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Food Applications of Nanotechnologies: An Overview of Potential Benefits and Risks

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Nanotechnology Applications

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- Current applications for the food sector and market drivers
- Likely benefits and concerns
- Main knowledge gaps

Sources of Information

The Food and Environment Research Agency

Food Additives and Contaminants, March 2008; 25(3): 241–258

Taylor & Francis

Review

Applications and implications of nanotechnologies for the food sector

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Food and Agriculture Organization of the United Nations

World Health Organization

FAO/WHO Expert Meeting on the Application of Nanotechnologies in the Food and Agriculture Sectors: Potential Food Safety Implications

MEETING REPORT

efsa

European Food Safety Authority

The EFSA Journal (2009) 958, 1-39

SCIENTIFIC OPINION

The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety[1]

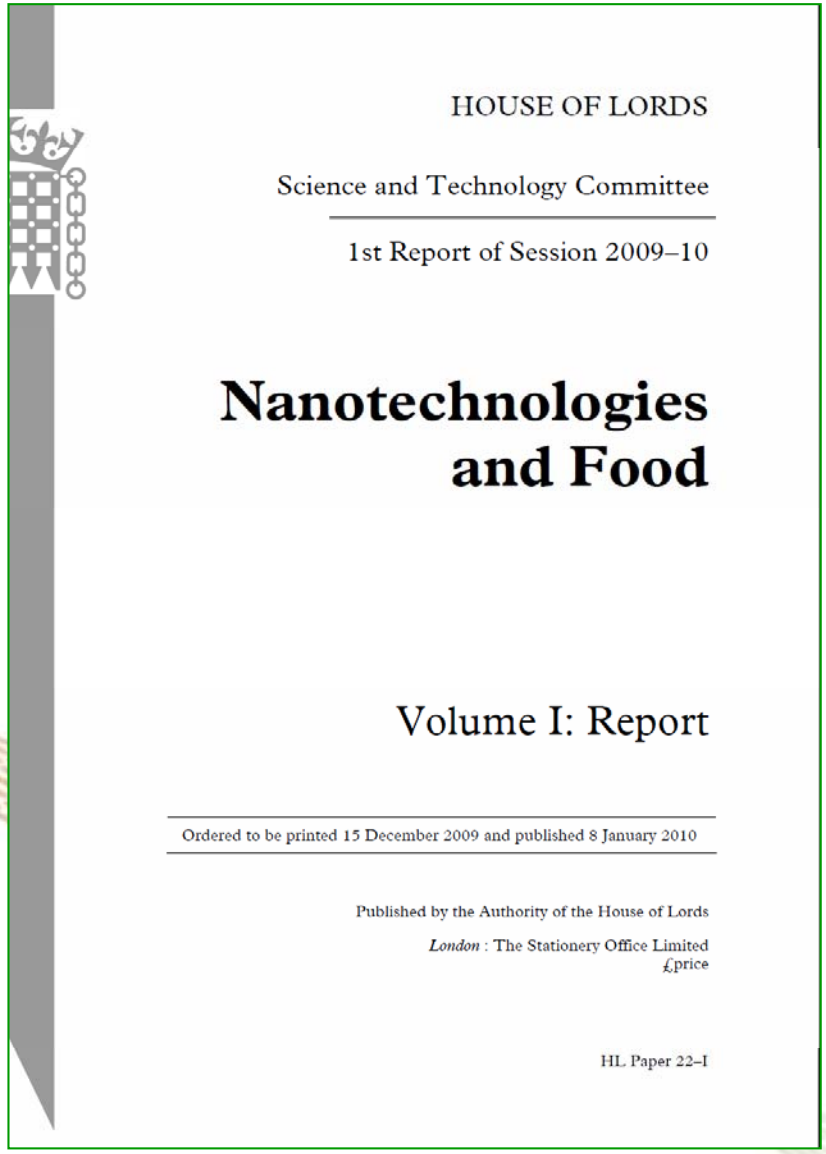
Scientific Opinion of the Scientific Committee

(Question No EFSA-Q-2007-124a)

