Preservation of Food through Packaging: Opportunities, Potentials and Challenges for Active and Intelligent Packaging

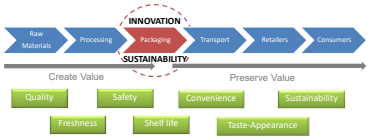
Selçuk Yildirim
Zurich University of Applied Sciences
8820 Waedenswil, Switzerland

Center for Technology and Packaging

Zurich University of Applied Sciences
Department of Life Sciences
Institute of Food and Beverage Innovation



Food Packaging Research



Innovative and Sustainable Packaging Development for Optimal Food Quality and Convenience

Active Packaging for Food

- Opportunities
  - Consumer awareness of health and wellness
  - Food loss and food waste
  - Sustainability
- Potentials
  - Global and european active packaging market
  - Benefits to foods
- Challanges
  - Packaging and Food Interactions

Opportunities

1. Consumer awareness of health and wellness

- Health awareness is the most important packaging growth driver
- Consumer health concerns are an increasing influence in many end-use markets for packaging
  - Rising sales of bottled water, fruit juice and milk drink markets in many countries,
  - Sales of spirits and, in some countries, carbonated soft drinks decreasing
  - Increasing demand for packaged fresh food products
  - Increasing demand for minimally processed, "fresh like", clean label products


Source: Pira/ WPO Survey

Consumer awareness of health and wellness

Increase in health awareness
- Less preservatives
- Less additives
- More natural ingredients
- Less processing
- Less preservation techniques



- New challenges for packaging
- Packaging has to compensate the preservation function
- Better barrier functions, new design, new preservation functions

2. Food Loss and food waste

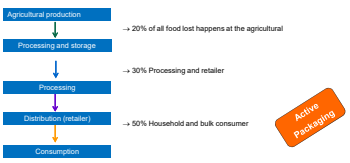
- 1/3 of edible food is wasted
  - → 1.3 billion tons per year (Gustavsson C. et al., 2011)
- Europe: 245 million tons per year
  - → 39.4% of available food (Skjoldebrand C., 2008)
- Switzerland: 2 million tons per year
  - → 300 kg per person per year (WWF & foodwaste.ch, 2012)

→ A significant part is avoidable

Skjoldebrand C., 2008

Food loss and food waste

- **Food loss through the food value added chain**

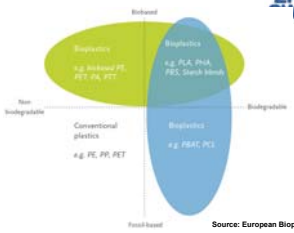


foodwaste.ch, 2012

3. Sustainability -Material Substitution

- Over the past few decades there have been significant changes in the relative proportions of the packaging materials glass, metal, paper and plastics used to pack food.
- Most noticeable has been the switch from glass (and to a lesser extent metal) to plastics
- From rigid to flexible packaging

Sustainability: Biopackaging



Source: European Bioplastics e.V.

Active Packaging for Food

Active packaging has potential to be used

- to extend the shelf life of the product (fresh produce and foods with short shelf life)
- to reduce or remove preservatives from food formulations (fresh, clean label)
- to decrease the food lost (food with short shelf lives)
- to enable to use particular types of packages (PET bottles)
- to simplify processing (additional hurdles)
- to prepare and to present the food (microwave susceptors)
- to develop new products (Some products could be only possible to develop if active packaging technologies are applied to preserve the quality)

Potentials

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Active Packaging Market

- The largest segment is oxygen scavengers with a 25.7% share
- Moisture scavengers have 25.3%, self-venting films have 14.4% and ethylene scavengers and emitters have 9.4%
- The fastest growth is recorded in antioxidants, although volumes are small, followed by temperature controlled packaging, antibacterial films and ethylene scavengers and emitters.
- Food is the largest segment with an 80.1% share; beverages have 10.1% and non-food 9.8%
- The fastest growing segments are ready meals, fresh fruit and vegetables and beverages

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Active Packaging Systems for Food

