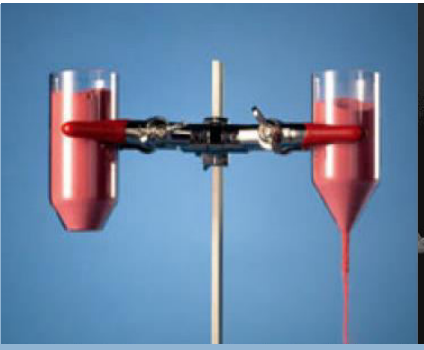
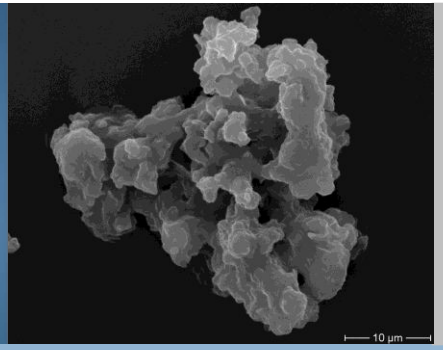
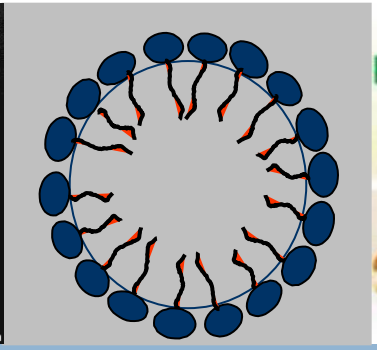
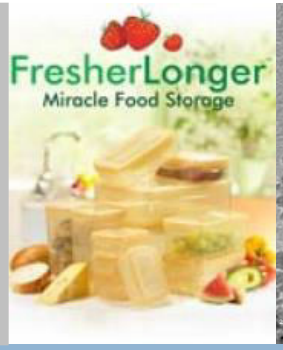
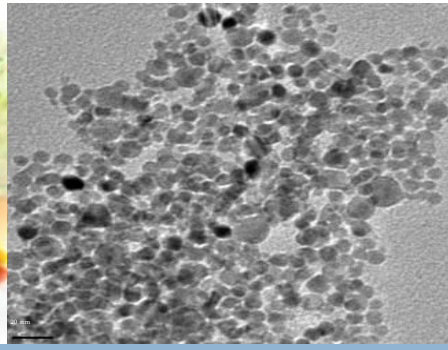
MRI
Max Rubner-Institut



Nanotechnology in the Food Sector – Tiny Particles, Big Effects

Ralf Greiner
Max Rubner-Institut,
Federal Research Institute of Nutrition and Food,
Department of Food Technology and Bioprocess Engineering,
Karlsruhe, Germany

Nanomaterials in the Food Sector

- nanotechnology applications are expected to bring changes to the food sector:
  - improved production and processing techniques
  - improved food contact materials
  - modification of taste, texture and sensation
  - monitoring food quality and freshness
  - reduced fat and salt content
  - enhanced nutrient absorption
  - improved traceability and security of food

Creation of Nanomaterials

Top Down

- use of mechanical or thermal energy
  - plant material, mineral materials



Bottom Up

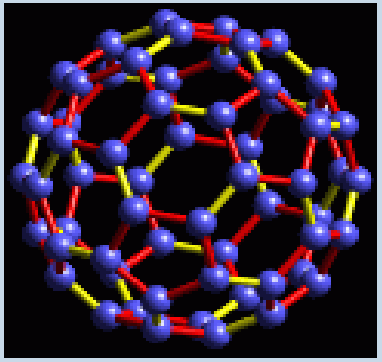
- creation of nanoparticles from singles molecules
  - by chemical reactions
    (e.g. enzymatic cross-linking of proteins)
  - molecular self association / self aggregation
    (e.g. micelles)



Creation of Nanomaterials
Nanotechnology versus Nanomaterials

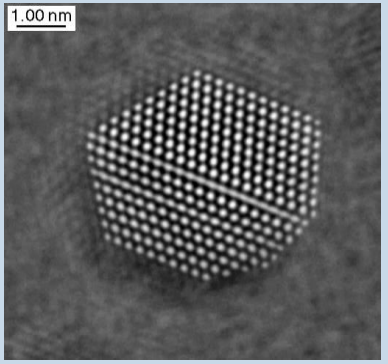
- nanotechnologies result in nanoparticles

Most do Not !!!



