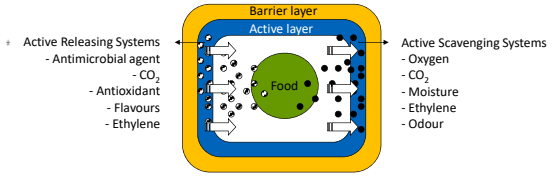
Active Packaging for Food

Selcuk Yildirim, Bettina Röcker, Marit Pettersen, Julie Nilsen-Nygaard, Zehra Ayhan, Ramune Rutkaite, Tanja Radusin, Patrycja Suminska, Begonya Marcos, Veronique Coma

COST Action FP1405
Active and intelligent fibre-based packaging – innovation and market introduction

Introduction – Active Packaging

Active Packaging: „..designed to deliberately incorporate components that would release or absorb substances into or from the packaged food or the environment surrounding the food“ Regulation (EC) No 1935/2004



* Yildirim S. Active Packaging for Food Biopreservation, in Protective Cultures, Antimicrobial Metabolites and Bacteriophages for Food and Beverage Biopreservation, Lacroix C (ed). Woodhead Publishing: Cambridge, 2011. 2

Forms of Active Packaging

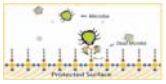
Active packaging can be incorporated in different formats

Sachets or other inserts

Label

Incorporated into the packaging material

Functional coating



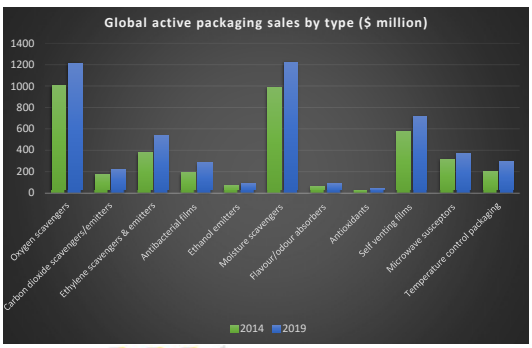
Film

Potential Applications

Active packaging has potential to be used

- to extend the shelf life of the product (fresh produce and foods with low 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 (Biopackaging, flexibles, transparent window)
- 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)

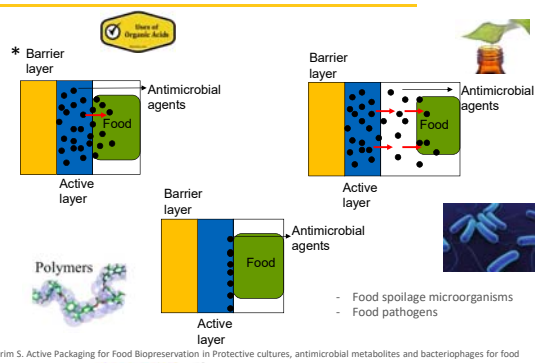
Market Potential



Source: Pira International Ltd.

Technologies

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, 2011

ANTIMICROBIAL PACKAGING -

- 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.

ANTIMICROBIAL PACKAGING - ESSENTIAL OIL

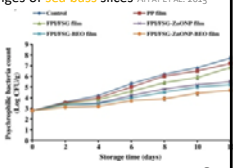
- Cinnamon EO – Retard of mould growth of bakery products NOSHIRVANI ET AL. 2017

After 2 weeks (50% RH, 23°C), chitosan film incorporated cinnamon

No visible fungal growth with 5% (w/w) cinnamon

- Basil leaf EO – Prevention of microbial and sensory changes of sea bass slices AFFAT ET AL. 2015

Psychrophilic bacterial count of sea bass slices wrapped without and with different films (BEO = basil Leaf EO), storage at 4 °C for 12 days



- Carvacro EO – Retard mould growth of strawberries such as *Botrytis cinerea* CAMPOS-REQUENA ET AL. 2015