Adopted on 10 February 2009

Sources of Information

The Food and Environment Research Agency



HOUSE OF LORDS

Science and Technology Committee

1st Report of Session 2009–10

Nanotechnologies and Food

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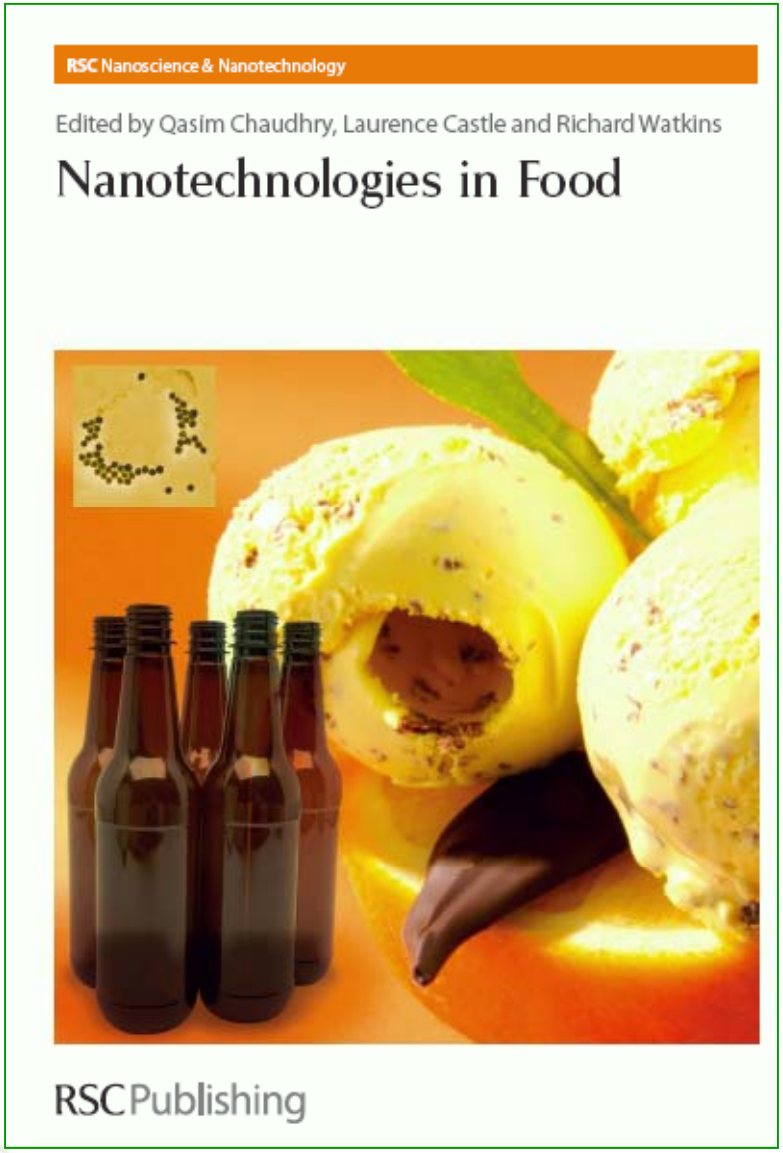
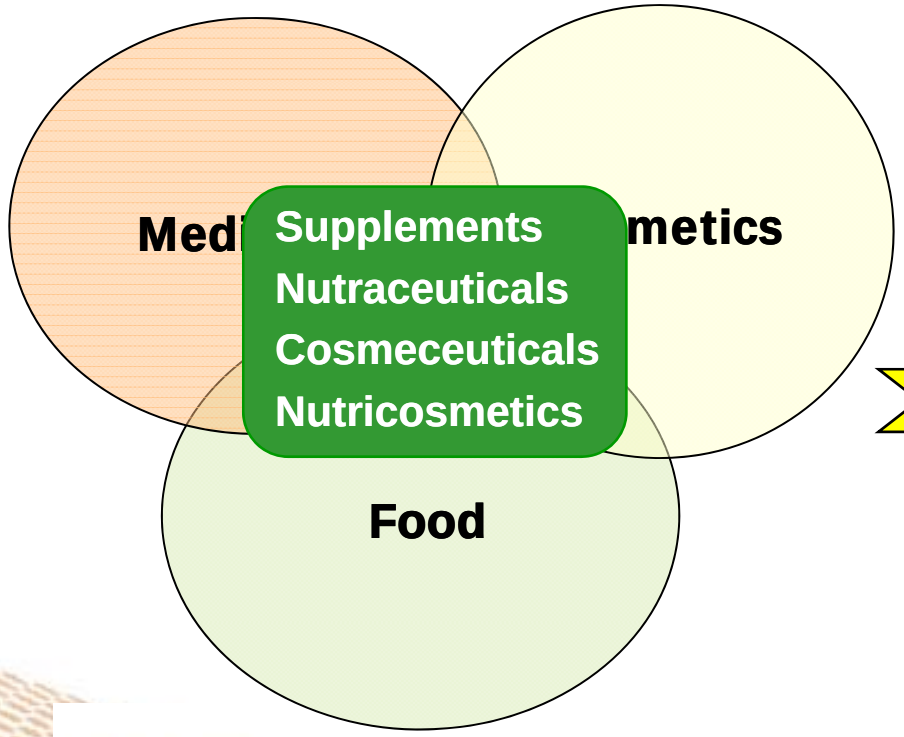