- nanoparticles derive from nanotechnologies

Most do Not !!!



Food Processing



raw material

naturally occurring nanostructures

Food Processing

proteins, starches, fats undergo structural changes at the nm and µm scales



huge variety of food products

naturally occurring nanostructures

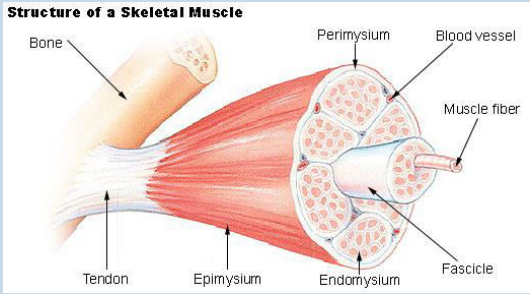
+

nanostructures introduced through processing

Naturally Occurring Nanostructures

- many food proteins are globular structures between 1 and 10 nm in size (true nanoparticles)
- structure of meat (myofibrils)
- the majority of polysaccharides and lipids are linear polymers less than one nm in thickness (1 dimensional nanostructures)
- the planer assemblies of cellulose fibrils in plant cell walls (2 dimensional nanostructure)





Nanostructures Introduced Through Processing

- many food processing operations such as coagulation, emulsifying or homogenising produce new nanostructures



- milk
  - fat globules of about 100 nm in size are produced through homogenisation