ANTIMICROBIAL PACKAGING - SORBIC ACID ORGANIC ACID

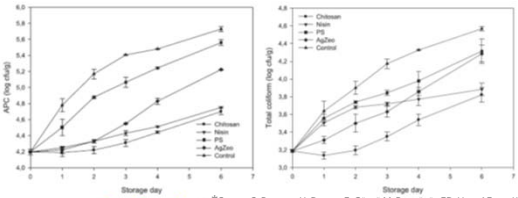
- Organic acids and their derivatives are well known preservatives for food application; can be also incorporated into packaging;
- For example 1% of sorbic acid into PLA films (with addition of alga *Fucus spiralis*) can protect megrim from microbial growth – the reduction of psychrotrophs of 0.9 log CFU/g in the comparison to PE films has been observed; also lower mean values of aerobes and Enterobacteriacae were observed (Garcia-Soto et al., 2015);
- Positive antioxidant effect – better sensorial properties (external odor, gill appearance) were reported;
- Sorbic acid incorporated into PVC prevents the growth of *Listeria monocytogens* on bologna slices with 7.1 logs lower population after 28 days of storage at 4 ^{0}C; and 1.3 logs on Cheddar cheese after 35 days of storage (Limjaroen et al., 2005).

ANTIMICROBIAL PACKAGING -

CHITOSAN, NISIN, POTASSIUM SORBATE (PS) OR SILVER SUBSTITUTED ZEOLITE (AGZEO) (2 %) INCORPORATED INTO LDPE FILM*

Effect of antimicrobial agents on APC (total coliform, mold and yeast counts) and total coliform counts of chicken drumsticks stored at 5°C for 6 days:

- The increase in APC in chitosan-incorporated packaging was about 0.5 log cfu/g whereas it was 1.53 log cfu/g in samples stored in control bags
- The lowest total coliform count observed in the chicken drumsticks packed with chitosan-containing film (increase from 3.19 to 3.82 log cfu/g, control – from 3.19 to 4.57 log cfu/g)



*SOYSAL Ç, BOZKURT H, DIRICAN E, GÜÇLÜ M, BOZHÜYÜK ED, USLU AE AND KAYA S. 2015 EFFECT OF ANTIMICROBIAL PACKAGING ON PHYSICOCHEMICAL AND MICROBIAL QUALITY OF CHICKEN DRUMSTICKS. FOOD CONTROL 54: P 294-99

ANTIMICROBIAL PACKAGING -

LYSOZYME AND LACTOFERRIN INCORPORATED INTO PAPER SHEETS*

The efficacy of the active papers on total aerobic count in samples of veal "carpaccio" (thin slices of veal fillet, meant for consumption as raw meat):

- Papers containing lysozyme and lysozyme/lactoferin performed the best on the microbiota in this meat samples, giving almost 1 log cycle reduction with respect to control (5.55 and 5.53 vs 6.48 log cfu/g).

Time (h)	Protein incorporated in the paper	Total aerobic count (log cfu/g)	Decimal reduction
0	None (control)	5.34 ± 0.09^a	–
48	None (control)	6.48 ± 0.11^b	–
48	LZ	5.55 ± 0.12^a	−0.93a
48	LF	6.30 ± 0.12^b	+ 0.18b
48	LZ and LF	5.43 ± 0.10^a	−1.05a

^{ab}means within the same column with different superscript letters are different ($P < 0.05$).

*BARBIROLI A, BONOMI F, CAPRETTI G, IAMETTI S, MANZONI M, PIERGIOVANNI L AND ROLLINI M. 2012. ANTIMICROBIAL ACTIVITY OF LYSOZYME AND LACTOFERRIN INCORPORATED IN CELLULOSE-BASED FOOD PACKAGING. FOOD CONTROL 26 (2): P 387-92.

ANTIMICROBIAL PACKAGING - NANOPARTICLES

Li L, Zhao C, Zhang Y, Yao J, Yang W, Hu Q, Wang C and Cao C. 2017. **Effect of stable antimicrobial nano-silver packaging on inhibiting mildew and in storage of rice**. Food Chem 215 477-82. DOI:10.1016/j.foodchem.2016.08.013

- The antimicrobial films were synthesized by blending polyethylene and highly dispersed nanoscale Ag/TiO_2 powder.
- Nano-packing has long-term antibacterial activity because of the strong interaction between Ag and TiO_2.
- Nano-packing retarded the changes of pasting qualities and texture of rice.

