I MATERIALI ATTIVI ED INTELLIGENTI DESTINATI al CONTATTO con ALIMENTI

Imballaggi Carta e Cartone: Nuove soluzioni sostenibili
30 Gennaio 2013, Milano

Sara Limbo
Università degli Studi di Milano

Department of Food, Environmental and Nutritional Sciences

DEFENS
DEPARTMENT OF FOOD, ENVIRONMENTAL AND NUTRITIONAL SCIENCES

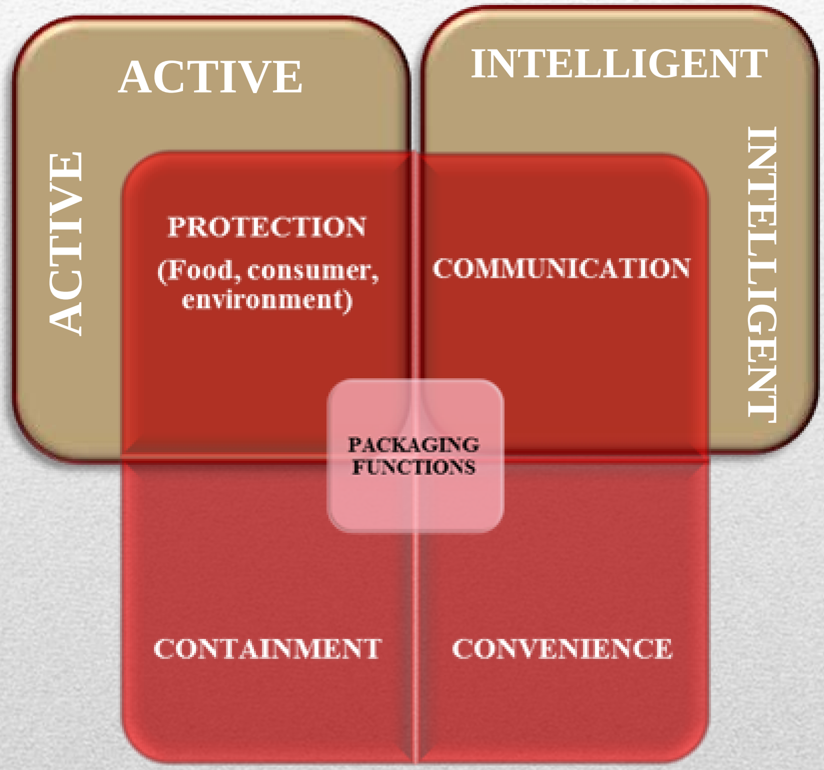
From traditional to active & intelligent packaging

Historically, **PRIMARY** packaging materials have been considered as “**PASSIVE**”:
they function only as an inert barrier to protect food against gas, moisture etc.

During the past 3 decades, the idea of **food-packaging INTERACTIONS** has been exploited.

The new paradigm:

The protection functions from **PASSIVE TO ACTIVE & INTELLIGENT**



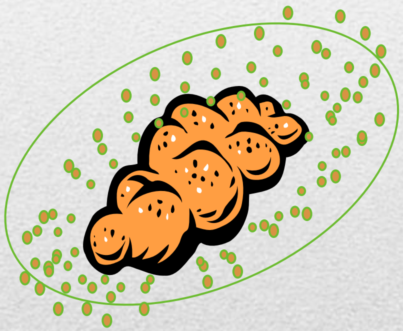
Yam et al., 2005. J.Food Sci, 70 (1) R1-R10

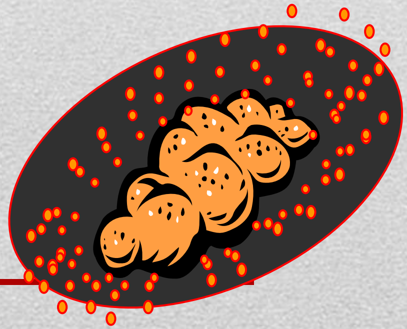
Active packaging definition

‘active materials and articles’ means materials and articles that are intended **to extend** the shelf-life or to **maintain** or **improve the condition of packaged food**

they are designed to **deliberately incorporate** components that **would release or absorb substances into or from the packaged food or the environment surrounding the food**

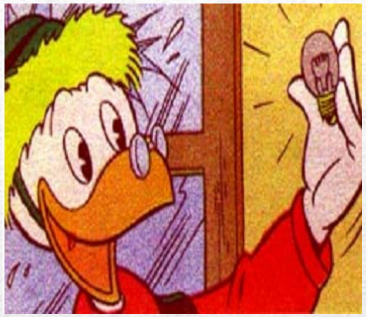
(EU Reg. 450/2009)