Food Related Applications



- ✓ Less use of agrochemicals
- ✓ Safer animal feeds (e.g. detoxification of mycotoxins)
- ✓ More hygienic food processing;
- ✓ Healthy food products (less fat, salt, preservatives);
- ✓ Improved bioavailability of nutrients & supplements
- ✓ Nano(bio)sensors for detection of contaminants;
- ✓ Smart packaging concepts (extended shelf-life of packaged foodstuffs);
- ✓ Water desalination/ decontamination

Sector Applications

- Cosmetics and personal care products ~60%
- Paints & coatings ~10%
- Catalysts & lubricants
- Security printing
- Textiles & sports
- Medical & healthcare
- Food and nutritional supplements ~10%
- Food packaging
- Agrochemicals
- Veterinary medicines
- Water decontamination
- Construction materials
- Electrical & electronics ~10%
- Fuel cells & batteries
- ~~Paper manufacturing~~
- Weapons & explosives

*Source: www.nanotechproject.org/inventories/consumer/

Current Market Status

- Increasing food related applications worldwide
- Only a few products available in Europe (supplements, food packaging);
- Food packaging has the largest share of market for nano-enabled products in the food sector;
  - ~$400m in 2006 (food packaging $200m)
  - predicted to grow to ~$6 billion by 2012 (food packaging $3 billion)*
  - packaging applications estimated to reach 19% of all nanotech products in the global consumer goods industry by 2015.**

* Cientifica report, 2006, ** Nanoposts report, 2008

Main Nanomaterial Types

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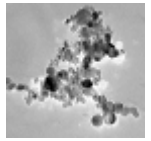
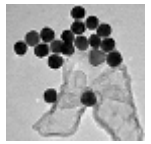
- Processed food nano-structures
  digestible – non-biopersistent
- Nano-encapsulated nutrients/ supplements
  digestible – non-biopersistent (?)
- Inorganic metal/ metal oxides
  insoluble, indigestible, potentially biopersistent
- Potential use of nano(bio)materials
  functionalised materials





Safety Concerns

Concerns raised over the safety of nanotechnologies to human health and the environment:

- Greenpeace
- The ETC Group
- Friends of the Earth
- The Soil Association
- The Royal Commission on Environmental Pollution