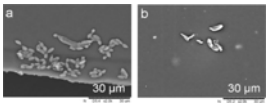


Fig. 1. The growth of *A. flavus* in NP (a) and ANP (b) films.

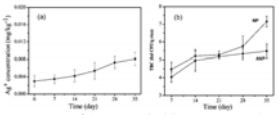
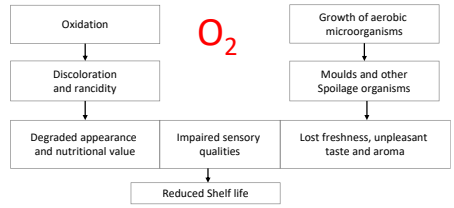


Fig. 2. Concentrations of silver ions in rice and total plant count on rice measured every week. Concentrations of silver ions (a) total plant count (b).

OXYGEN SCAVENGERS – NEEDS



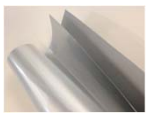
Oxygen scavengers can be used to remove the oxygen remaining in the headspace of packaging and thereby can prevent oxidation of food or growth of microorganisms in food, to maintain food quality and improve food safety.

OXYGEN SCAVENGERS - AVAILABLE TECHNOLOGIES

INORGANIC SCAVENGERS
- oxidizable metal powders, e.g. iron, zinc
- sulphite
- dithionite (sodium hyposulfite)
- photosensitive dyes

LOW- AND HIGH-MOLECULAR ORGANIC SCAVENGERS
- ascorbate (vitamin C)
- polyamide copolymers
- polyolefin copolymers (aliphatic or cyclic)
- unsaturated oils and fats

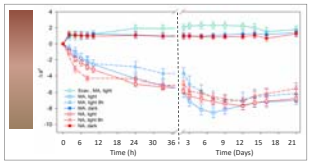
CATALYTIC SYSTEMS
- Pd-catalyst, Pt-catalyst
- Enzyme-based system, e.g. glucose



OXYGEN SCAVENGERS -

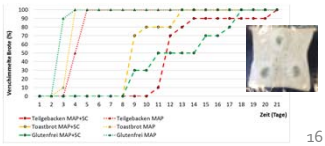
PALLADIUM (PD)-DEPOSITED ACTIVE FILM - PET/SiO_x/PD YILDIRIM ET AL. 2015

- Prevention of discoloration of cooked cured ham HUTTER ET AL. 2016



- With Pd-Scavenger:
- illumination 24 h/day
→ 21 days color preservation
- Without Pd-Scavenger:
- illumination 24 h/day
→ Discoloration started immediately after packaging

- Retard of mould growth of bakery products RÜEGG ET AL. 2016
- With Pd-Scavenger:
- 2-3 fold delay of mould growth for all types of bread



ETHYLENE ABSORBERS - NEED

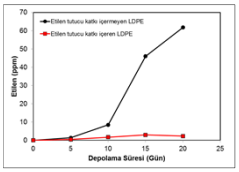
- Ethylene-Ripening hormone
  - accelerates senescence and softening
  - increases chlorophyll degradation
  - reduces shelf life of fresh and minimally processed fruits and vegetables

ETHYLENE ABSORBERS - ACTIVE FUNCTION / AVAILABLE TECHNOLOGIES

- A sachet containing potassium permanganate
  - oxidizes or inactivates ethylene
- The use of finely dispersed minerals (zeolite, active carbon, pumice etc.)
  - to absorb ethylene

ETHYLENE ABSORBERS -

- LDPE films with 8% Tazetut masterbatch was produced and applied for broccoli florets
  - Tazetut masterbatch is an inorganic product containing 50% of various aluminosilicate minerals (zeolite).
- LDPE bags including zeolite prolonged storability of broccoli florets up to 20 days, however, this period was only 5 days in unpackaged broccoli
- Extension of shelf-life by establishing equilibrium atmosphere and higher sensory quality (Esturk et al 2014)



