Advances in Food Packaging

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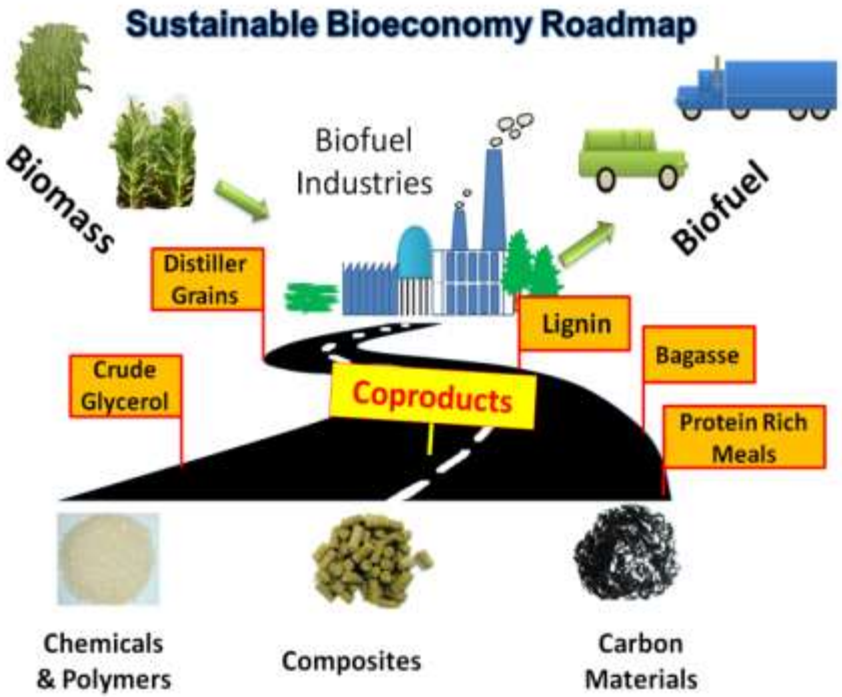
Bioeconomy

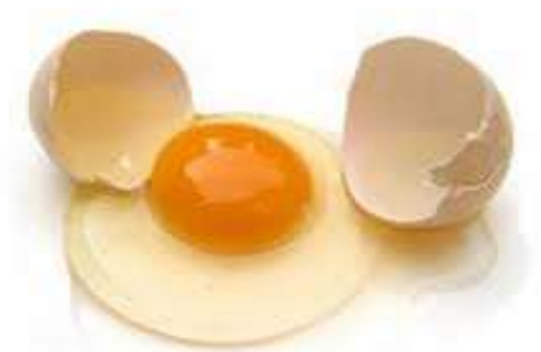


From: Vivekanandhan et al. (2013)

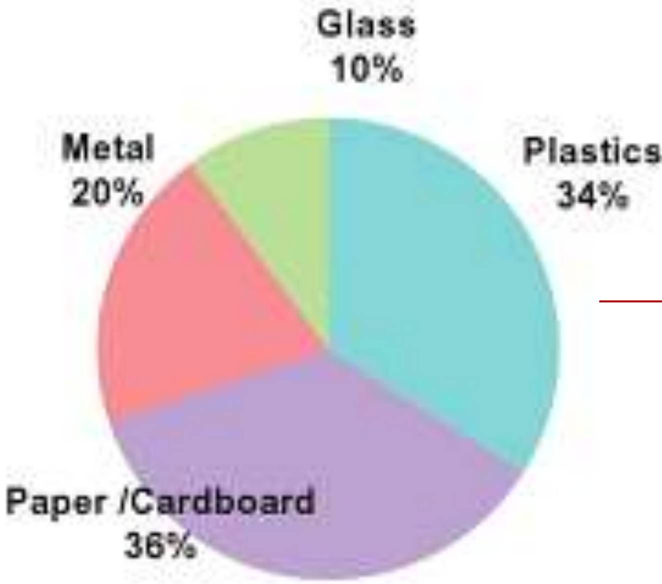
- **Bioeconomy** plans include a bio-based industries sector in which some oil-derived plastics and chemicals are replaced by new or equivalent products derived, at least partially, from biomass (Philp et al., 2013).

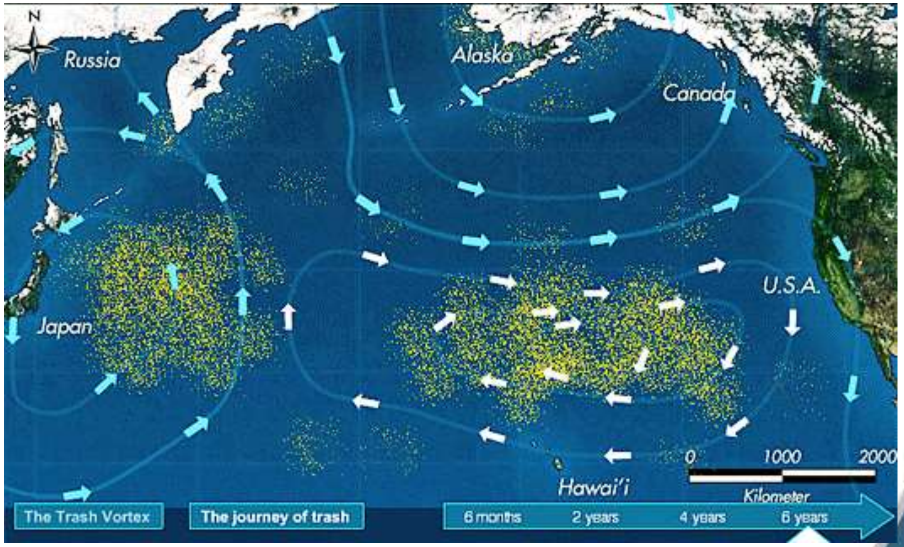
Packaging and environment

- “The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact”(Marsh & Bugusu, 2007).



Packaging Materials





Materials used for packaging in the world (Kim et al., 2013)

Bioplastics

Current methods for biopolymer production	Biopolymers	Examples of marketed biopolymers
Modified natural polymers from plant material	Starch, starch derivatives; Cellulose, cellulose derivatives; Lignin	Novamont's starch resin: Mater-Bi
Polymers made directly by micro-organisms or plants	Polyhydroxialcanoates, such as Polyhydroxi-butyrate and copolymers (PHB/PHA); Polylactic acid (PLA)	Metabolix's PHA: Mirel
Polymers made from monomers obtained by fermentation	Polylactic acid (PLA) Polypropylene-terephtalate (PPT)	NatureWorks' PLA DuPont's PPT: Sorona
	Polyethylene (PE) and other ethylene derivatives	Braskem's Green PE

From: Iles and Martin (2013)

Biopolymers in Food Packaging

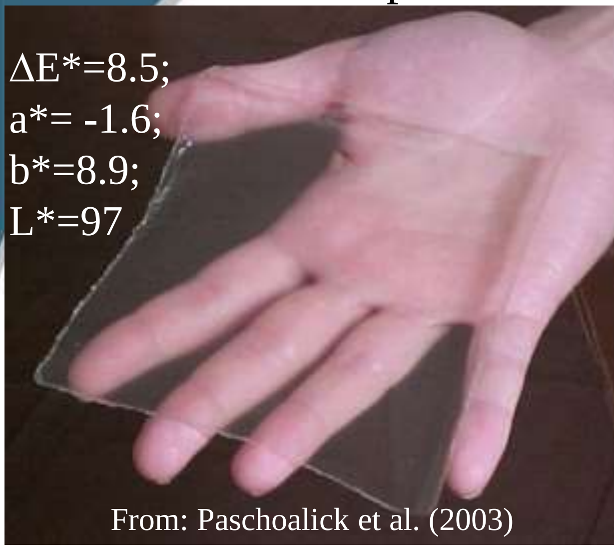
Biopolymers are macromolecules from biological origin:

- i) Proteins: gelatin, soy protein, gluten, zein, whey proteins isolate,…;
- ii) Polysaccharides: starch, cellulose, chitosan, gums,…

Used to produce a **continuum matrix** or to produce **nanoparticles** to be used as load.