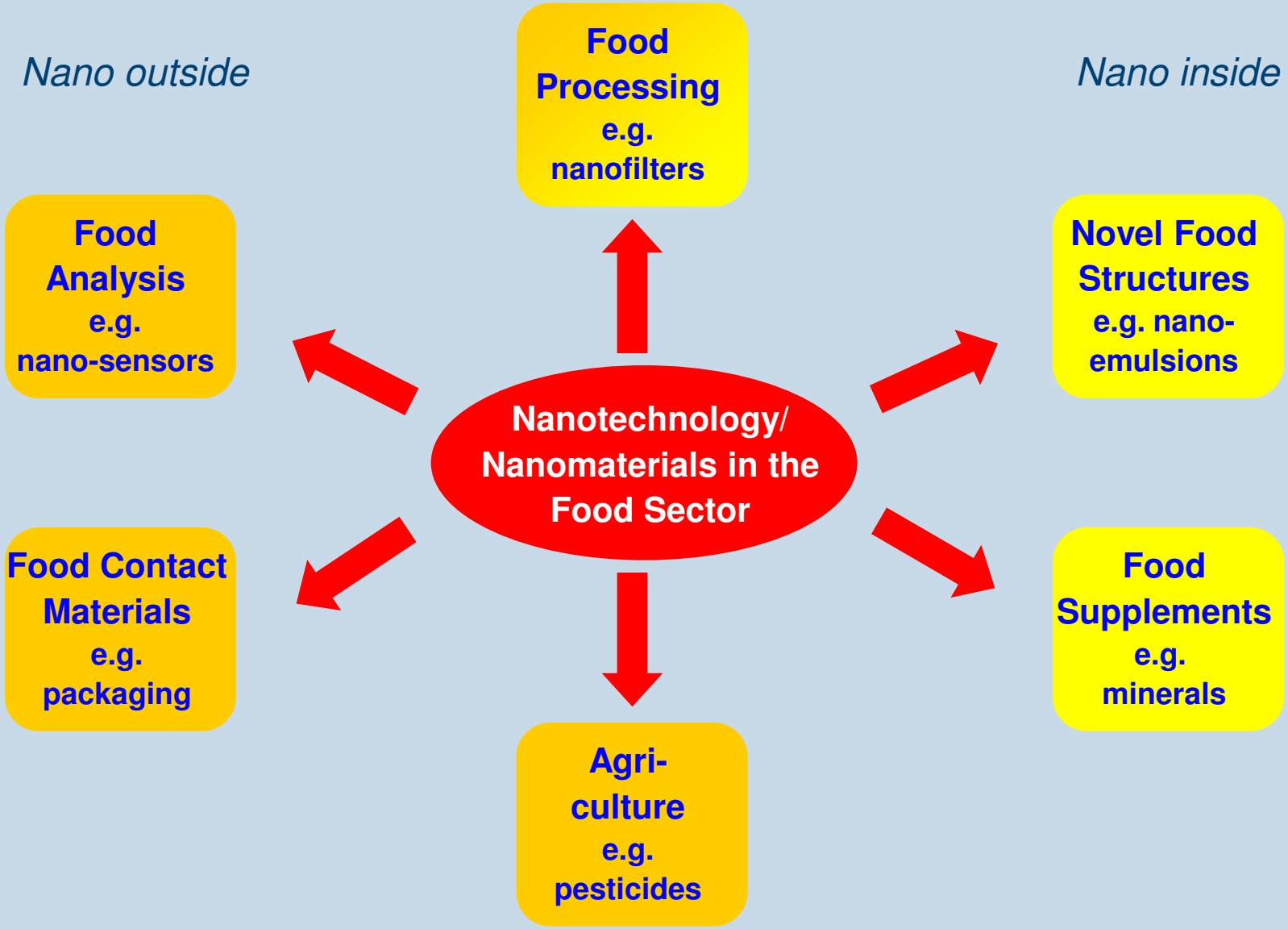


- foams
  - their creation and stabilisation requires the production of two dimensional nanostructures (e.g. the head on a glass of beer, ice cream, whipped cream, sauces, butter, margarine)



- custard / yogurt
  - involves creation of three dimensional networks

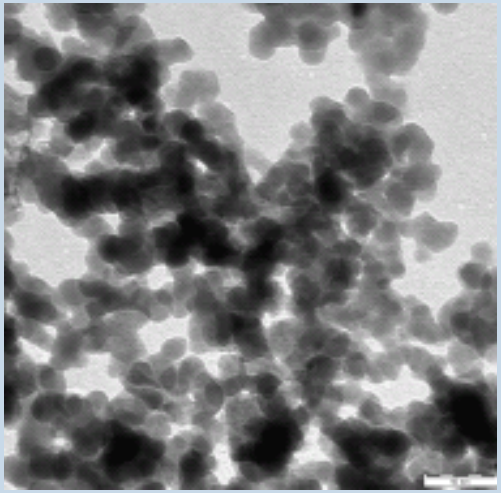
Potential Applications of Engineered Nanomaterials in the Food Sector



Food Structures

Properties

- texture
- consistency
- mouth feeling
- sensation
- energy density
- ....