19

MOISTURE SCAVENGERS – NEED

- Are the most important for:
  - dry products;
  - products, where the moisture balance is the crucial factor for keeping the quality;

H_2O → Necessary in respiration of horticultural products

Changes of temperature can influence on moisture distribution in food

Excesive moisture in packaging can have negative impact on food products quality:
- promoting of microbial growth (especially fungi);
- chemical changes of biochemical composition;
- changes of texture;
- colour, taste, and odour changes – sensoric quality;

20

MOISTURE SCAVENGERS - ACTIVE FUNCTION / AVAILABLE TECHNOLOGIES

- Most popular: sachets and absorbing pads
- Pads/blankets made of porous materials, such as polymers (PP, PE), cellulose, combined with superabsorbent polymers/minerals/salts:

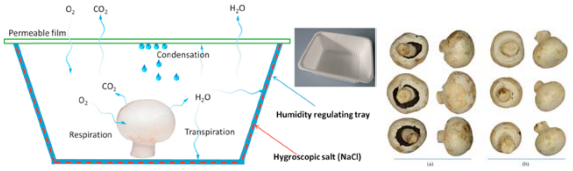
  - polyacrylate salts, carboxymethylcellulose, starch copolymers, silica/silicates;

- Sachets are filled with desiccants: silica gel, clays, molecular sieves (zeolite, sodium, potassium, calcium alumina silicate), humectant salts (sodium chloride, magnesium chloride, calcium sulfate), calcium oxide;
- Others: combination of hydrophilic substances with packaging materials

21

MOISTURE SCAVENGERS - HUMIDITY REGULATING TRAYS

- Developed by Leibniz Institute for Agricultural Engineering and Fraunhofer Institute of Process Engineering and Packaging;
- Humidity regulating trays maintain a stable RH inside the packaging by absorbing the water vapor;
- The quality of mushrooms has been maintained during 6 days of storage (figure on right: a. PP trays; b. humidity regulating trays)



Rux et al., Application of humidity regulating tray for packaging of mushrooms, Postharvest Biology and Technology, 108(2015), 102-110

22

CO_2 EMITTERS – NEEDS

- CO_2 is a commonly used packaging gas for fresh foods such as fish and meat in modified atmosphere packaging (MAP)
- CO_2 dissolves in the products and the proliferation of some bacteria (Gram negative) is reduced leading to improved product quality and increased shelf life.
- However: Standard MAP requires a high gas to product volume ratio; 3 times as much gas as product for an optimal effect. High amounts of CO_2 may cause package collapse.

A CO_2 emitter produces CO_2 inside the package after sealing
→ Increases product shelf life
→ Prevents package collapse (limiting product liquid loss)
→ Facilitates smaller package sizes: economical and environmental benefits

23

CO_2 EMITTERS – ACTIVE FUNCTION / AVAILABLE TECHNOLOGIES

CO_2 releasing systems

- Ferrous carbonate based
- Sodium bicarbonate and citric acid:

$C_6H_8O_7\ (aq) + 3NaHCO_3\ (aq) \rightarrow 3CO_2\ (g) + 3H_2O\ (l) + Na_3C_6H_5O_7\ (aq)$
$H^+\ (aq) + HCO_3^-\ (aq) \leftrightarrow H_2CO_3\ (aq) \leftrightarrow CO_2\ (g) + H_2O\ (l)$

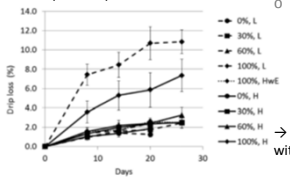
Combined CO_2 releasing/O_2 absorbing system
- Sodium bicarbonate and ascorbic acid

Cellcomb Active Pad

24

CO_2 EMITTERS –

- Study of impact of CO_2 emitter on shelf life and drip loss of chicken filets in MAP *
- Lab type emitter: Citric acid and sodium bicarbonate in a ratio adjusted to product pH.



↑ Drip loss from chicken filets in packages with different CO2 levels (%) and g/p ratios (L:low, H: high, HwE: high with CO_2 emitter).