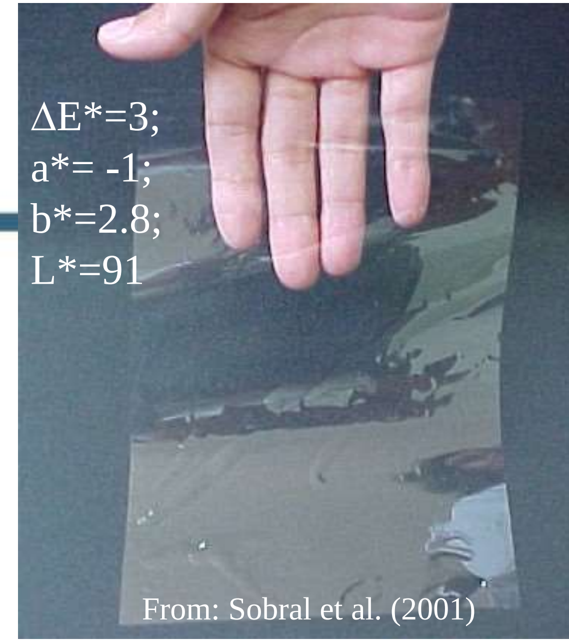
Films produced by casting

Protein from Tilapia fillet



From: Paschoalick et al. (2003)

gelatin

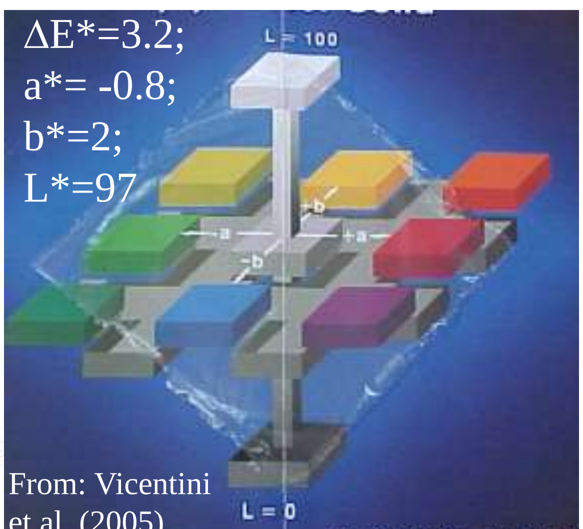


From: Sobral et al. (2001)

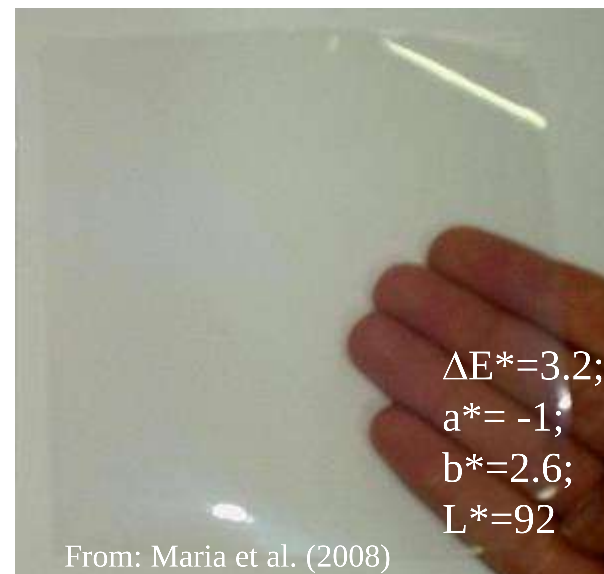
From: Alvarado et al. (2007)

Chitosan

Cassava starch



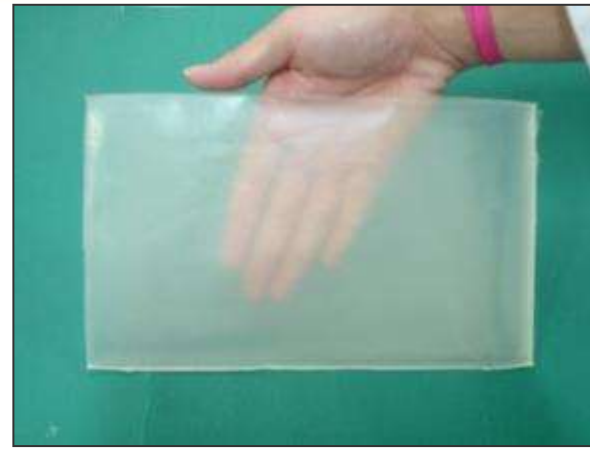
From: Vicentini et al. (2005)

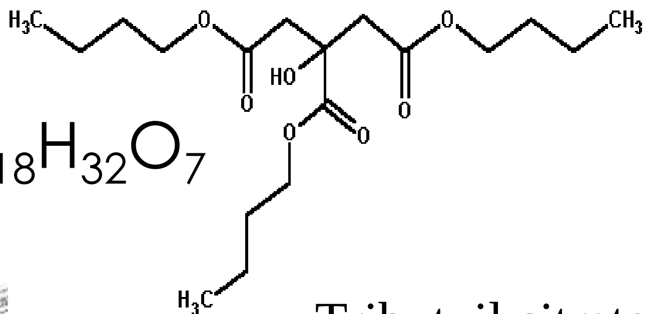


From: Maria et al. (2008)