Active packaging	Example of benefits	Possible food applications
Antimicrobial releasers	Inhibition of growth of pathogens and spoilage microorganisms on food	Fresh meat, processed meat, fish, bread, cheese, cakes
Carbon dioxide releasers	Inhibition of growth of aerobic bacteria and molds	Fresh meat, fish, cakes
Antioxidant releasers	Inhibition of oxidation of fats and oils	Snack foods, dried foods, meat
Flavour releasers	Enhancing the flavour of food	Cereals, dried foods
Ethylene releasers	Accelerated ripening	Fruits, vegetables
Oxygen absorbers	Inhibition of oxidation of food component and growth of aerobic bacteria, yeast and molds	Bread, snack foods, dried foods, wine, cakes, tea, nuts, milk powder
Moisture absorbers	Remove the excess moisture	Snack foods, cereals, dried foods, sandwiches
Ethylene absorbers	Reduce the rate of ripening	Fruits, vegetables
Carbon dioxide absorbers	Prevention of bursting of the package	Coffee
Odour absorbers	Improving the flavour of the food	Fried snacks

Antimicrobial Packaging

Introduction

Antimicrobial packaging

- can help to maintain food quality by
  - inhibiting the growth of food spoilage microorganisms (bacteria, yeast and molds)
  - preventing the organoleptic spoilage of the food due to the production of off-flavors, unpleasant odors and slime
- can contribute to food safety by
  - inhibiting the food pathogens and toxin producers (*C. botulinum, L. monocytogenes, Salmonella, E. coli, S. aerous, B. cereus, Campylobacter*)

Antimicrobial Packaging

- Antibacterial food packaging are change the atmosphere inside the package, reduce the proliferation of bacteria and thereby increase the shelf life of the food
- In fresh or processed food, the development of bacteria occurs mainly on the food surface. Traditionally, antimicrobial agents are added directly to the whole bulk of food
- Their activity could be inhibited as a result of interaction between preservatives and nutrients in the food
- Effectiveness of antimicrobial agents could be reduced by diffusion into the food, or evaporation.
- The activity of the antimicrobial agents could also be inhibited by processing
- For these cases, antibacterial packaging can be more effective (less agents, more effective)

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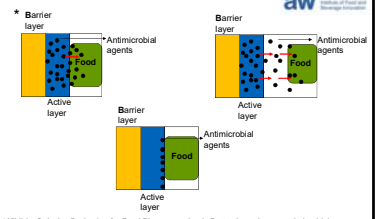
Antimicrobial Packaging Systems



* Yildirim S. Active Packaging for Food Biopreservation in Protective cultures, antimicrobial metabolites and bacteriophages for food and beverage biopreservation, Ed. Christophe Lacroix, Woodhead 2014

Natural Antimicrobial Agents

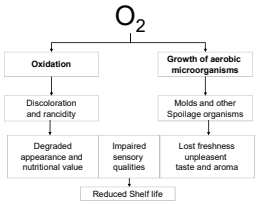
- Natural antimicrobial agents occur in nature or isolated from microbial, plant, or animal sources.
- Antimicrobial agents produced by microorganisms include
  - bacteriocins such as nisin or pediocin
  - antibiotics such as natamycin
  - organic acids such as sorbic and benzoic acids
  - enzymes such as lysozyme
- Plant origin antimicrobial agents include
  - extracts of spices such as thyme, oregano etc..
- Chitosan is an example of natural antimicrobial polymer obtained by deacetylation of chitin obtained commercially from shrimp and crabshell.