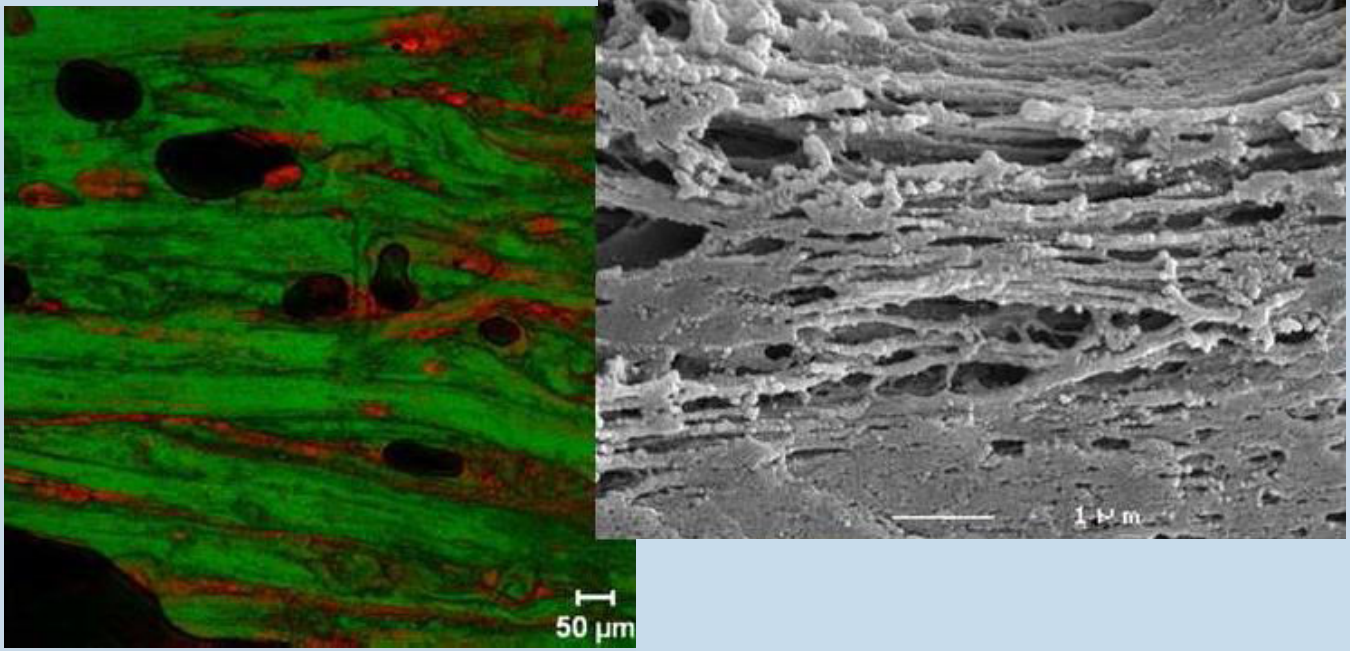


fat-reduced ice cream

Structuring of Foods
Meat Substitute

Alternative Protein Source

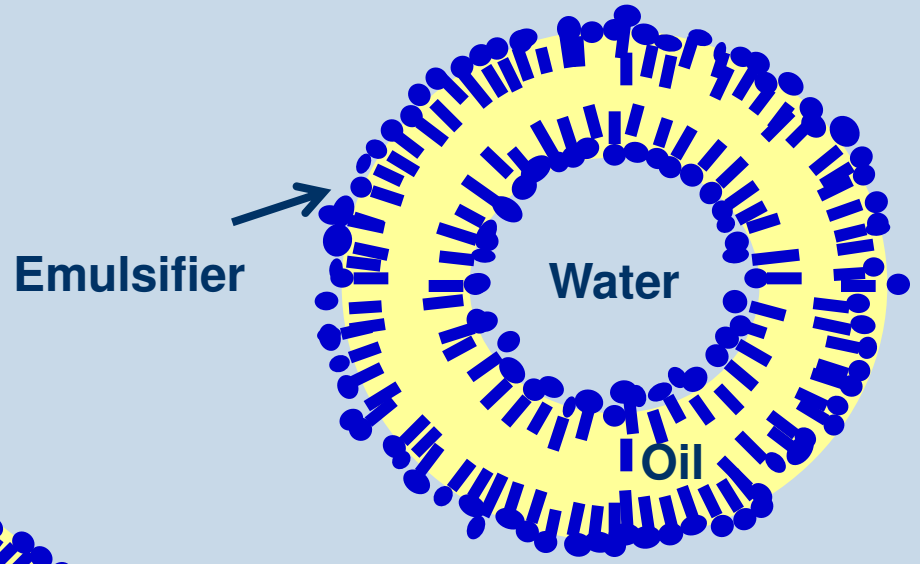
- calcium caseinate / fat

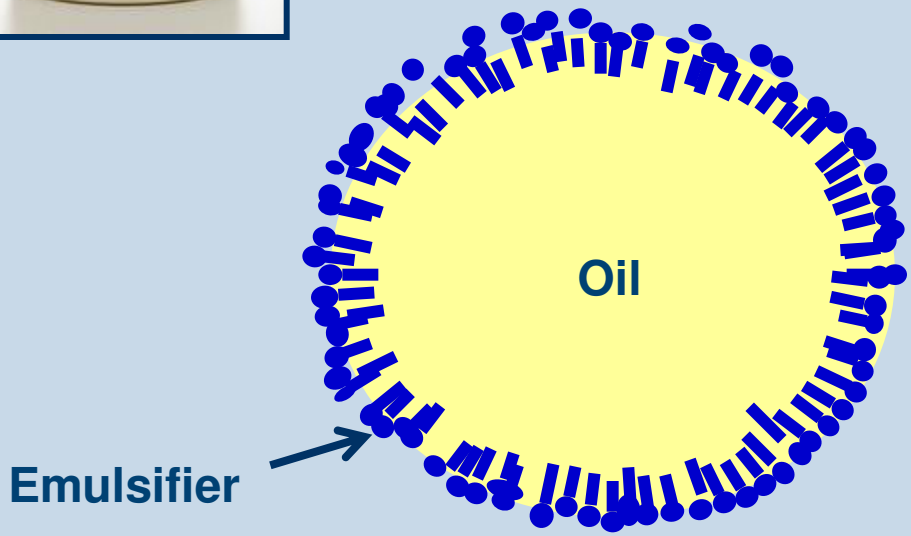


Kampers, 2011

Structuring of Foods
Fat-reduced Mayonnaise







Food Additives and Supplements

Silicon dioxide (E 551)

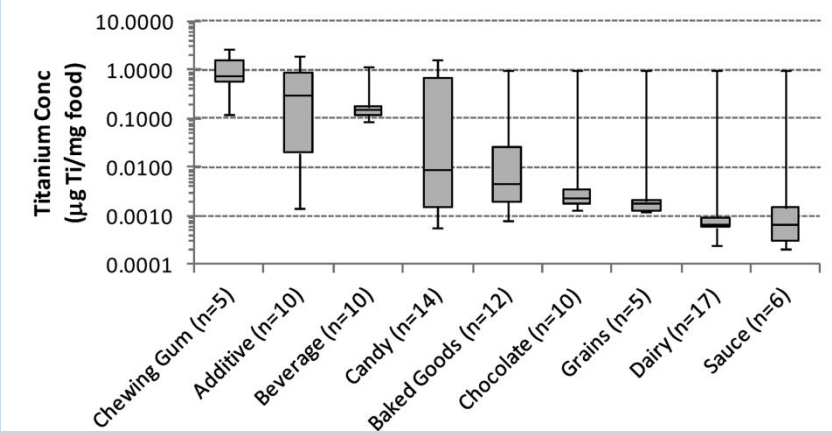