gelatin + PVA

Films based on gelatin with hydrophobic plasticizers

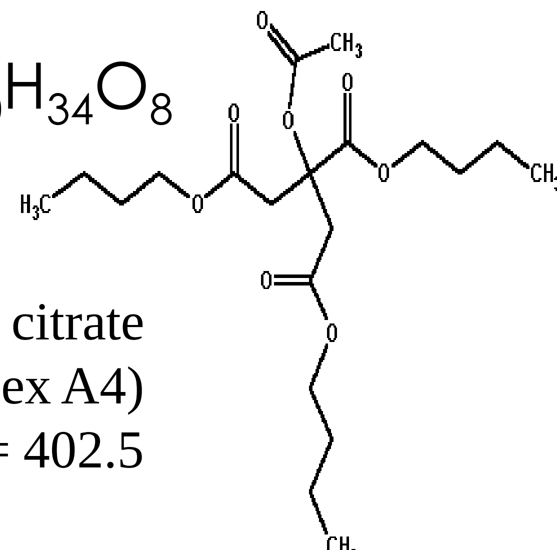




$C_{18}H_{32}O_{7}$

Tributyil citrate
(Citroflex 4)
MW= 360.4

$C_{20}H_{34}O_{8}$



Acetyl tributyl citrate
(Citroflex A4)
MW= 402.5

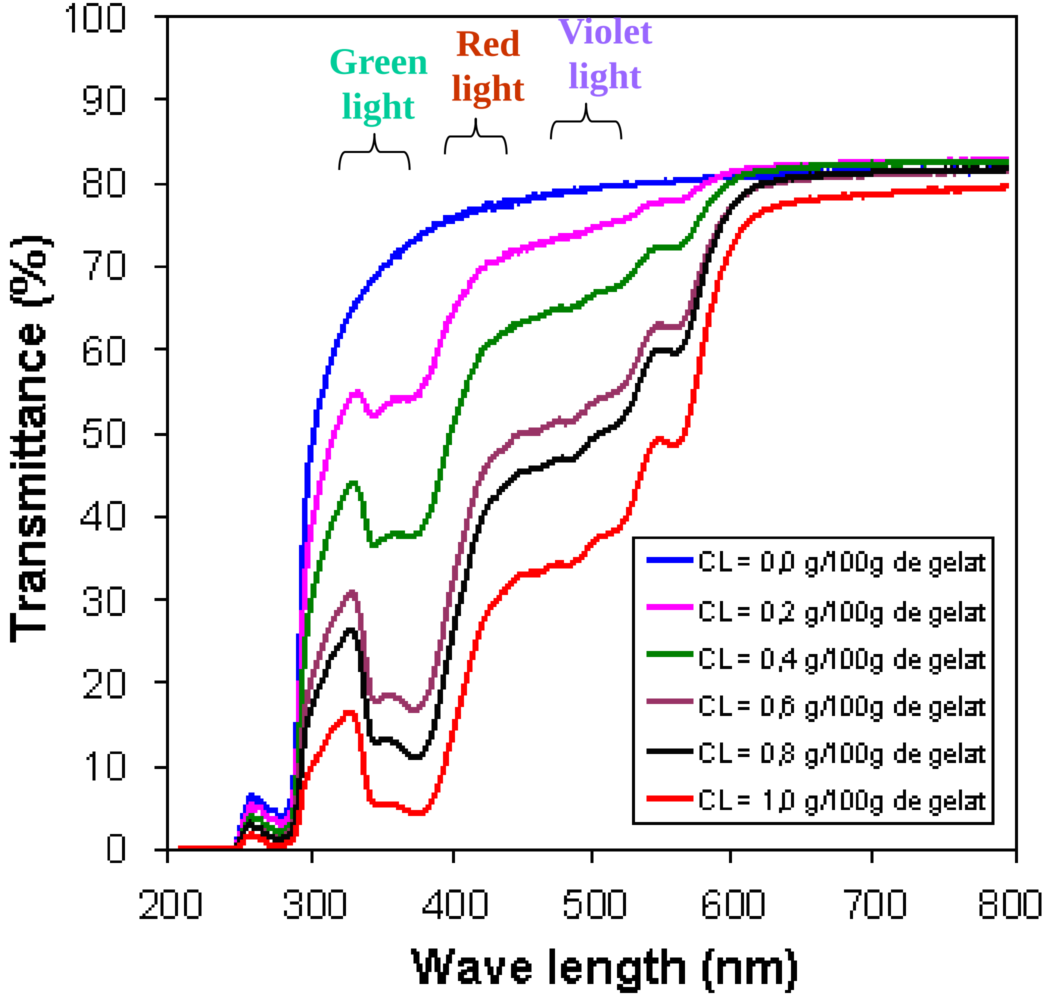
Film produced by extrusion

Cassava starch and PE.

From Prof. Dr. Fábio Yamashita, UEL, Brazil.

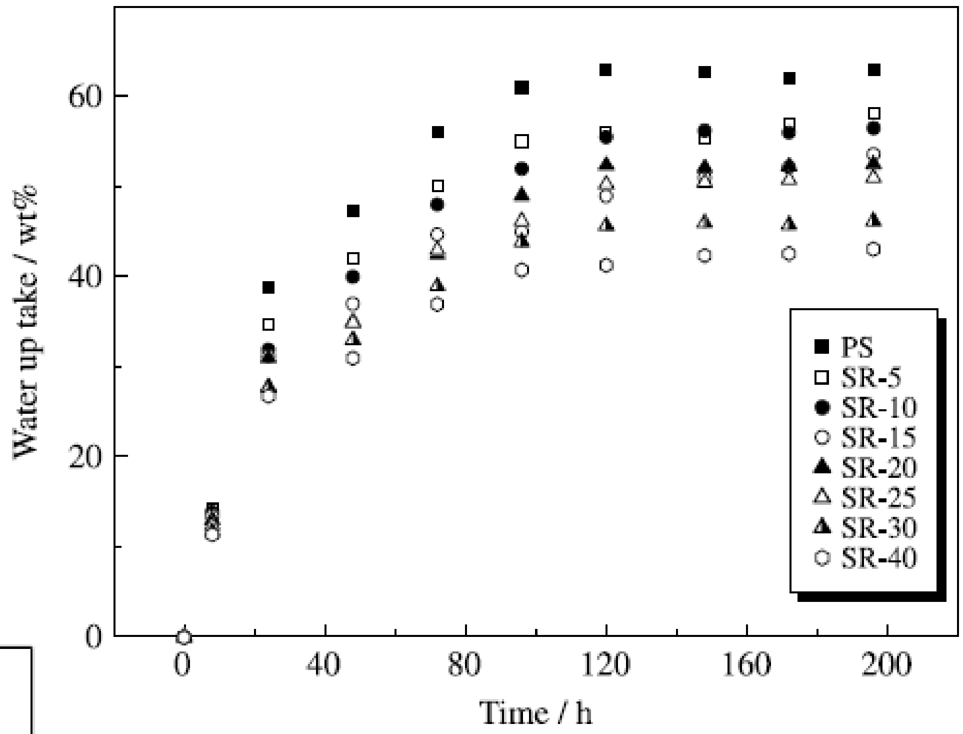
Gelatin based films colored with lycopene