Consumer Safety Concerns

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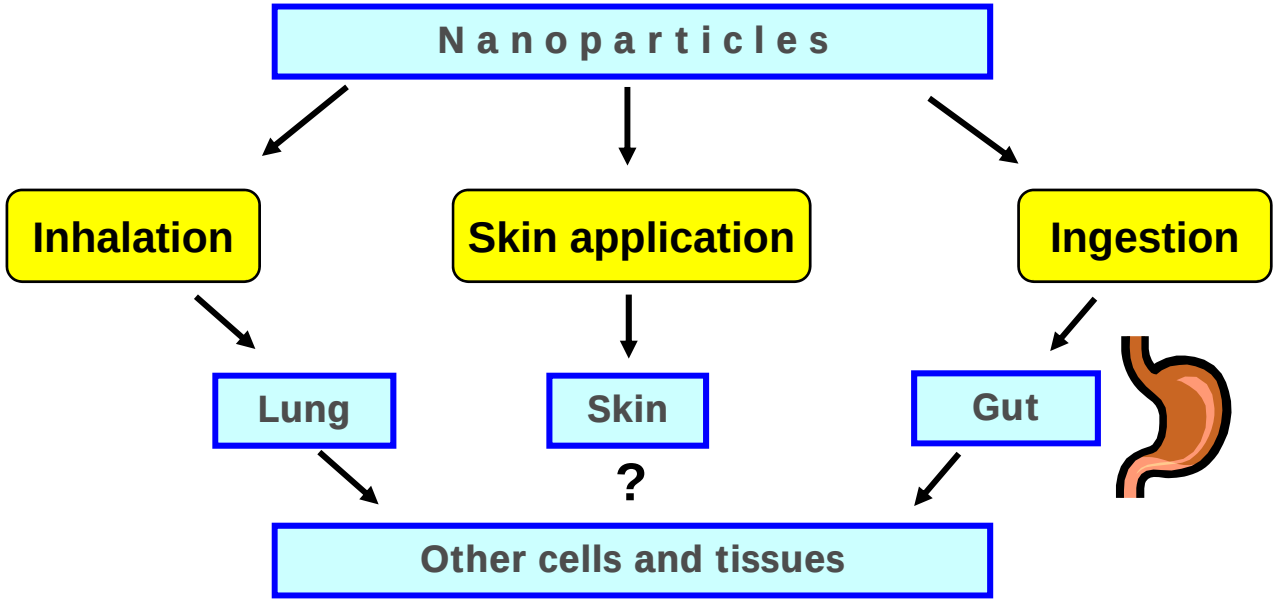

- Growing scientific evidence indicates that:
  - Insoluble nanoparticles may cross cellular barriers, and reach new targets in the body
  - exposure to **insoluble / biopersistent nanoparticles** via food may lead to certain adverse health effects