From traditional to active packaging

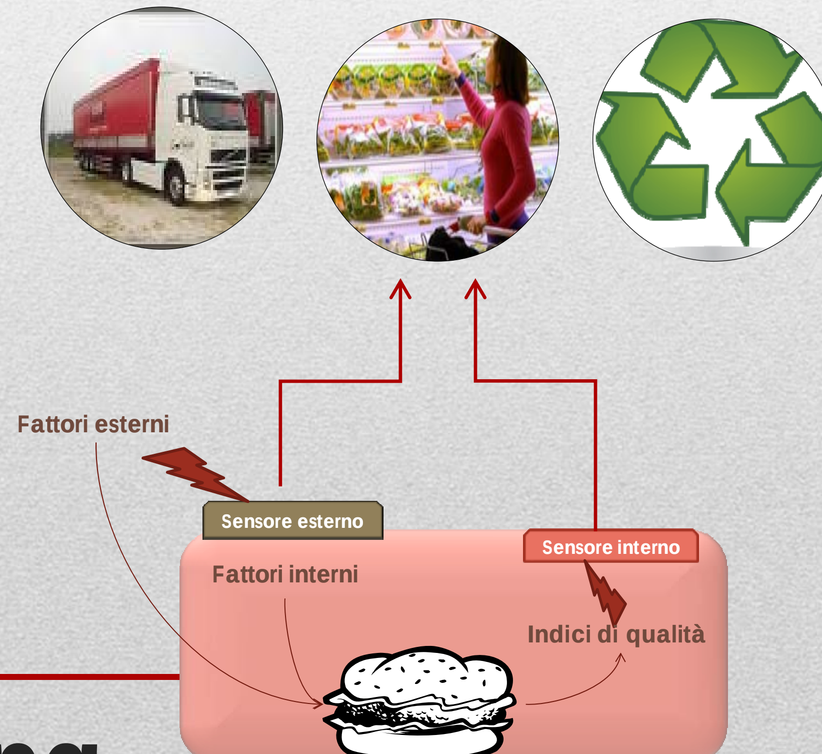
Intelligent packaging definition



Intelligent materials and articles' means materials and articles which **monitor the condition of packaged food** or
the **environment surrounding** the food
(EU Reg. 450/2009)

Intelligent packaging is an emerging technology that uses the **communication function** of the package to **facilitate decision making to achieve the benefits of enhanced** food quality and safety

A package is "intelligent" if it has the ability to **track the product**, **sense the environment inside or outside** the package, and **communicate** with human.
For example, an intelligent package is one that can monitor the quality/safety condition of a food product and provide early warning to the consumer or food manufacturer.



From traditional to intelligent packaging

From traditional to active & intelligent packaging

Active packaging is not a recent issue:

1938: patent in Finland

1943: patent in UK

1977: Japanese market

L 338/4 | EN | Official Journal of the European Union | 13.11.2004

REGULATION (EC) No 1935/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 27 October 2004

on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC

30.5.2009 | IT | Gazzetta ufficiale dell'Unione europea | L 135/3

REGOLAMENTO (CE) N. 450/2009 DELLA COMMISSIONE

del 29 maggio 2009

concernente i materiali attivi e intelligenti destinati a venire a contatto con i prodotti alimentari

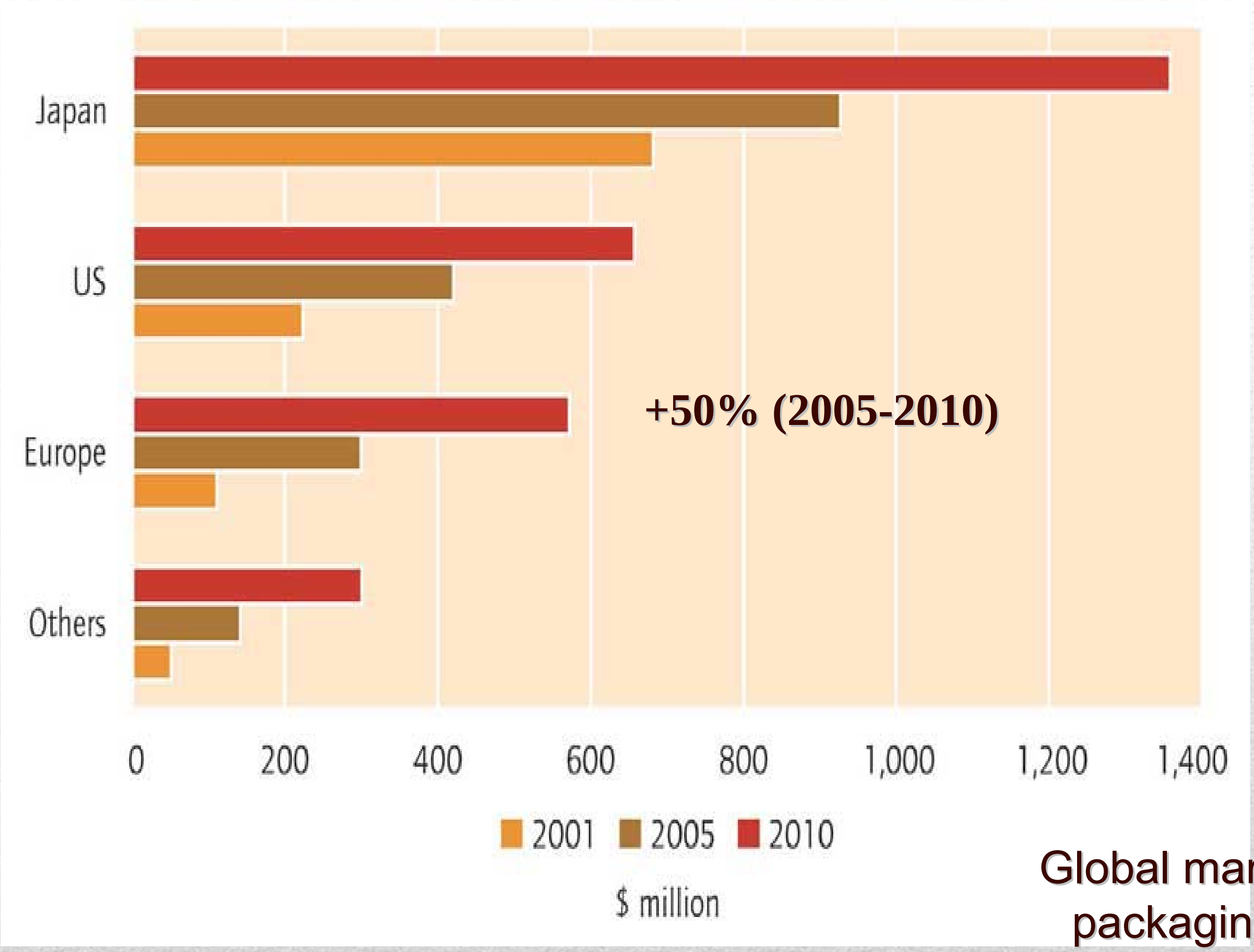
BUT

only recently it found a placement on European market thanks to the legislative framework

2004: EU Framework Regulation 1935 for materials and articles in contact with foods

2009: EU Regulation 450 for active and intelligent materials

FOCUS on ACTIVE PACKAGING



Global markets for active packaging 2001-2010

From traditional to active packaging

(Source:Pira International Ltd.)