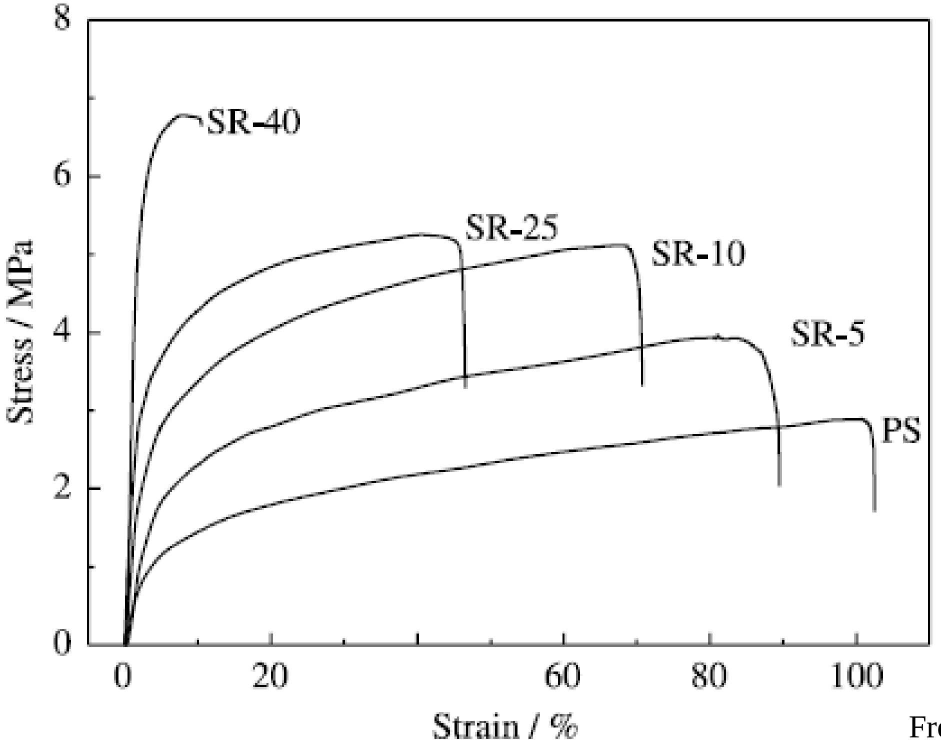
X= 0.080 mm



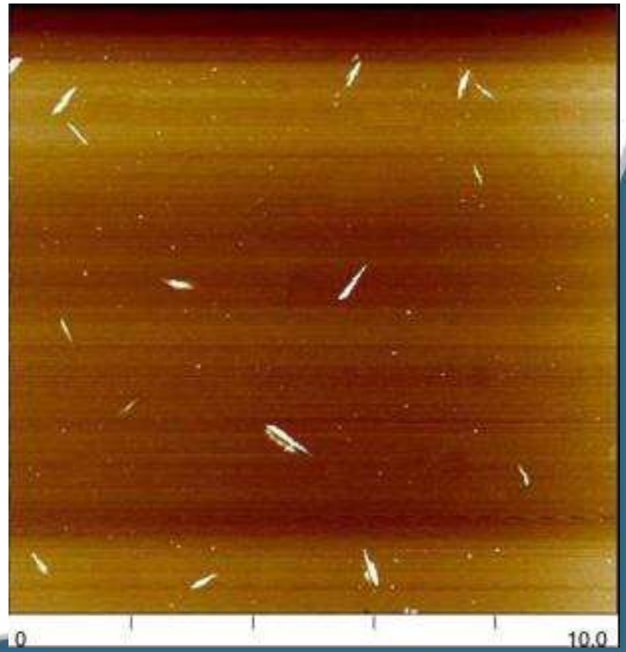
X= 0.400 mm

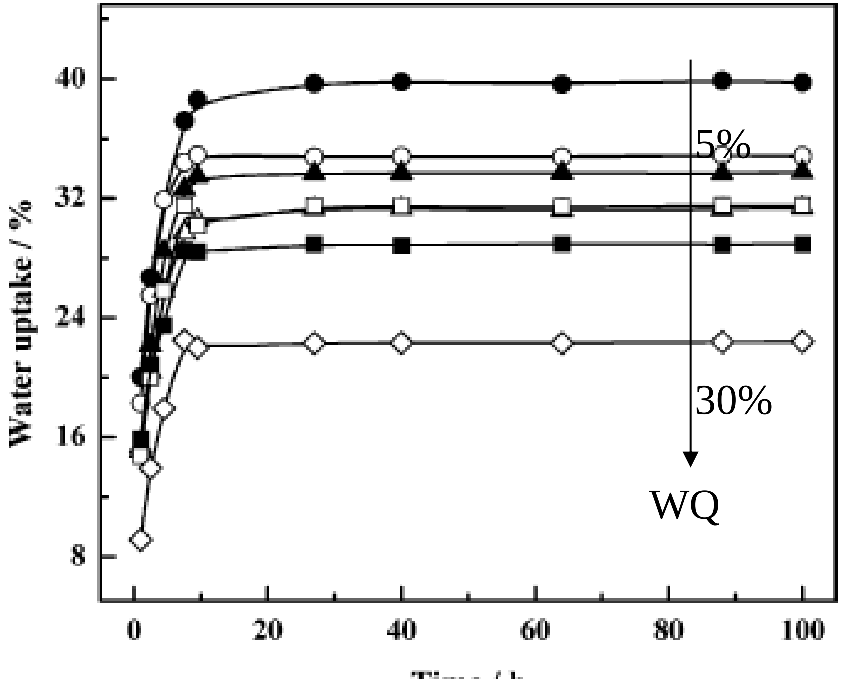
Starch based films charged with nanocrystals produced from ramie cellulose.



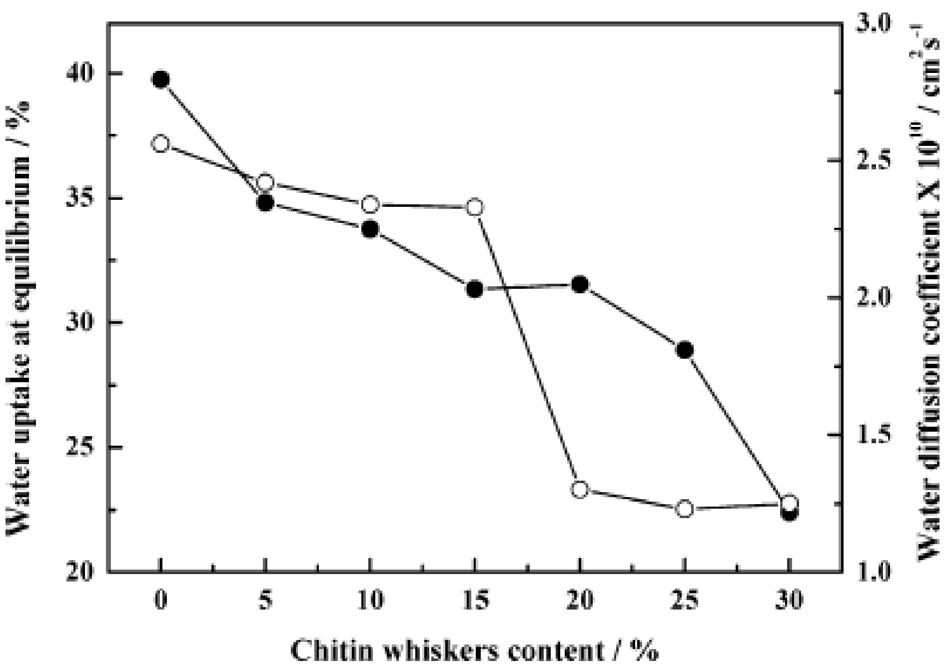


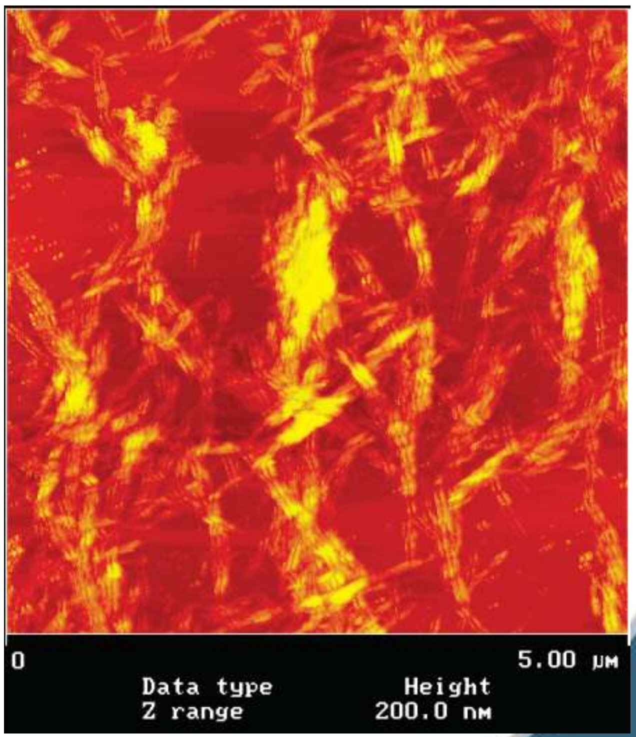
From: Lu et al. (2006).