Absorption of Nutrients Through the GIT

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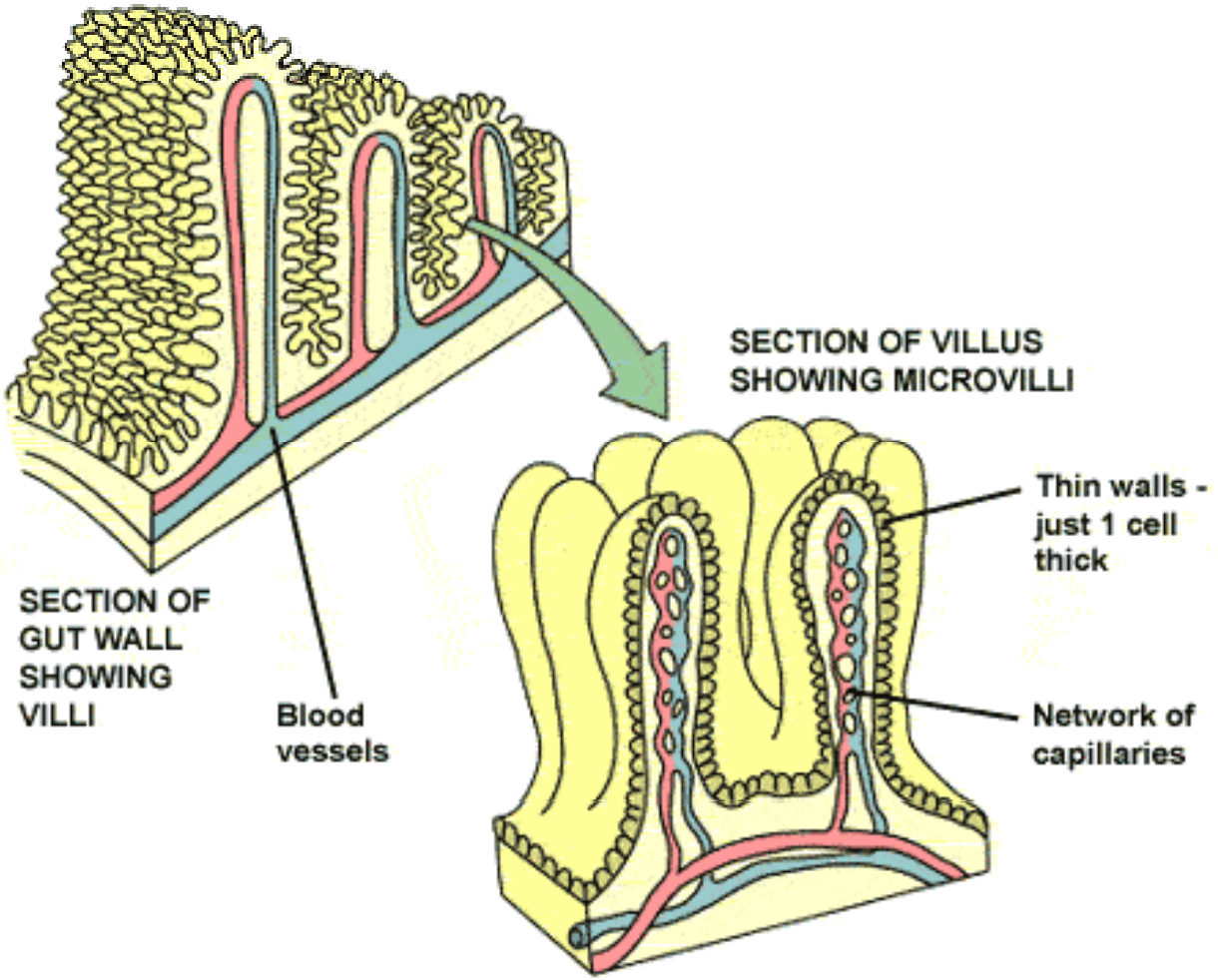

Image source: www.bbc.co.uk/gcsebitesize

GI Uptake and Translocation of ENPs

fera
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- Particles diffusion rate through GI mucus depends on size, charge (Szentkuti, 1997), and surface coating (Lai et al., 2007)
- Smaller nanoparticles can cross mucus layer faster than larger ones (Hoet et al., 2004)
- The rate of GI uptake of nanoparticles is greater in Peyer's Patches than enterocytes (Des Rieux et al., 2006)
- Translocation of nanoparticles is greater than larger particles (Desai et al., 1996; Hillyer and Albrecht, 2001; Des Rieux et al., 2006)
- Translocation has been shown after oral administration of nano-gold (Hillyer and Albrecht, 2001); nanosilver (Kim et al., 2008); magnetic nanoparticles (Kwon et al., 2008).
- No clear association between dietary particulates and gut diseases such as Crohn's or irritable bowel syndrome

Agriculture & Food Production

• **Animal feed**	• Nano-supplements – better uptake and bioavailability • Nanomaterials to bind toxins in feed
• **Animal Husbandry**	• Nano-diagnostic kits for animal diseases • Nano-formulated veterinary medicines and biocides
• **Crop production**	• Nano-formulated fertilizers • Nano-sensors for monitoring pests and diseases, and environmental conditions in the field (‘nano-dust’)
• **Crop protection**	• Nano-sized or nano-encapsulated active ingredients (pesticides) • Nano-carrier system for pesticides

Concerns

- Potential risk of worker exposure to hazardous materials, consumer exposure through potential carry-over into food

Food Processing

Technology

- Rational processing of food structures at nano-scale to improve quality, nutritional value, taste, texture, aroma.

Benefits

- Improved texture, flavour, taste
- Reduction in the amount of salt, fat, sugar, and other additives
- Enhanced bioavailability/ health benefits

Examples

- Nano additives (colours, flavouring agents, preservatives, antioxidants)
- (R&D) Nano-starch, Nano-cellulose…… Nano-salt, WOW Mayonnaise.