Chemical agents

- According to the EU regulations (Commission regulation (EC) No 450/2009) active agents that are incorporated into the packaging material to be released into the food should comply the legislation on food additives.
- Chemical antimicrobial agents that are released from the packaging into the food or its environment should be food grade chemicals.
- Non-food grade chemicals can be incorporated into packaging if they are not released into the food (specific migrations).
- Fungicides such as imazalil and benomyl
- Silver in polymers as an antimicrobial agent
- Several silver-ion containing zeolite or glass systems have been incorporated into many polymers, such as polyethylene, polypropylene, and polyamide and become commercially available

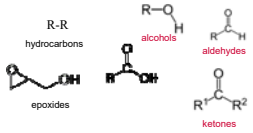
Oxygen Scavengers

Oxygen Effect on Food Quality



Oxygen Effect on Food Quality

- Auto-oxidation: Fatty acids at room temperature undergo a chemical change known as auto-oxidation



Characteristic stale, rancid, cardboard odors

Measures to exclude Oxygen

- Amount of oxygen in the headspace
  - The method of packaging
  - Packaging material
  - Oxygen conc. in food
- Vacuum packaging (cured meat, roasted and ground coffee)
- Packaging under inert gas (instant coffee, nuts)
- Deaerating (orange juice)
- Sparging with an inert gas (instant coffee, edible oil)
- MAP (fresh vegetables, cured meat, fresh meat)
- Heating to expel air (canned food, ketchup)
- Addition of antioxidants
- Addition of oxygen scavengers

Oxygen Scavenger

- Dry foods high in fat, such as beef jerky, processed, smoked and cured meats
- Nuts and snacks, dried coffee beans
- Spices and seasonings
- Cheese and dairy products
- Dried fruit and vegetables
- Flour and grain
- Birdseed and pet food
- Fresh and cooked pasta and noodles
- Bread, cakes, biscuits, confectionery
- Non-food products including pharmaceuticals, vitamin pills and uses such as medical diagnostic kits, syringes, preservation of books, artworks, consumer product packs

Ethylene Absorbers

- Ethylene is a **growth hormone** that functionsin the growth of plants and fruits
- It helps to **accelerate ripening in fruit**, followed by **aging** and ultimately **death**
- Ethylene production is a biochemical process, **independent of respiration**, that occurs in each living cell for the purpose of producing energy
- **Apples and kiwis** do not respire at high rates but do produce large amounts of ethylene. **Potatoes** respire slowly and emit small amounts of ethylene. **Asparagus** respires at a high rate and produces little ethylene
- Ethylene production is greatly increased during **bacterial or fungal infections** of fruits and vegetables, as well as by **mechanical and/or chemical damage** (stress ethylene)
- When ethylene is removed from the fresh fruit or vegetable environment, the **ripening and deterioration processes of plant products are slowed**, and so the storage life is extended

Ethylene Absorbers - Affects of Ethylene

Fruit	Intensity of ethylene production	Sensibility for ethylene	Affecs of ethylene
Apple	++	+	Tisue softening
Kiwi	++	+	Tisue softening
Banana	-	+	Tisue softening
Pear	+	+	Tisue softening
Grapefruit	--	-	Mould growth
Melon	+	-	Tisue softening
Tomato	--	+	Tisue softening
Assparagus	--	+	Toughening and thickening of fibres
Cucambers	-	+	Turns yellow and become soft

Moisture Absorbers

- Excess moisture is a major cause of food spoilage
- Soaking up moisture by various absorbers or desiccants is very effective in maintaining food quality and extending shelf life by inhibiting microbial growth and moisture-related degradation of texture and flavour
- Moisture ingress into the pack can also be detrimental to bakery and dried goods, causing spoilage and affecting the quality of these products
- Excess moisture from drip by meat and fish looks unappealing, affects the quality of the product and causes spoilage
- A moisture absorber can reduce the levels of moisture within the pack
- Moisture absorbers in the form of sachets, pads, sheets or blankets

Challanges

Packaging – Food Interactions

Packaging ➡ Food ➡ Preservation of Quality

Packaging ➡ Food ➡ Negative Effect on Quality

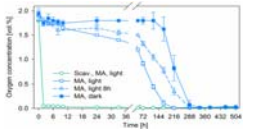
Packaging ⬅ Food ⬅ Increasing the Effect

Packaging ⬅ Food ⬅ Decreasing the Effect

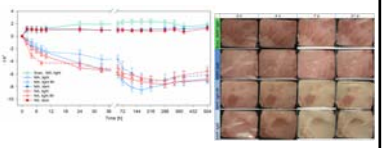
Packaging – Food Interactions

Packaging ➡ Food ➡ Preservation of Quality

$$H_2 + \tfrac{1}{2} O_2 \xrightarrow{Pd} H_2O$$



Yildirim S, Röcker B, Rüegg N, Lohwasser W. Development of Palladium-based Oxygen Scavenger: Optimization of Substrate and Palladium Layer Thickness. *Packaging Technology and Science* 2015, 28(8): pp. 710-718, DOI: 10.1002/pts.2134.