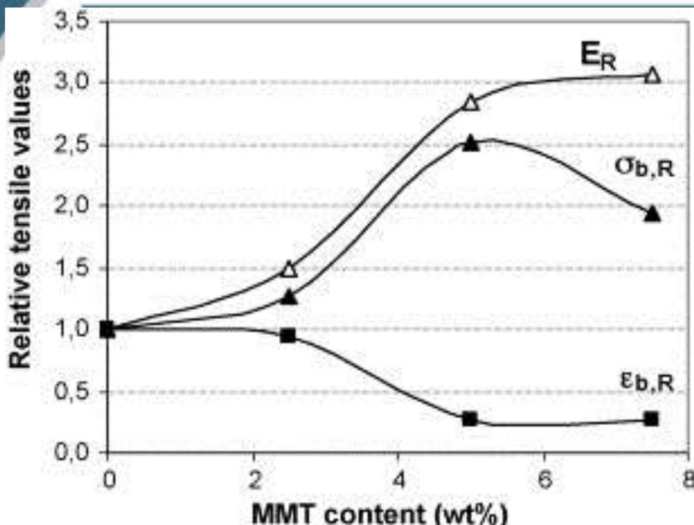
Soy protein isolate based films charged with whiskers from chitin.

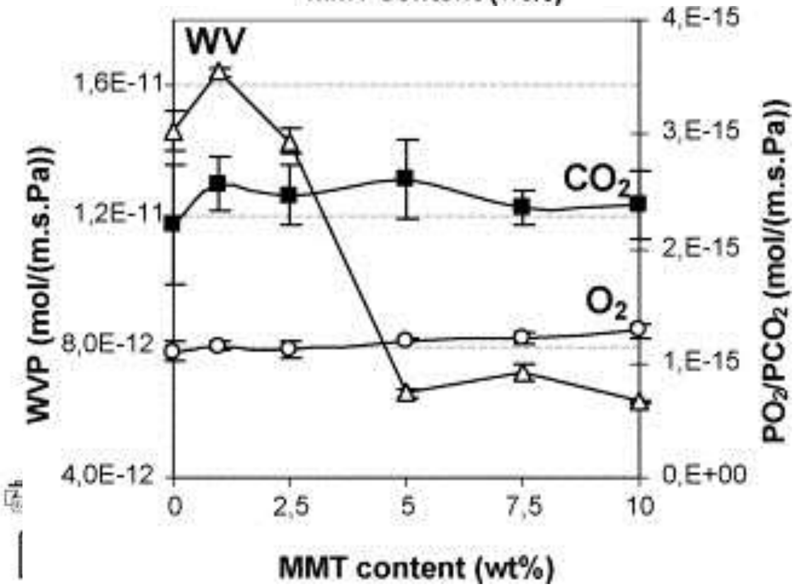




From: Lu et al. (2004).

Gluten based films charged with Montmorillonite.





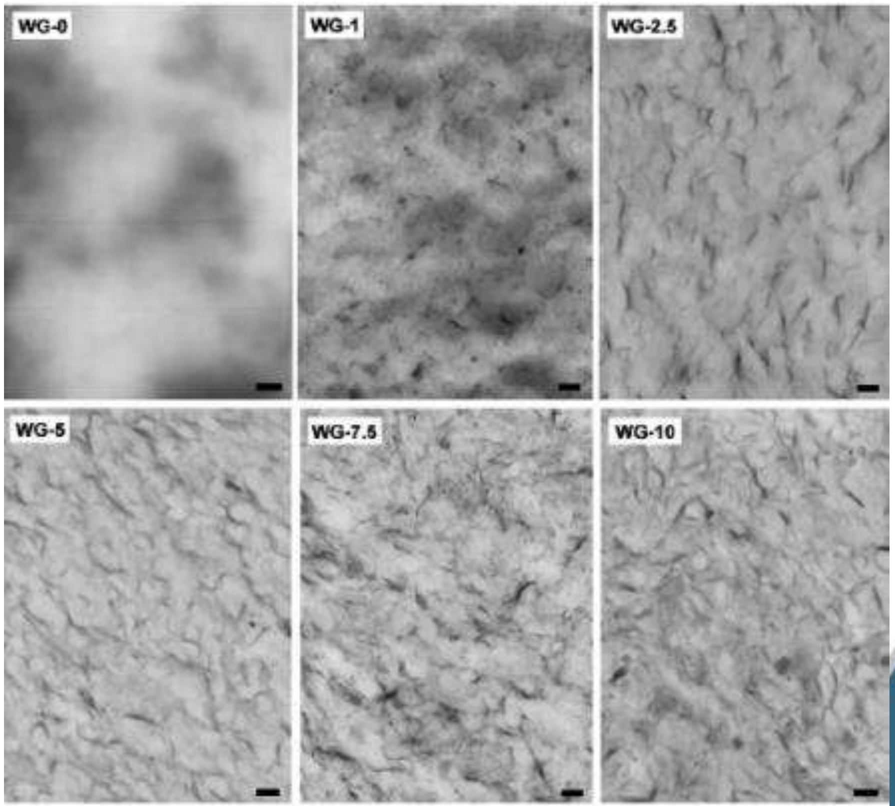


Fig. 3. TEM pictures of WG/MMT films. Samples are indicated in the figure. Scale bar: 200 nm.

From: Tunc et al. (2007).

Active Packaging

- They contain deliberately incorporated components intended to release (controlled) or absorb substances into or from the packaged food or from the environment surrounding the food (Dainelli et al., 2008).

Examples of active packaging applications for use within the food industry.

Absorbing/ scavenging properties	Oxygen, carbon dioxide, moisture, ethylene, flavors, taints, UV light
Releasing/emitting properties	Ethanol, carbon dioxide, antioxidants, preservatives, sulfur dioxide, flavors, pesticides
Removing properties	Catalysing food component removal: lactose, cholesterol
Temperature control	Insulating materials, self-heating and self-cooling packaging, microwave susceptors and modifiers, temperature-sensitive packaging
Microbial and quality control	UV and surface-treated packaging materials

From: Restuccia et al. (2010).