- dietary supplement (source of silicon)
- to improve technical properties
  - nano-scale amorphous SiO_2 ➔ agglomerated particles
  - anti-caking agent for powdery ingredients (e.g. whole egg powder, dried spices, tomato powder, coffee creamer)
  - addition in the single-digit percentage range
  - widely used since the 60ties

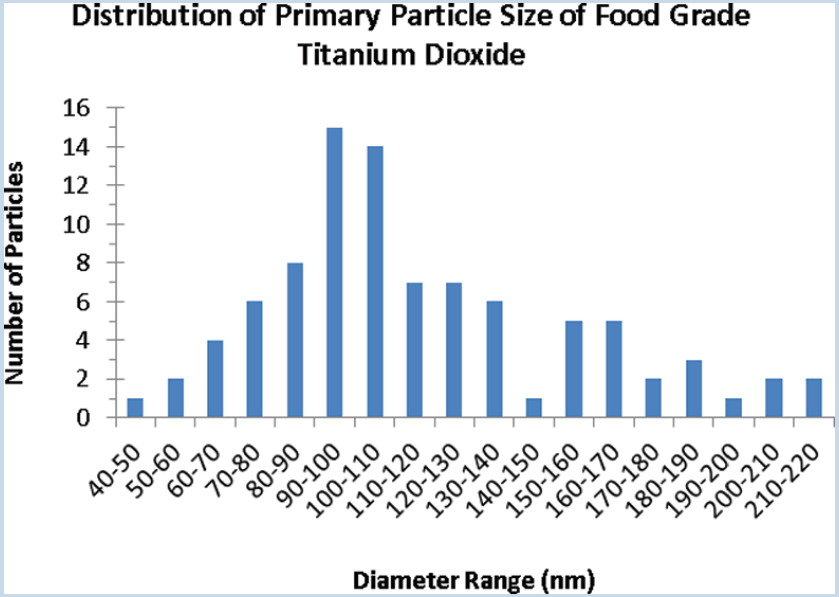


Food Additives and Supplements

Titanium dioxide (E 171)