1

FOOD PROCESSING

- Engineering/Processing limitations
- Processing Side Effects

2

FOOD PACKAGING

- Shelf life extension/optimization (Time-dependent reactions)
- Sustainability (Shelf life extension, Packaging waste reductions, compostability, etc)

3

FOOD DISTRIBUTION/MARKET

- Convenience
- Clean labelling
- Distribution systems (centralization, vending machines..)

Drivers for choice of active packaging

Rooney, 2005. In «Innovations in Food Packaging»

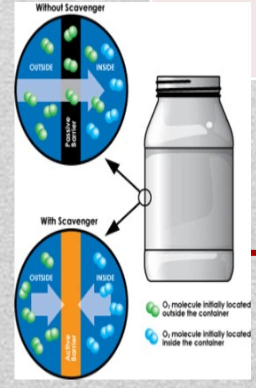
Substances able to induce food modification during shelf life

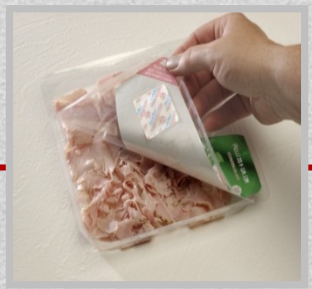
- **Oxygen:** rancidity, color changes, moulds, aerobic bacteria spoilage nutrient loss, insect infestations...
- **Water:** moulding, aerobic respiration, texture changes…
- **Ethylen:** vegetables ripening, senescence…
- **Off flavours:** sensorial changes, oxidation propagation…
- **Trimethylammine:** proteic degradation, sensorial changes
- **Hexanal:** lipid degradation, sensorial changes…
- ……

Main principles and applications

Main principles and applications

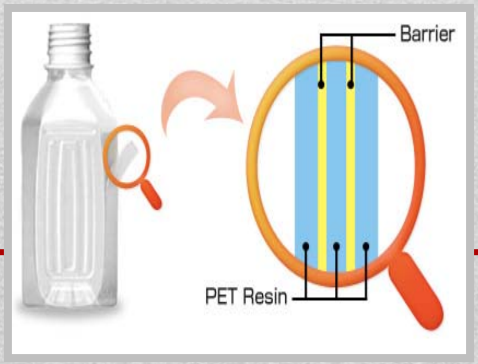
FUNCTION	ACTION	APPLICATION
Oxygen absorbers/scavengers	-oxidative reactions; - bacteria growth;	Bakery product, meat, processed meat, fish, beverage
CO_2 absorbers/emitters	- bacteria growth; + shelf life; coadiuvant in MAP	Meat, fish, beer, cheese
Water absorbers	-bacteria growth; + aesthetic appearance (-exudates)	Meat, fish..
Moisture regulators	-bacteria growth; +texture maintainance;	Meat, fish. cheese, bakery product, vegetables, fruit

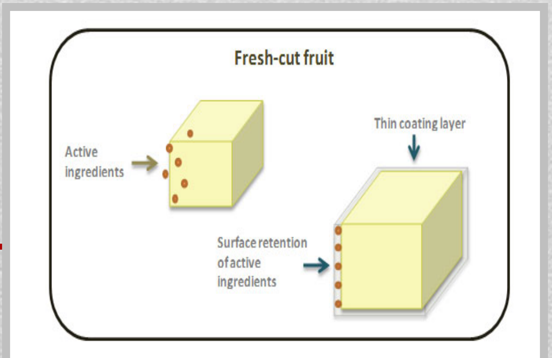




Main principles and applications

FUNCTION	ACTION	APPLICATION
Ethylene absorbers	-ethylene; +ripening control;	Fruit, vegetables
Ethanol emitters	-microbial growth	Bakery products
Aroma emitters	+sensorial quality	Bakery products; processed meats
Antimicrobials	-microbial growth; +safety control	Fish, meat, bakery products (high aw), minimally processed vegetables….