Antimicrobial activity

- Antimicrobial packaging can take several forms including (Appendini and Hotchkiss, 2002):
- - Addition of sachets containing volatile antimicrobial agents into packages.
- - Incorporation of volatile/non-volatile antimicrobial agents directly into polymers.
- - Coating or adsorbing antimicrobials onto polymer surfaces.
- - Immobilization of antimicrobials to polymers by ion or covalent linkages.
- - Use of polymers that are inherently antimicrobial.

Examples of Antimicrobial Packaging

Antimicrobial compound	Tradename	Producer Company	Packaging forms for food applications	Reference
Silver substituted zeolite	AgIon™	AgIon Technologies LLC	Bulk food storage containers, paperboard cartons, plastic or paper food wraps and milk containers.	http://www.healthshield.com/index1.html Last accessed: 01/25/02
	Novaron®	Toagosei, Co. LTD	Many (Japan)	Toagosei, Co. LTD Brochure
Triclosan	Microban®	Microban Products	Deliwrap, reheatable food containers (UK)	Sherman (1998), Rice (1995)
Allylisothio-cyanate	WasaOuro	Lintec Corporation	Pressure sensitive labels, sheets (Japan)	http://www.lintec.co.jp/index-e.html Last accessed: 01/25/02
		Dry Company LTD	Sachets	Anon (1995)
Chlorine dioxide	Microsphere™	Bernard Technologies Inc.	Storage bags for produce, paperboard coating, rigid containers, pressure sensitive labels	Gray (2000)
Carbon dioxide	Freshpax™	Multisorb Technologies	Sachets	Smith et al. (1995)
	Verifrais	SARL Codimer	Sachets (France)	Smith et al. (1995)
Ethanol vapor	Ethicap®	Freund	Sachets	Smith et al. (1995)
	Negamold®			
	Fretek®		Sachets	Rice (1989)
	Oitech™	Nippon Kayaku	Sachets (Japan)	Smith et al. (1995)
Glucose oxidase (hydrogen peroxide)	Bioka	Bioka LTD	Sachets (Finland)	http://www.bioka.fi/index.html Last accessed: 01/25/02

[a] For additional commercial antimicrobial packaging references, see Brody et al. (2001).

From: Appendini and Hotchkiss (2002)

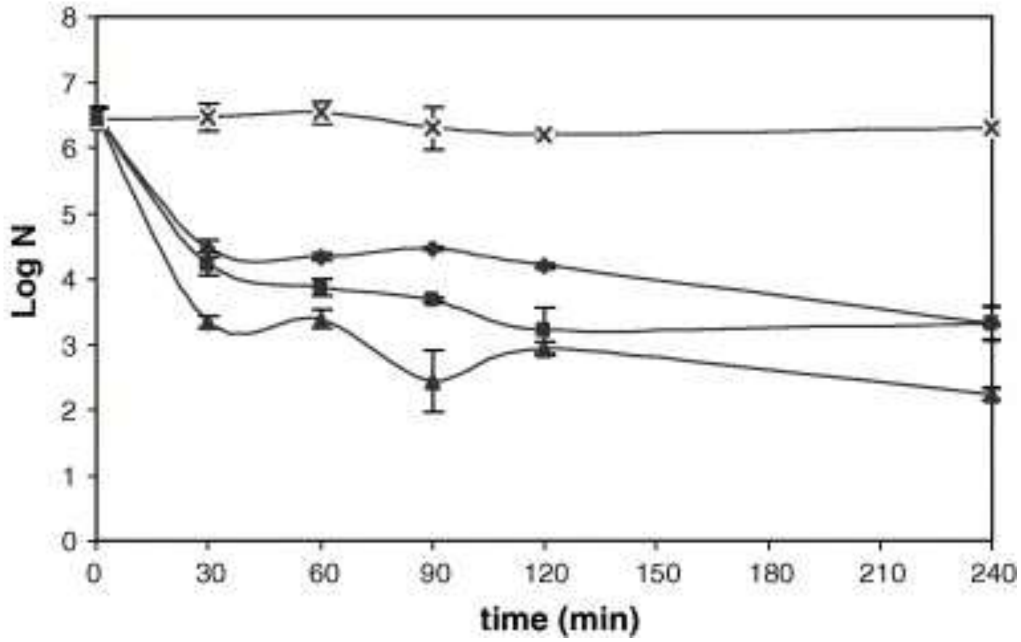
Antimicrobial Agents for Food Application

Antimicrobials	Polymer/carrier	Main target microorganisms	References
Organic acids / anhydrides: Propionic, benzoic, sorbic, acetic, lactic, malic	Edible films, EVA, LLDPE	Molds	Guilbert (1988), Baron & Sumner (1993) Torres & Karel (1985) Devlieghere, Vermeiren, Bockstal & Debevere, (2000) Weng & Hotchkiss (1993)
Inorganic gases: Sulfur dioxide, chlorine dioxide	Various polyolefins	Molds, Bacteria, Yeasts	CSIRO (1994) Wellinghoff (1995)
Metals: Silver	Various polyolefins	Bacteria	Ishitani (1995)
Fungicide: Benomyl, imazalil	LDPE	Molds	Weng (1992)
Bacteriocins: Nisin, pediocins, lacticin	Edible films, cellulose, LDPE	Gram-positive bacteria	Padgett, Han & Dawson (1998) Siragusa, Cutter & Willett (1999) Scanell, Hill, Ross, Marx, Hartmeier & Arendt (2000)
Enzymes: Lysozyme, glucose oxidase	Cellulose acetate, PS Edible films	Gram-positive bacteria	Appendini and Hotchkiss (1997) Padgett et al. (1998)
Chelating agents: EDTA	Edible films	Gram-negative bacteria	Padgett et al. (1998)
Spices: Cinnamic, caffeic, *p*-coumaic acids Horseradish (allylisothiocyanate)	Nylon/PE, cellulose	Molds, yeast, bacteria	Hoshino, Iijima, Hayashi & Shibata (1998) Anon (1995), Nielsen & Rios (2000)
Essential oils (plant extracts): Grapefruit seed extract, hinokitiol, bamboo powder, Rheum palmatum, Coptis chinesis extracts	LDPE, cellulose	Molds, yeast and bacteria	Lee, Hwang & Cho (1998) Imakura, Yamada & Fukazawa (1992) Oki (1998), Chung, Cho, & Lee (1998) Hong et al. (2000)
Parabens: Propylparaben, ethylparaben	Clay-coated cellulose LDPE	Molds	Katz (1998) Dobiaš et al. (1998)
Miscellaneous: Hexamethyl-enetetramine	LDPE	Yeasts, anaerobes and aerobes	Devlieghere et al. (2000)

Abbreviations: EVA (ethylene vinyl acetate); LLDPE (linear low density polyethylene); LDPE (low density polyethylene); PS (polystyrene); PE (polyethylene).

