
  - Used to colorimetrically signal seafood microbiological spoilage
  - Commercial
Ripeness Sensors

- ripeSense Label
  - Reportedly senses aromatics emitted from ripening fruit
  - Signals ripeness by label visual cue/color change – for fruit that does not change color during ripening
  - Pears
  - Melons
  - Avocados
**UPC (Universal Product Code) Bar Codes**

The first digit of the manufacturer is called the number system character: 0 for standard UPC number, 2 for random weight items (fruits, vegetables, meat), 3 for pharmaceuticals, etc.

- **Manufacturer ID (6 digits)**
- **Item Number (5 digits)**
- **Check Digit (1 digit)**

UPC of 12 oz can of Coke

Packaging/Brody, Inc.
PDF 417 Symbol (2-Dimensional)

- PDF417 is a two-dimensional symbol
- It can carry up to 1.1 kilobytes of machine-readable data in a space no larger than a standard bar code.
- A PDF scanner is required to read PDF symbols. Ordinary bar code scanners would not work.
- PDF stands for “Portable Data File”
INVENTORY “CONTROL”

- Determine the presence, absence or impending decrease in quantity of a packaged food in pantry/refrigerator inventory
- Signal consumer that the pantry is empty or near empty
  - Alert consumer to restock
- Signal retail grocer that Mr./Mrs./Ms. X is low on product and to remind her/him by telephone, e-mail or by sending replenishment stock
- Signal distribution center that the stock is low or out
- Indicator on package as empty package is discarded
- Active signaller – or messenger to grocer - on package as empty package is discarded
INTELLIGENT PACKAGING FOR THE HOME/FOOD SERVICE OPERATOR

- Inventory control
  - Tracks inventory of food in home
  - Senses when empty package is discarded
  - Places tentative order with retailer/delivery service
  - Confirm by consumer
- Complemented by interaction with retailer
  - Special requests
  - Change order schedule
INTELLIGENT PACKAGING FOR THE HOME/FOOD SERVICE OPERATOR

- Provides product information
  - Recipe specific to consumer’s “kitchen” equipment
  - Nutritional characteristics
    - Beyond reading the label
    - Integrates individual consumer’s nutritional needs
    - Takes into account the age and time/temperature experience
    - Overtly signals the individual consumer as to dietary value
INTELLIGENT PACKAGING FOR THE RETAILER

- Automatic self-check out
- No direct reading by scanner
- RDID or equivalent
  - Printed on package
  - Read remotely as consumer moves out of retail establishment
  - Totals all items acquired
  - Debits consumer account
  - No movement of product from “shopping cart”
- Automatic shelf price change
INTEGRATE PACKAGING WITH APPLIANCES

- Many attempts to integrate food packaging and food heating appliances
  - Generally few successful marriages
  - Microwave reheating for home meal replacements
    - But not appliance specific
    - Do not accommodate to the wide variety of microwave ovens
  - Other appliances
    - Toaster ovens
    - Refrigerators
    - Coffee brewers
FOOD PREPARATION: MICROWAVE

- Microwave ovens
  - Major differences in ovens
    - Power levels
    - Distribution of energy
    - Age of oven
  - Major differences in energy absorption
  - Microwave heating now judged by operator
  - Automatic control integrates food, package and oven
COOKING/HARDWARE

- Trends
  - Multi-modal heating
    - Single mode too limiting
  - Multi-modal cooking
    - Consumer education
    - Cost higher than conventional
    - Food processor/packager involvement
      - Not all foods can be prepared in multi-modal ovens
  - High speed oven
  - Smart ovens
SMART OVENS

- Because new energy source ovens cook differently, automatic operating controls are required
- Convert from conventional recipes and cooking instructions
- Download recipes from internet since consumers will need directions
HEALTH MONITORING

- Records the food intake by the consumer. Display a summary of food intake, nutritional and other information.
- Connect to an electronic scale for monitoring the weight of the consumer.
- Provide the consumer useful suggestions based on the above information. The information may also be transmitted to the doctor’s office.
THE FUTURE

- Food shelf life will be shorter
- Time in home will be shorter
- Food preservation and preparation will integrate with packaging
  - Packaging will be integrated with processing and distribution
  - Package will be a preparation and serving aid
NEEDS FOR THE FUTURE

- Visible inventory communication for refrigerated and frozen foods
  - Age
  - Time temperature integral
    - Possible quality signal
  - Overt signal to consumer
NEEDS FOR THE FUTURE

- Cooperation among food processors, retailers which offer prepared foods
  - Product packaging to fit home processing
  - Instruction
  - Linkage by computer sensor read and response
  - Long term program
THE FUTURE

- Long term
  - Accurate information
    - Target each household member individually
  - Quality
    - Flavor, mouth feel
    - Nutrient value
    - Other value
  - “Spoilage”
  - Preparation directions based on food, consumer and in-home equipment/interface
- Communication channel/message
THE FUTURE IS PURCHASED BY THE PRESENT

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