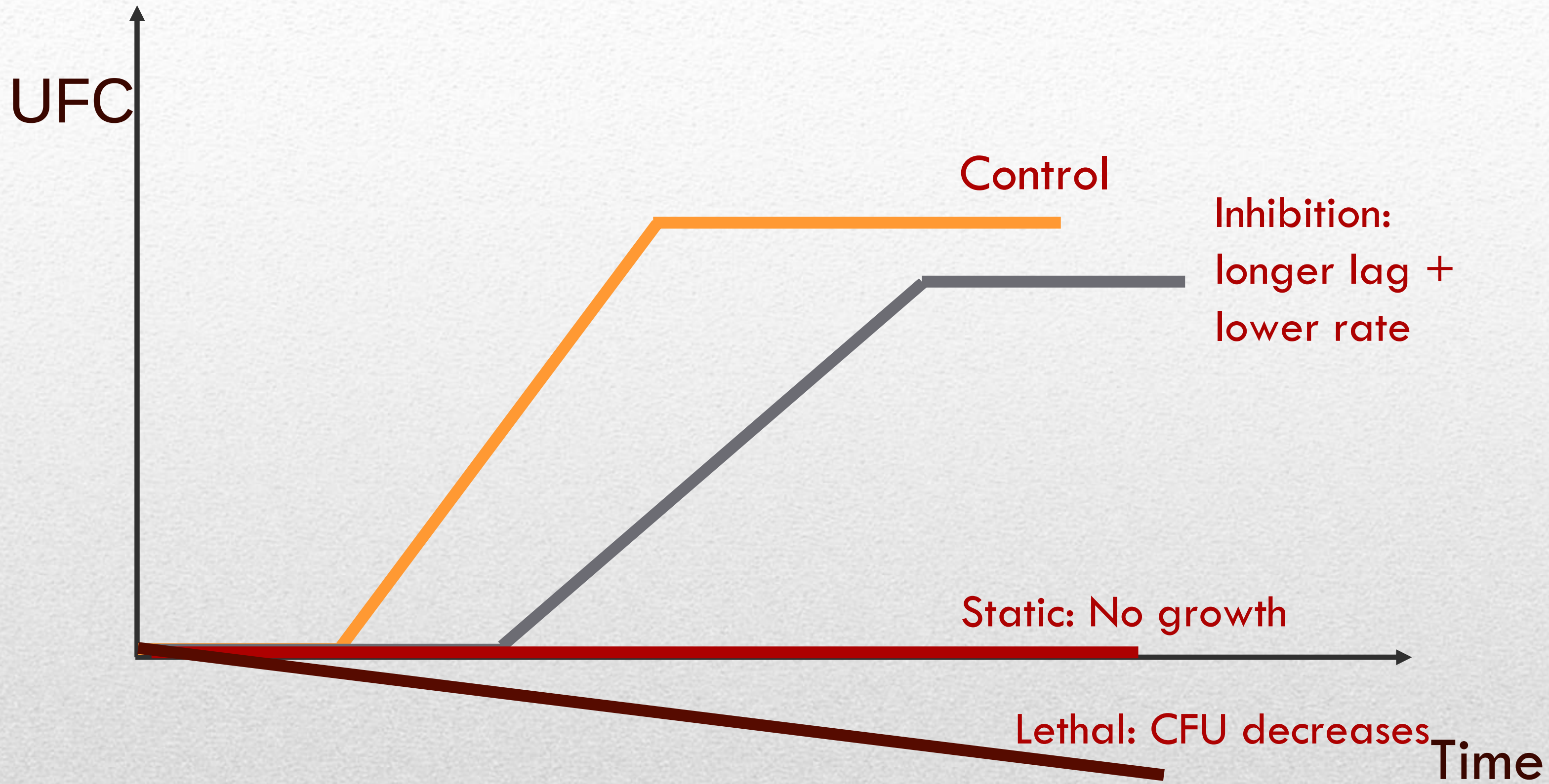


FOCUS on ANTIMICROBIAL ACTIVE PACKAGING

Antimicrobial packaging is a system that can kill or inhibit the growth of micro-organisms and thus extend the shelf life of perishable products and enhance the safety of packaged products

(Han, 2000)

Antimicrobials: definition



Antimicrobials: different mechanisms of action

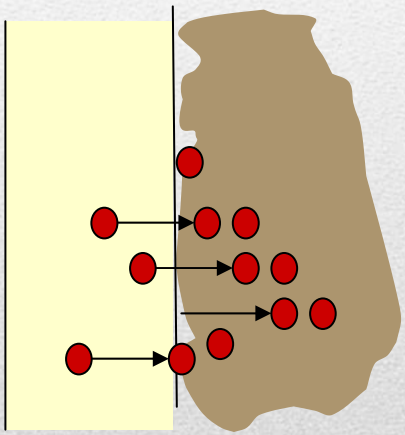
Class	Examples
Organic acids	Propionic acid, benzoic ac. , sorbic ac. , lactic ac…
Polymers	Chitosan
Organic Gas	SO_2 ,, ClO_2
Metals	Silver
Fungicid	Benomyl, imazalil
Bacteriocins	Nisin, pediocin, etc
Enzymes	Lysozyme, glucose oxidase
Chelating agents	EDTA
Spices (extracts)	Horseradish (allileisocianato), cinnamon
Essential oils/oleoresins	Carvacrol, cinnamaldheyde, eugenol..

Antimicrobials: different active substances

Antimicrobials: different forms

- **Sachets** directly inserted into the package
- **Pads** directly inserted into the package
- **Polymers** naturally antimicrobials (ex.chitosan) or polymers with induced antimicrobial effects (ex. Irradiated polyammine)
- Incorporation via **Blending/Extrusion**
- **Coating, varnishes**…
- **Immobilization** via covalent bonds……

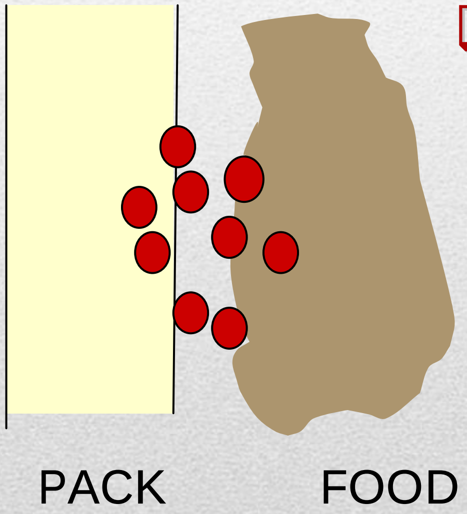
Incorporation methods and transferring/releasing tecniques are critical in designing effective antimicrobial packaging systems.



- Non-volatile migration
  - The mass transfer of non-volatile ANTIMICROBIALS (AM) is dominated by diffusional migration. The AM is positioned in the packaging materials.and the direct contact with food is required
  - Therefore, the solubility (or partition coefficient) and diffusion coefficient are very important to maintain the surface concentration above the MIC during the expected shelf life

Antimicrobials: different ways of releasing

Incorporation methods and transferring/releasing tecniques are critical in designing effective antimicrobial packaging systems.