From: Appendini and Hotchkiss (2002)

Example of an edible film with Nisin: release controlled by diffusion

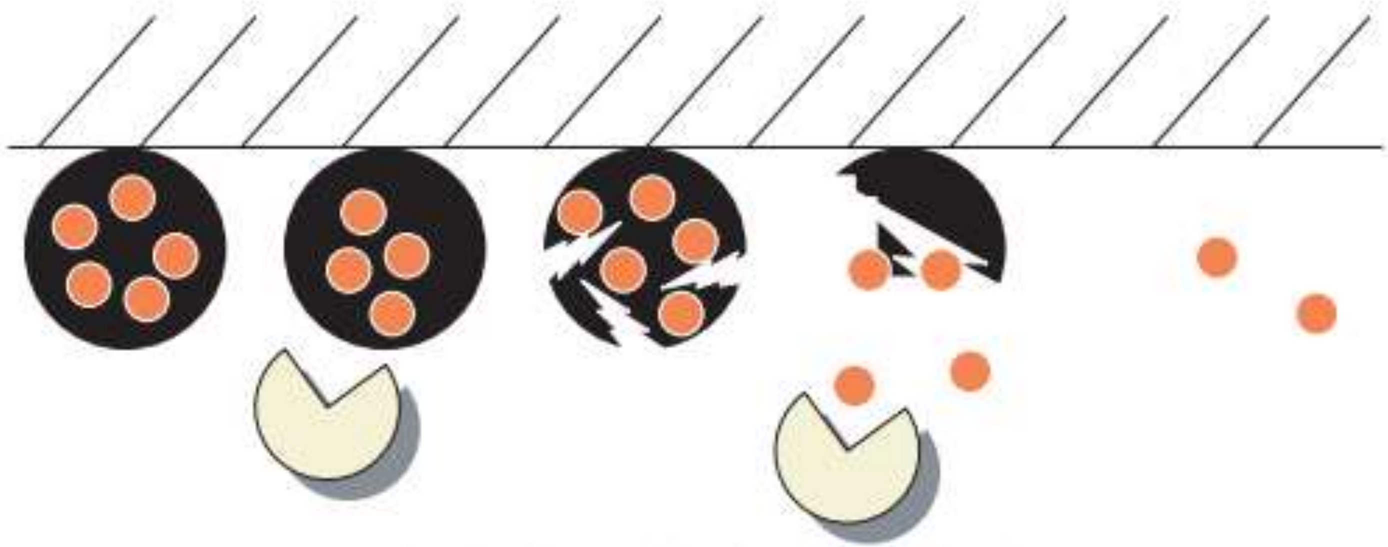


Films based on cassava starch with nisin: *N*: # CFU (*L. innocua*); x: control; ♦: 881 IU /cm^2; ■: 1322 IU/cm^2; ▲ : 2204 IU/cm^2.

From: Sanjurjo et al. (2006)

Antimicrobial activity on command

This system only releases its preservative on command: the preservative will be released from the packaging material if bacterial growth occurs (De Jong et al., 2005).

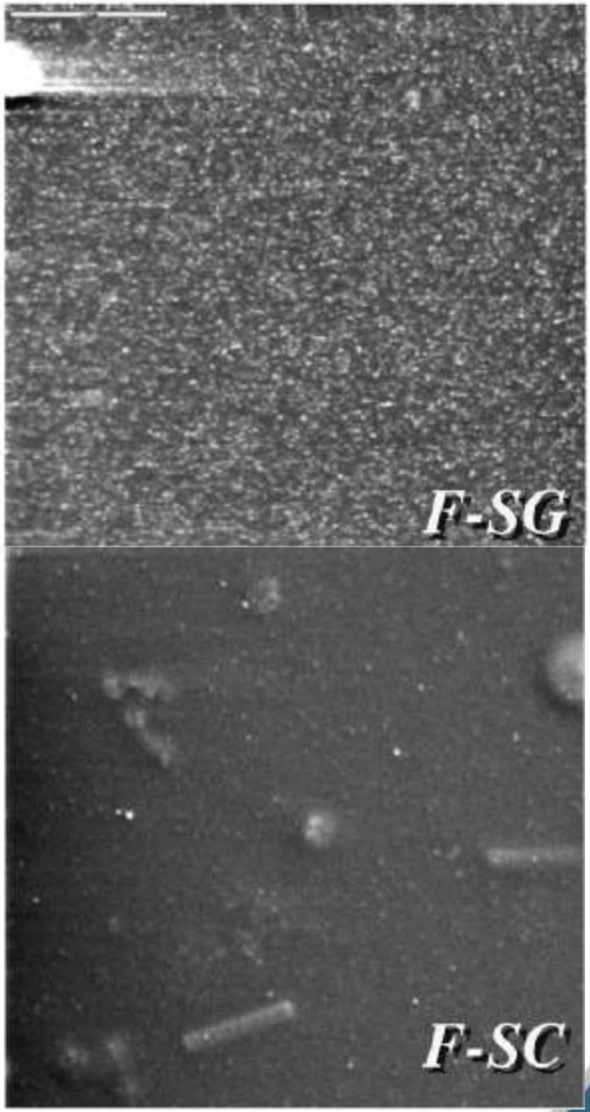


Micro-organisms hydrolyze starch-based particles, causing release of the antimicrobial lysozyme, resulting in inhibition of microbial growth.

Antioxidant activity

Antioxidant capacity of aqueous extracts of Soloyo Grande (SG) and Soloyo Chico (SC), filmogenic solutions (S) and films (F) with Soloyo Grande (SG) and Soloyo Chico (SC) Pumalal ecotypes, through the FRAP method. (S-C Filmogenic solution control without extract, F-C Film control without extract)

Samples	μmol $FeSO_4$ 7 H_2O	
	4 min	30 min
SG	670.16 ± 8.97	1148.21 ± 35.74
SC	902.79 ± 15.24	1475.09 ± 11.15
S-C	81.31 ± 14.67	200.14 ± 38.03
S-SG	496.20 ± 30.95	908.22 ± 38.81
S-SC	568.27 ± 11.64	908.27 ± 29.52
F-C	299.81 ± 5.96	424.61 ± 8.35
F-SG	394.65 ± 43.13	667.38 ± 70.42
F-SC	542.43 ± 45.70	943.50 ± 44.71



Films based on gelatin with aqueous extract from leaves of “murta”: «Soloyo Grande, SG; Soloyo Chico, SC».

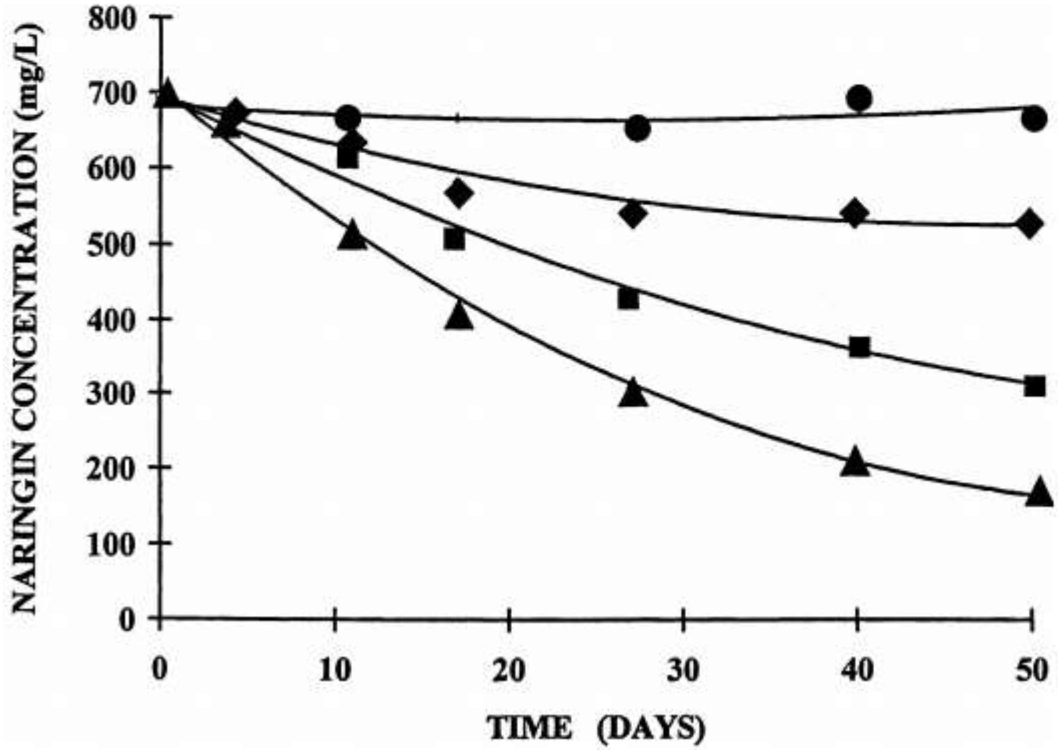
From: Gomez-Guillen et al. (2007).