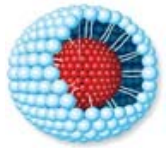
Concerns

- Area of least concern. Food nanostructures are likely to be digested/ solubilised in the GIT. Safety assessments must consider digestibility, and any major changes in bioavailability.

Nano-formulation

Technology

- Nano-encapsulation of ingredients, additives and supplements - based on liposomes/ other bio-polymers



Benefits

- Taste masking, protection from degradation during processing
- Enhanced bioavailability of nutrients/ supplements
- Antimicrobial and other health benefits

Examples

- Food additives (benzoic acid, citric acid, ascorbic acid), Supplements (vitamins A and E, isoflavones, ß-carotene, lycopene, lutein, omega-3 FAs, coenzyme-Q10)

Concerns

- Area of concern if encapsulates are not degraded in the GIT - ADME of nano-encapsulates may be different from bulk forms. A greater bioavailability of certain additives may have health implications.

*** Tip Top UP Bread contains microencapsulated tuna fish oil**

Nanoparticulate Additives/ Supplements

Technology

- Manufactured nanoparticle forms of mineral additives and supplements

Benefits

- Enhanced bioavailability of nutrients/ supplements
- Antimicrobial and other health benefits

Examples

- Mineral supplements (Ca, Mg)
- Nano – SiO_2, Se, TiO_2(?), Fe, Zn, Ag, Au, Pt .....

Concerns

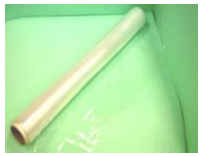
- Area of major concern. Potential consumer exposure to insoluble biopersistent ENPs - toxicological properties of which may not be known

Food Packaging

- **Improved nano-composites**
  - ENP-polymer composites with improved flexibility, durability, temperature/ moisture stability, barrier properties
- **‘Active’ nano-composites**
  - ENP-polymer composites incorporating nanomaterials with antimicrobial properties
- **‘Intelligent’ & ‘Smart’ packaging**
  - Packaging incorporating nano(bio)sensors to monitor condition of packaged foodstuffs

Examples






Concerns

- Potential consumer risk if ENPs migrate into food and drinks

Potential Migration of ENPs

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Two nanotech FCMs tested at Fera:

- Bottles containing nanoclay composite embedded between PET layers. No detectable migration of nanoclay from PET.
- Food containers made of polypropylene-nanosilver composite. Very low level of silver migration (less than the limit of quantification).
- In either case, the presence of nanoparticles did not affect migration of non-nano components.
- Lack of migration of titanium nitride also reported in PET containers.*

*EFSA (2008) 21st list of substances for food contact materials, Scientific Opinion of the Panel on food contact materials, enzymes, flavourings and processing aids (CEF) (Question No EFSA-Q-2005-151, EFSA-Q-2006-324, EFSA-Q-2006-323), Adopted on 27 November 2008, The EFSA Journal (2008) 888-890, 1-14.

Nano-coatings

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- Gas-barrier coatings – e.g. silica;
- Hydrophobic coatings – e.g. silica and lipid nano-structures for self-cleaning surfaces for hard-to-reach parts of machinery and conveyer belts.
- Antimicrobial coatings – e.g. silver for “active” surfaces, titanium dioxide and zinc oxide for photocatalytic sterilization of surfaces;

Smart Packaging Concepts

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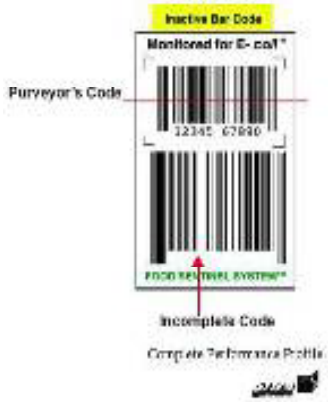
Nanotechnology derived intelligent packaging

- nanoparticle based intelligent inks
- reactive nanolayers
- analyte recognition at nanoscale