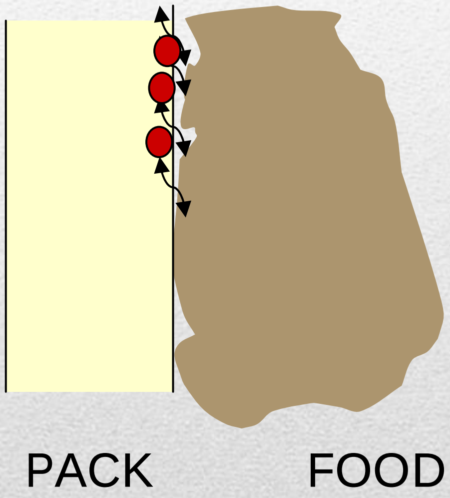


- Volatile migration
  - In this case, the AM is released from the package to the headspace. The volatile AM's concentration in the headspace has to be balanced.
  - The release rate of the AM from the packaging is highly dependent on the volatility, which relates to the chemical interactions between the AM and the packaging material
  - The volatility can be controlled by using microencapsulation, oils etc.
  - The absorption rate into the food is dependent on the food composition (ex.lipid content)

Antimicrobials: different ways of releasing

Antimicrobials: different ways of releasing

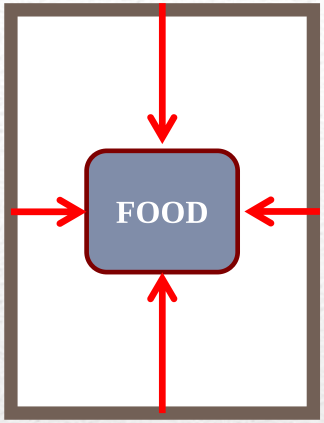
Incorporation methods and transferring/releasing tecniques are critical in designing effective antimicrobial packaging systems.



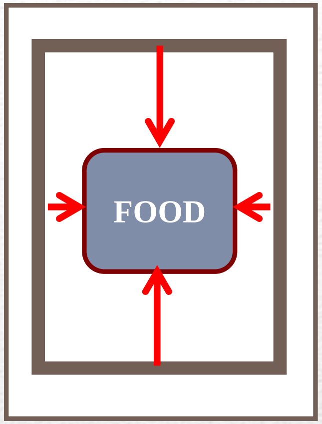
- Non-migration and absorption
  - The non-migration system uses non-migratory antimicrobial polymers, where the AM agent does not migrate out of the polymer due to its covalent attachment to the polymer backbone (grafting, immobilization through cross-linking)
  - The activity is limited to the contact surface only

Antimicrobials: different ways of releasing

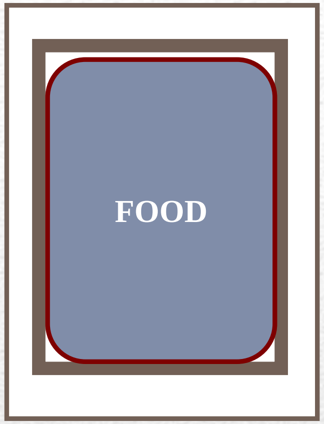
From the **polymer** vs food via **headspace**



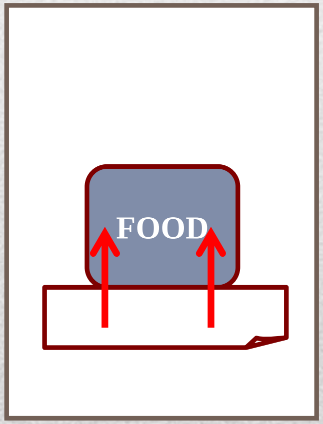
From a **coating** vs food via **headspace**



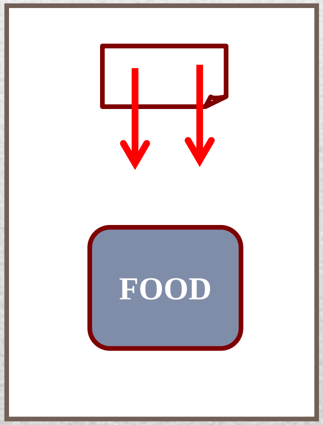
From a **coating** vs food via **direct contact**



From a **pad** vs food via **direct contact**



From a **sachet** vs food via **headspace**



From an **edible film** vs food via **direct contact**

Controlled release packaging (CRP) is a new generation of packaging materials that can release active compounds at **different controlled rates** suitable for en**hancing the quality and safety of a wide range of foods** during extended storage. The basic concept is to use the package as a **delivery system** for active compounds, such as antimicrobials, antioxidants, enzymes, flavours and nutraceuticals

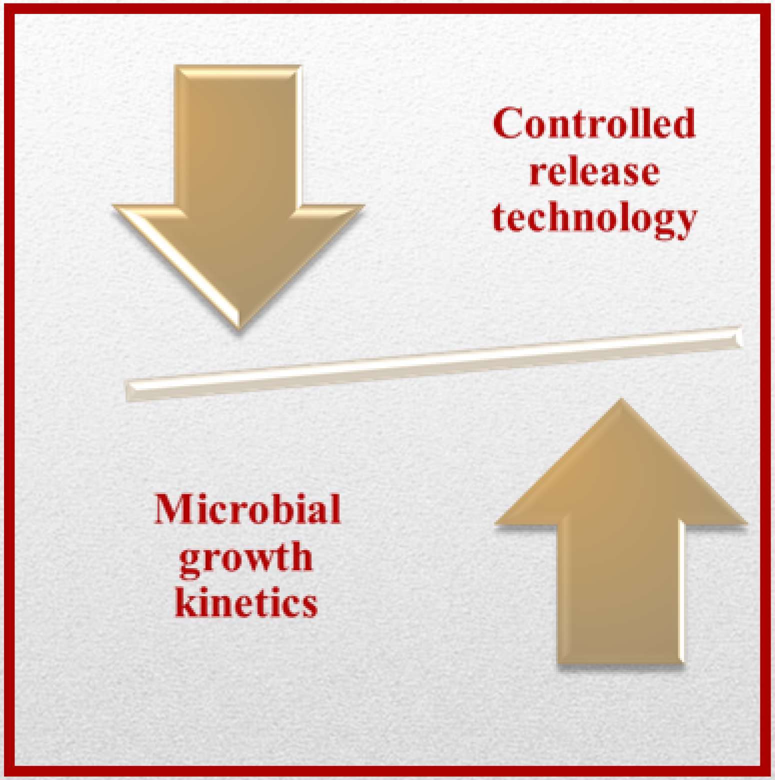
LaCoste. Packag. Technol. Sci. 2005; 18: 77–87

Antimicrobials: controlled release

What does an AM packaging system require?