Absorbers...

Concept	Food groups						
	Dry	High fat	Minimally processed	Meat and dairy	Frozen	Bakery	Beverages
O_2-scavenger	Roasted nuts, coffee, dried fish, cerals, species	Potato chips, chocolate	Fresh, pre-cooked pasta	Cheese, salami, smoked meats, fish, sausages	Fish, vegetables	Pizza crust, bread, cakes, cookies, pastries	Beer, fruit juice, ready-to-drink tea, tomato-based products, wine
CO_2-scavenger	Coffee		Fruit	Cheese, beef jerkey, poultry products			
CO_2-emitter	Nuts	Potato crisps, peanuts	Produce	Fresh meat and fish		Sponge cake	
C_2H_4-emitter				Climacteric produce			
C_2H_4-scavenger			Climacteric produce				
Moisture scavenger	All		Fresh pasta, produce	Meat, fish, cheese	Seafood, meat, fish	Bread, biscuites	
Ethanol emitter	Semi-dry fish			Cheese	Fish	Sweet bread, high moisture bakery products	
Antimicrobial release			Fruit	Cheese, meat		Bread, cakes	
Antioxidant release	Breakfast cereal						Bag-in-box wine
Flavour releasing film					Ice-cream		Orange juice
Flavour absorption				Fish			Fruit juicess

From: Vermeiren et al. (1999).

Processing Packaging



Naringin hydrolisis in grapefruit juice using increasing ratios of film area to juice volume during 6 weeks storage at 7 °C. Ratios of film area/juice volume were 3.6 cm^2/ml (▲), 2.1 cm^2/ml (■), 1 cm^2/ml (◆) and 0 cm^2/ml (●) (from Soares & Hotchkiss, 1998).

Intelligent Packaging

- Defined as materials and articles that monitor the condition of packaged food or the environment surrounding the food (Dainelli et al., 2008).

Examples of intelligent packaging applications for use within the food industry (Ozdemir & Floros, 2004).

Tamper evidence and pack integrity	Breach of pack containment
Indicators of product safety/quality	Time–temperature indicators (TTI's), gas sensing devices, microbial growth, pathogen detection
Traceability/anti-theft devices	Radio frequency identification (RFID) Labels, tags, chips
Product authenticity	Holographic images, logos, hidden design print elements, RFID

Smart package devices

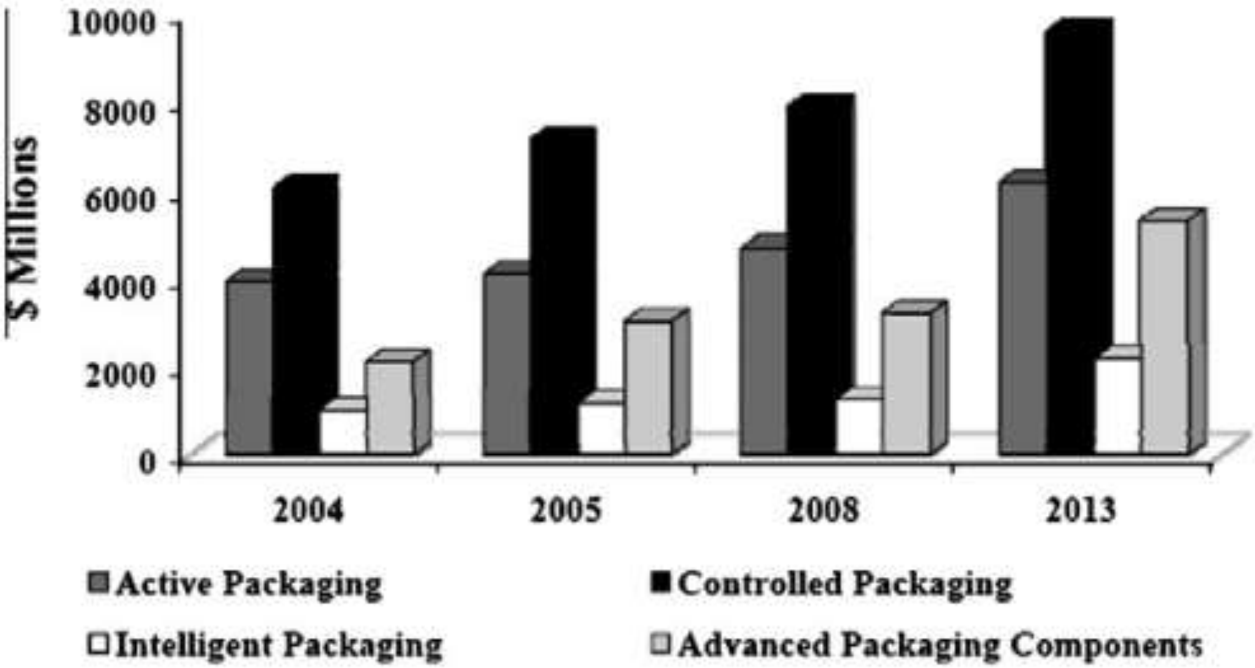
- Barcodes.
- Radio frequency identification tags: passive tags that have no battery, and active tags that have their own battery for powering the microchip's circuitry and broadcasting signals to the reader.
- Time-temperature indicators: critical temperature indicators, partial history indicators, and full history indicators.
- Gas indicators: usually by change of color of the device.
- Biosensors: consists of a bioreceptor that recognizes a target analyte and a transducer that converts biochemical signals into a quantifiable electrical response.

Freshness detector: the bumper sticker of the Japanese company To-Genkyo changes its color as more ammonia releases the meat. If not consumable, the bottom of the hourglass appears gray. (photo: To-Genkyo).

From: http://www.interempresas.net/Packaging/Articles/47806-Intelligent-packaging-with-built-in-freshness-detector.html.

Final Remarks

Growth of active, controlled, and intelligent packaging for the food and beverage industry 2004–2013 ($ millions).



From: Restuccia et al. (2010).

The Future

- Increasing of use of biodegradable material in food packaging.
- More researches are needed about the chemical, microbiological and physiological effects of various active agents.
- Discuss specific regulations on the use of active and intelligent packaging.

Muchas gracias por su atención

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