- white pigment, icing material, flavour enhancer
  - candies, confectionaries
  - chewing gum
  - food icing
  - dried vegetables, nuts, seeds, soups, mustard, beer, wine



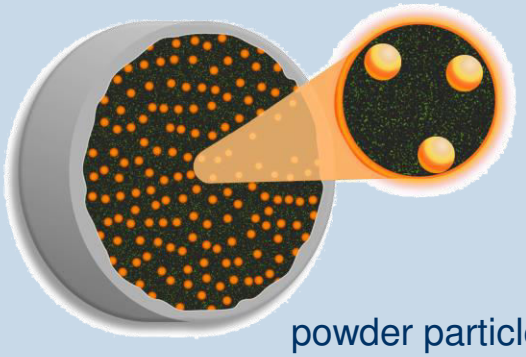


Weir *et al.*, Environ. Sci. Technol. 46, 2242−2250 (2012)

Food Additives and Supplements

Nano-lycopene (Lycovit®, since 2009 approved as a novel food)

- BASF produces a synthetic form of the tomato carotenoid lycopene
- mean particle diameter in the range of 300 nm
- nanoparticles in powders or in oil
- additive for beverages and other foods
- addition not only for health purposes, but also for colouring



powder particle 0.3 mm



nanoparticles
300 nm



BASF, 2006

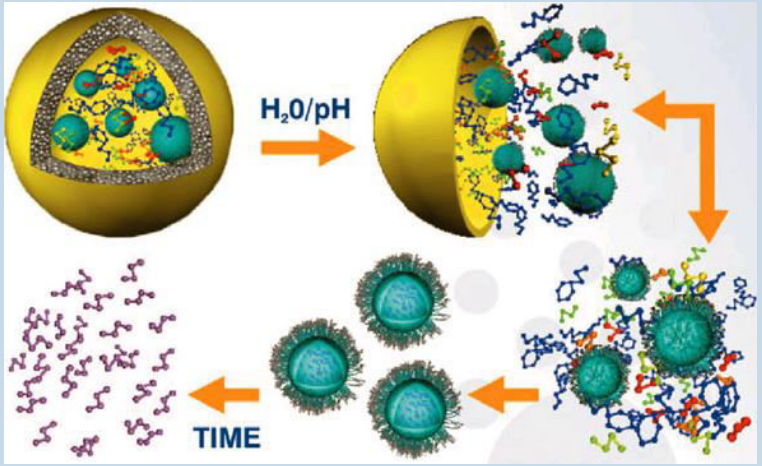
Food Additives and Supplements

Food Supplements

- bioavailability (nano-Se, nano-Pt, nano-Mg, nano-Zn, nano-Ca, nano-Fe)

Nano-encapsulation

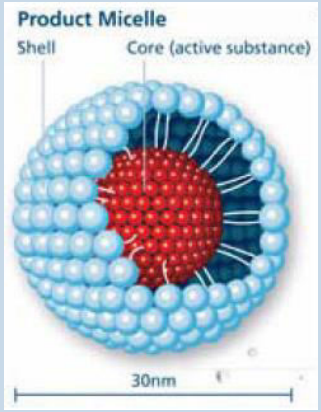
- bioavailability (e.g. fat-soluble vitamins)
- protection / stabilisation
  (e.g. acid-labile compounds)
- masking (e.g. omega-3 fatty acids)
- controlled release



Organic Carrier Systems

- coenzyme Q10 / α-lipoic acid
- benzoic acid
- citric acid
- ascorbic acid (vitamin C)
- vitamin A, D, E, K
- soybean isoflavones
- ß-Carotene
- lycopene
- lutein
- omega-3 fatty acids
- phytosterols





Examples:

- NovaSOL® solubilisates (Aquanova AG, Germany)
- Nutralease™ (NutraLease Ltd., Israel)
- VESIsorb® (Vesifact AG, Switzerland)

Organic Carrier Systems



Easy Iron, Sunactive Fe™
Taiyo International, Inc. (Japan)
- iron supplemented milk (Maeil, Korea)