A) the mass transfer rate of an AM agent is FASTER than the growth rate of microrganisms

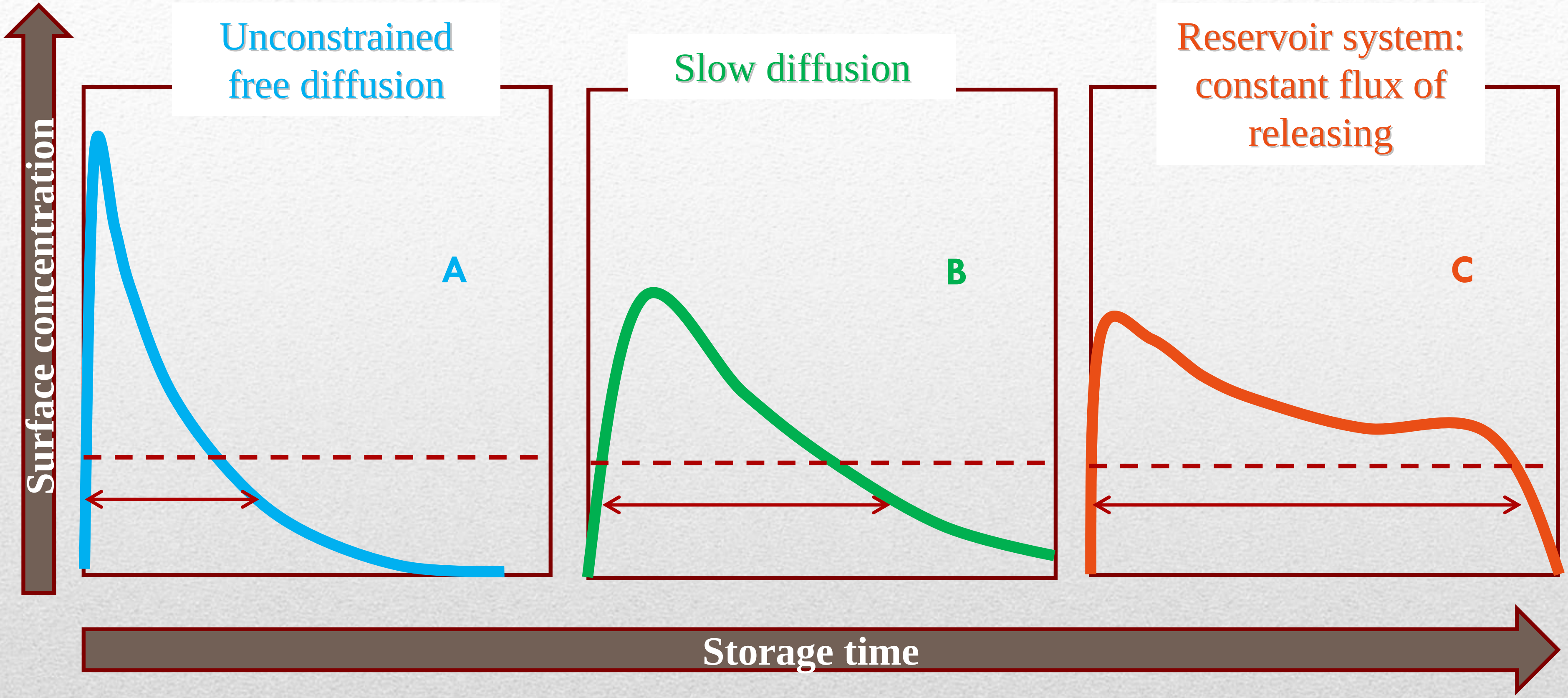
the AM will be diluted to less than the effective critical concentration; the packaging system will deplete its AM activity