- For chicken in MAP with 100 % CO_2 the drip loss was drastically reduced; from a weight loss of 7.5 % without emitter, to 2.5 % with CO_2 emitter. A result of reduction in package collapse and physical squeeze on the meat.

→ Packaging in 100 % CO_2 is not possible without emitter!

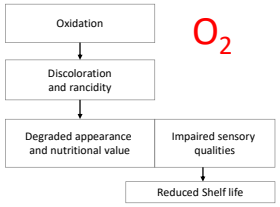
100 % CO_2 with emitter: significant bacterial growth inhibition.

* HOLCK, A. L., PETTERSEN, M. K., MOEN, M. H., & SØRHEIM, O. (2014). PROLONGED SHELF LIFE AND REDUCED DRIP LOSS OF CHICKEN FILETS BY THE USE OF CARBON DIOXIDE EMITTERS AND MODIFIED ATMOSPHERE PACKAGING. JOURNAL OF FOOD PROTECTION, 77(7), 1133–1141.

25

ANTIOXIDANT RELEASERS - NEEDS

Incorporation of antioxidant substances in food packaging systems to prevent oxidative processes and to extend the shelf life of food products



26

ANTIOXIDANT RELEASERS - ACTIVE FUNCTION / AVAILABLE TECHNOLOGIES

ACTIVE FUNCTION CAN BE OBTAINED WITH :

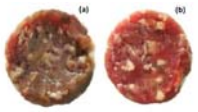
- Synthetic antioxidants: e.g. BHT, BHA, EDTA
- Natural antioxidants:
  - Compounds: e.g. citric acid, ascorbic acid, catechins, tocopherols, thymol, carvacrol, resveratrol, quercetin
  - Plant extracts: e.g. green tea, oregano, rosemary
  - Essential oils: e.g. rosemary, oregano, cinnamon
  - By-products: e.g. beet root residue, brewery residual waste

27

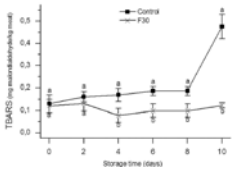
ANTIOXIDANT RELEASERS -

ANTIOXIDANT STARTCH-LLDPE FILMS (MELT BLENDING+EXTRUSION)*

- Citric acid: concentrations of 0.15-0.75%
- Antioxidant packaging prevented lipid oxidation of fresh ground beef and contributed to color preservation



Ground meat after 10 days of storage packed in: control film (a) and active film (b)



*VARGAS JÚNIOR ET AL 2015. BIODEGRADABLE DUO-FUNCTIONAL ACTIVE FILM: ANTIOXIDANT AND ANTIMICROBIAL ACTIONS FOR THE CONSERVATION OF BEEF. FOOD BIOPROCESS TECH 8:75-87.

28

THANK YOU FOR YOUR ATTENTION

Active Packaging for Food

Journal:	*Comprehensive Reviews in Food Science and Food Safety*
Manuscript ID	Draft
Manuscript Type:	Comprehensive Review
Date Submitted by the Author:	n/a
Complete List of Authors:	Yildirim, Selcuk; Zurcher Hochschule fur Angewandte Wissenschaften Life Sciences und Facility Management, Institute of Food and Beverage Innovation Rocker, Bettina; Zurcher Hochschule fur Angewandte Wissenschaften Life Sciences und Facility Management, Institute of Food and Beverage Innovation Pettersen, Marit; Nofima AS, ; Norwegian University of Life Sciences, Chemistry, Biotechnology and Food Sciences Nilsen-Nygaard, Julie; Nofima AS Ayhan, Zehra; Sakarya University, Faculty of Engineering, Department of Food Engineering Rutkaite, Ramune; Kaunas University of Technology, Faculty of Chemical Technology, Department of Polymer Chemistry and Technology Radusin, Tanja; University of Novi Sad, Institute of Food Technology Suminska, Patrycja; West Pomeranian University of Technology, Faculty of Food Science and Fisheries, Center of Biommobilization and Innovative Packaging Materials Marcos, Begonya; IRTA Tecnologia de los Alimentos Coma, Veronique; Bordeaux University

29