Slim Shake Vanilla
RBC Life Sciences® Inc. (USA)
- silicon dioxide particles (4-6 nm) coated with flavour molecules





Shemen Industries (Israel)
- active canola oil contains phytosterols

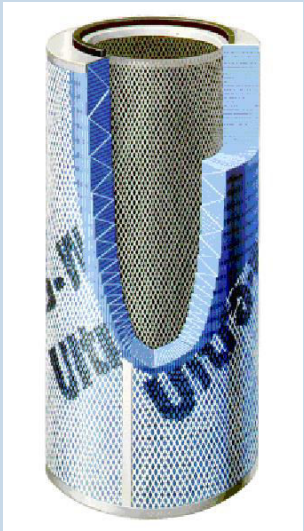
Food Processing

Nano-filtration

- nano-ceramics for restaurant deep-frying machines
- treatment of effluents from the food industry
- food industry
  - global market for nanofiltration membranes should reach USD 310.5 million by 2012
  - the water treatment sector was projected to account for 72.7% of total revenues in 2007
  - the main applications of nanofiltration in food production are in the dairy and sugar industry
  - around 300,000 m^2 of nanofiltration membranes are assumed to be currently applied in the food



nano-ceramic for deep-frying machines

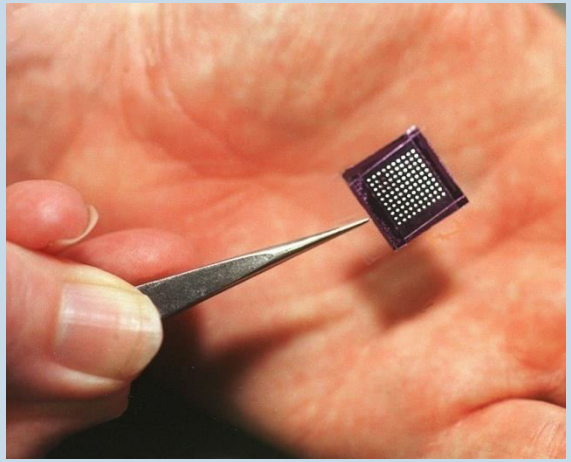


commercial air filter cartridge using nanofibre filter media

Food Analysis: Process- and Product Control

Nano-sensors / Nano-indicators

- detection of food-borne pathogens
- detection of toxins, allergens etc.
- quality control (freshness etc.)
- traceability
- ....



electronic tongue

Food Contact Materials

Packaging / Surfaces

- anti-microbial coatings (e.g. nano-Ag)



FresherLonger Miracle Food Storage, The Sharper Image (USA)



Nano Silver Spray, Nanogist Co. Ltd. (South Korea)



Anti-bacterial Kitchen Utensils, Nano Care Technology Ltd. (Hong Kong)



Baby Milk Bottles with Nano-Silver-Soother, Baby Dream Co. Ltd. (South Korea)

Food Contact Materials

Packaging

- anti-microbial coatings (e.g. nano-Ag, nano-MgO, nano-ZnO, release-systems)
- improved mechanical and technical properties (e.g. nano-clay, nano-titanium nitride)
- improved barrier properties for gas and moisture (e.g. nano-clay)



ketchup bottle with a non-stick coating to improve emptying

Food Packaging

composite of polyamide (nylon) + nano-clay



- used for:
  - bottles (multi-layer)
  - wraps, films
  - containers

- trade names:
  - Imperm® (Nanocor® Inc., USA))
  - Aegis™ NC (Honeywell Specialty Polymers, USA)