B) the mass transfer rate of an AM agent is too SLOW

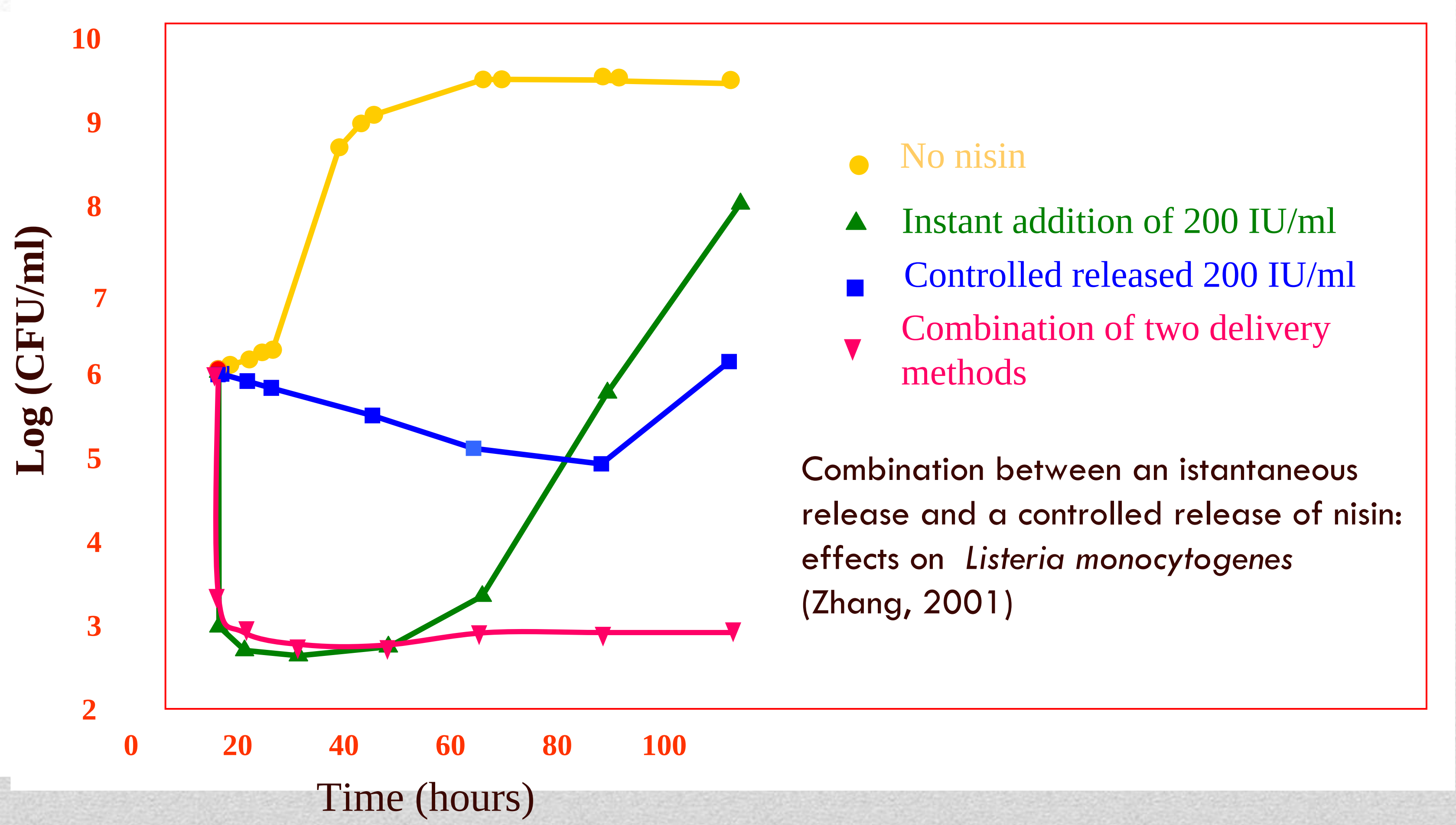
the microorganisms will growth instantly, before the AM is released

Antimicrobials: controlled release



Han, 2005. Antimicrobial packaging system

Antimicrobials: controlled release



Antimicrobials: controlled release

Efficacy of LAE films against *L. monocytogenes* and *S. enterica* in a milk infant formula

Antimicrobial effectiveness against *L. monocytogenes*, *E. coli*, and *S. enterica*. EVOH-44 films with 0.25%, 1%, 5%, and 10% LAE at 37 °C expressed as logarithm of colony forming units (Log(CFU)) and log reduction value (LRV).

	L. monocytogenes		*E. coli*		*S. enterica*	
	Log(CFU)	LRV	Log(CFU)	LRV	Log(CFU)	LRV
Control	8.43 ± 0.47		8.56 ± 0.28		8.87 ± 0.14	
10% LAE	Total inhibition		Total inhibition		Total inhibition	
5% LAE	Total inhibition		Total inhibition		Total inhibition	
1% LAE	4.21 ± 0.14	4.22	5.53 ± 0.62	3.03	5.49 ± 0.53	3.38
0.25% LAE	6.99 ± 0.22	1.44	6.16 ± 0.48	2.40	6.41 ± 0.24	2.46

LAE (N^{α}-Lauroyl-*L*-arginine ethyl ester monohydrochloride)

-Broad spectrum of antimicrobial activity

-GRAS (Generally Recognized as Safe)

-Food preservative (limit 200 ppm) by FDA

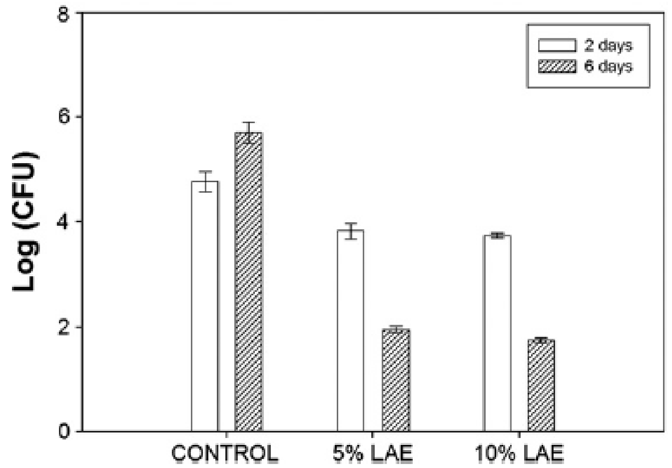


Fig. 6. Growth reduction of *S. enterica* inoculated in an infant formula at 2nd and 6th days of storage caused by EVOH-29 films (control, 5% LAE and 10% LAE).

V. Muriel-Galet et al. International Journal of Food Microbiology 157 (2012) 239–244

Nafispack

(Natural Antimicrobials for Innovative and Safe Packaging)

Innovative and safe packaging systems to increase fresh product shelf life by using two novel packaging technologies: **antimicrobial active** packaging and **intelligent packaging** for fresh fish, chicken, and minimally processed vegetables (MPVs).

Development of a safety assessment methodology that includes the **chemical characterization** and **toxicological profile of intentionally and non-intentionally added substances** present in these new packaging materials and that might migrate to the foodstuffs.