Hutter S, Rüegg N, Yildirim S. Use of palladium based oxygen scavenger to prevent discoloration of ham. *Food Packaging and Shelf Life* Volume 8, June 2016, Pages 56–62

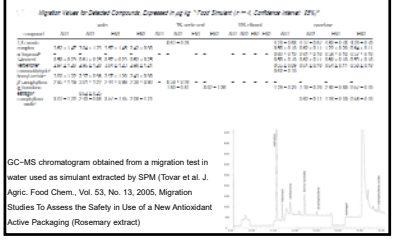
Packaging – Food Interactions

Packaging ➡ Food ➡ Negative Effect on Quality

Migration

Sensory

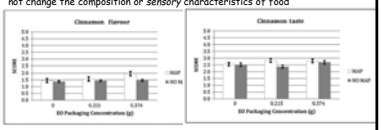
Migration



GC–MS chromatogram obtained from a migration test in water used as simulant extracted by SPM (Tovar et al. J. Agric. Food Chem., Vol. 53, No. 13, 2005, Migration Studies To Assess the Safety in Use of a New Antioxidant Active Packaging (Rosemary extract)

Sensory

EU Directive 1935/2004. '*Active* and *intelligent* food *packaging* materials should not change the composition or *sensory* characteristics of food

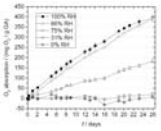


Gutierrez et al. Packag. Technol. Sci. 2011; 24 : 485 - 494, Evaluation of Antimicrobial Active Packaging to Increase Shelf Life of Gluten-Free Sliced Bread

Packaging – Food Interactions

Packaging ⟵ Food ⟵ Increasing the Effect

Effect of relative humidity on iron based oxygen scavenging system



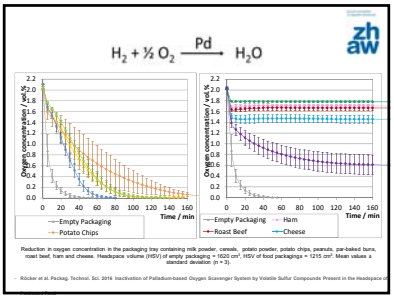
O2 absorption by gallic acid (GA) incorporated in multilayer films at 21 °C and different relative humidities (RHs) (Pant et al. Materials **2017**, 10, 489)

Packaging – Food Interactions

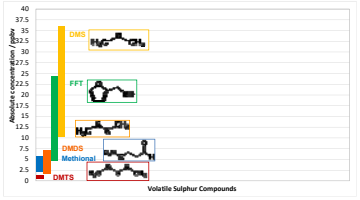
Packaging ⟵ Food ⟵ Decreasing the Effect

Effect of food components on the activity of films

-Silver based antimicrobial systems ➔ Meat



Results
Minimum Inhibitory Concentration Ranges of CSP Inactivation



CSP = Catalytic System based on Palladium, ppbv = parts-per-billion by volume

Results
Volatile Sulphur Compounds (VSCs) in Foods

Volatile sulphur compounds (VSCs)	Beef (Roast Beef)	Pork (Ham)	Potato Chips	Roasted Peanuts	Cheese	Bread
Dimethyl sulphide (DMS)	x		x	x	x	x
Dimethyl disulphide (DMDS)	x	x	x	x	x	x
Dimethyl trisulphide (DMTS)	x	x		x	x	x
Furfuryl thiol (FFT)	x	x	x	x		
Methional (MET)	x	x	x	x	x	x

Summary

- Why
- For what
  - Which food?, what conditions,
- Interactions between packaging and Food
- Migration and food Safety