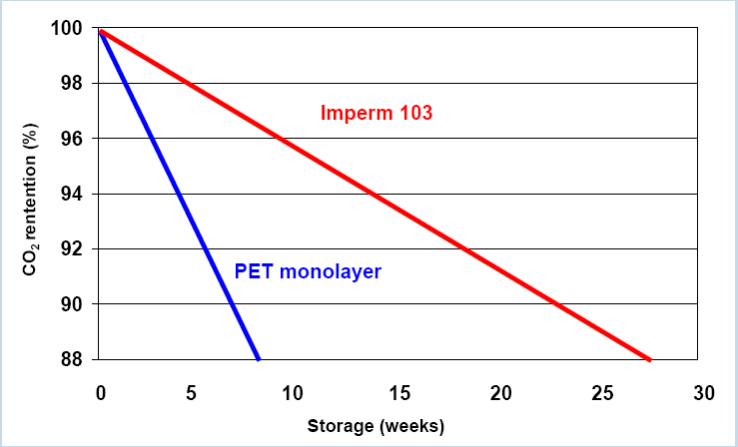
Food Packaging - Imperm®



Nanoclay particle-based nanocomposite of Nanocor







- reduced entrance of oxygen (80%) and minimized loss of carbon dioxide
- lighter and stronger
- used in plastic beer bottles, films and multilayer bottles, could replace EVOH layer in ketchup bottles

Food Packaging

composite of polyamide (nylon) + nano-clay



- used for:
  - bottles (multi-layer)
  - wraps, films
  - containers

- trade names:
  - Imperm® (Nanocor® Inc., USA)
  - Aegis™ NC (Honeywell Specialty Polymers, USA)



composite of starch and / or cellulose + nano-clay

- used for:
  - fruit bowls

Food Contact Materials

Packaging

- anti-microbial coatings (e.g. nano-Ag, nano-MgO, nano-ZnO, release-systems)
- improved mechanical and technical properties (e.g. nano-clay, nano-titanium nitride)
- improved barrier properties for gas and moisture (e.g. nano-clay)
- UV-protection in transparent wraps, films or containers (e.g. nano-titanium dioxide)
- non-stick coating
- active and intelligent materials (e.g. nano-clay with metal oxides)
- ....



ketchup bottle with a non-stick coating to improve emptying

Food Packaging

Active Packaging

- actively changes the condition of the packaged food to extend shelf-life or to improve safety or sensory properties, while maintaining the quality of the food

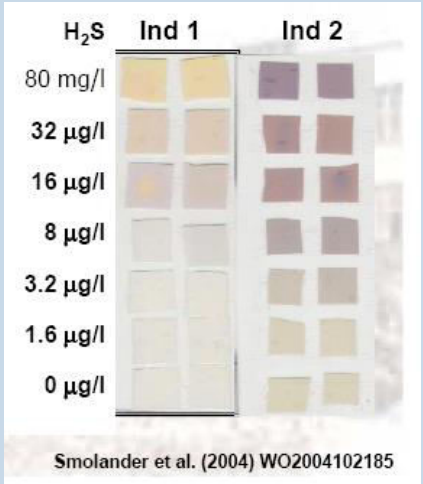


ethylene scavenging foils for packaging of fruit products to prevent early ripening

Intelligent Packaging

- monitor the conditions of packed foods to give information about the quality of the packed food during transport and storage

hydrogen sulphide indictor



Active Food Packaging



composite of polyamide (nylon) + nano-clay + oxygen scavenger

- used for:
  - bottles (multi-layer)
- trade names:
  - Aegis™ OX (Honeywell Specialty Polymers, USA)

Intelligent Food Packaging



reactive nano-layers

- used as a hydrogen sulphide indicator for:
  - Food Packaging
- Raflatac® Pro Label:
  - UPM Raflatac, Finland



nano-particle based intelligent inks

- used as „Printed Digital Content“ for:
  - Food Packaging
- nano-scale pigments, colours, gravures:
  - Inkbyte®, Finland

Food Contact Materials

Surfaces

- anti-microbial properties (e.g. Nano-Ag)
- improved mechanical properties
- water- and dirt-repellent surfaces
- ....



refrigerator with a nano-silver coating, Daewoo (South Korea)

Market Situation

- virtually all known applications of nanotechnology in food and food packaging are currently outside the EU, mainly in the USA, Australia, New Zealand, South Korea, Taiwan, China and Israel
- reservation on the EU market

Source: Chaudhry *et al.*, 2008

- market situation unclear
  - no register existing (in France from 2013, in Belgium from 2014 on)
  - up to now no labelling required (in the EU from December 2014 on)
  - the presence of engineered nanomaterials could not be clearly established in many products

Thank You Very Much
For Your Attention !!



Nanos (Greek) - dwarf

Ralf Greiner

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