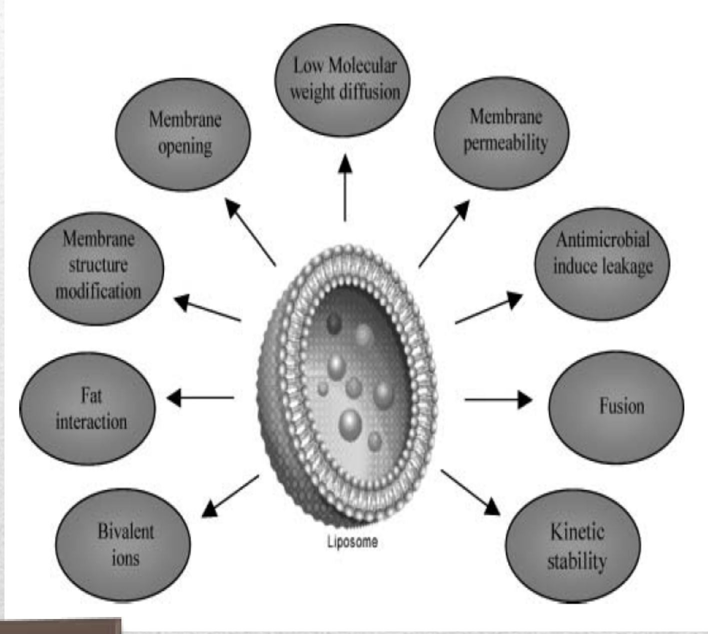
http://www.nafispack.com/

Active Food Packaging Evolution: Transformation from Micro- to Nanotechnology

Imran et al. (2010)

The technology of nanoparticles in the near future involves the incorporation of nano–active agents into packaging materials to increase and modulate some FUNCTIONAL properties of packaging materials

GAS BARRIER
HEAT/LIGHT RESISTANCE
MECHANICAL STRENGHT
……..

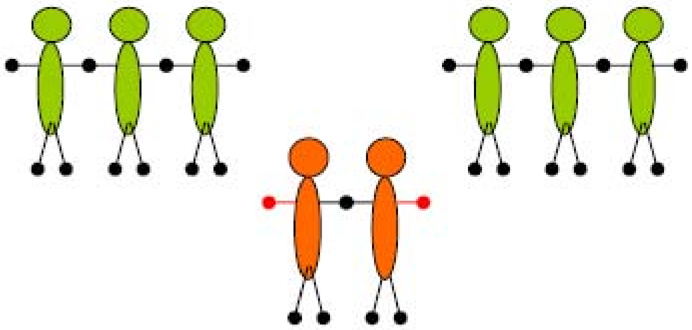


Micro- and nanoencapsulation of the active substances either in packaging and/or within food will make available alternative, more efficient and, in some cases, unique merits to offer food with an improved impact on human health

Lopez-Rubio et al. (2006)

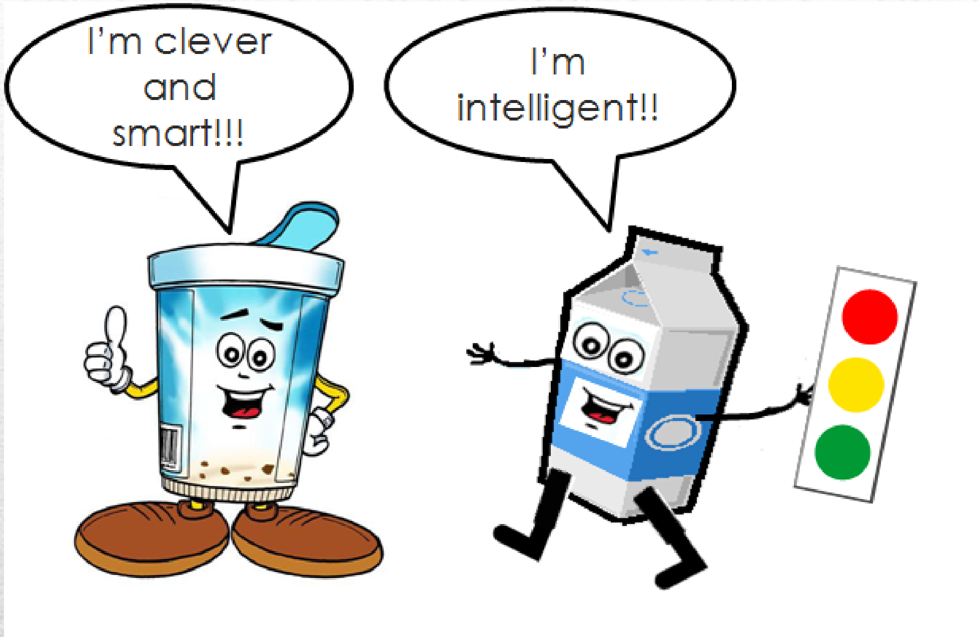
A last consideration:

Whether absorbers, releasers or even grafted, active packaging systems may release chemicals into food. Hence the need of a risk assessment requested by the regulation.
The risk assessment approach is documented in EFSA's guidelines.



The degradation products of the polymer can **migrate into food**

Source: Food safety linked to chemical contamination through packaging materials: EFSA's guidelines for active and intelligent packaging (Feigenbaum, Spyropoulos, Joly, 2008. CCM Conference, Bonn)



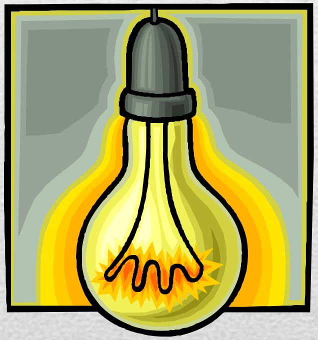
Grazie per l'attenzione

Active Food Packaging Evolution: Transformation from Micro- to Nanotechnology

EMERGING CONCEPT OF NANOTECHNOLOGY BLEND WITH 3-BIOS

Imran et al. (2010)

The next technological revolution in the pasture of food science and nutrition would be 3-BIOS blend with nanotechnology



Bioactive, Biodegradable, Bio-nanocomposite

It is likely to be the smartest development yet to be seen in modern food packaging innovations.