Safety requirements

- non-toxic & compatible with legislation
- reliability of products
- waste issues

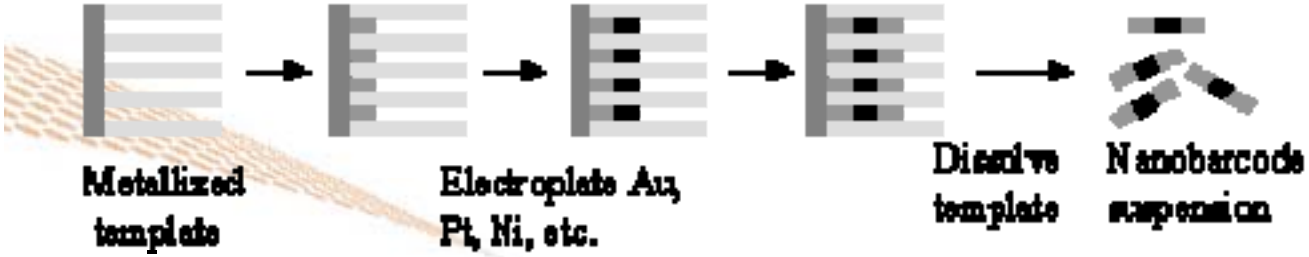


- Temperature
- Pathogens
- Freshness
- Integrity
- Humidity

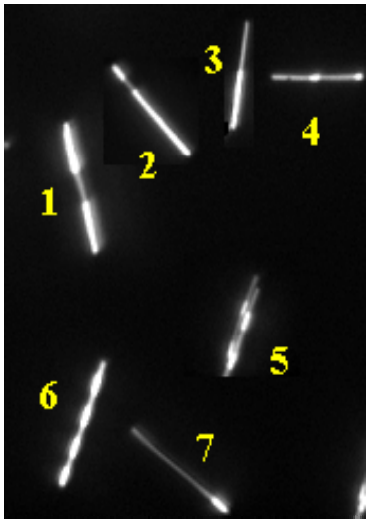
Slide courtesy of Dr. Maria Smolander, VTT Finland

Brand protection with Nanobarcodes

- commercially available Nanobarcodes® particles by Nanoplex < www.nanoplextech.com>
- encodeable, machine-readable, durable, sub-micron sized taggants
- manufactured by electroplating inert metals- such as gold, nickel, platinum, or silver- into templates that define the particle diameter, and then releasing the resulting striped nano-rods from the templates



Template-directed synthesis of Nanobarcodes particles.



Nanobarcode particles with different patterns of gold (Au) and silver (Ag) stripes.

Major Challenges

- How to detect and characterise nanoparticles in food matrices*;
- How nanoparticles will behave in the body, and the environment;
- Major knowledge gaps in regard to toxicological evaluation of short and long term exposure to insoluble, indigestible and potentially biopersistent nanoparticles via food and drinks

Some Risk Considerations

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- Nanotechnologies are likely to involve the use of relatively smaller amounts of materials;
- Nano additives are likely to undergo many transformations in food/ GI tract and may lose nano-character*;
- Acutely toxic materials are unlikely to be used in food products – risk assessment need to focus on longer-term exposure;
- Any nanotech application will have to go through the approval system – and thorough safety assessment.

* Due to agglomeration/ aggregation, binding with other food components, reaction with stomach acid, enzymes, other bio-transformations in the body

Regulatory Aspects

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- Nanotechnology developments are not happening in a regulatory vacuum; they are covered under current regulatory frameworks*;
- Food applications of nanotechnologies would come under existing risk assessment and approval processes in the EU and most other countries;
- Existing models for risk assessment are applicable; some modifications may be needed in testing methodologies.

e.g. relating to general food safety, food additives, novel foods, chemical safety, food contact materials, water quality, biocides, pesticides, veterinary medicines etc.

Summary

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- **Early days for nanotechnology applications**
  Most developments are at R&D stage, more products can be expected in the future
- **Potential benefits for the consumer**
  Reduction in the amount of salt, sugar, fat, preservatives, maintenance of quality and freshness, improved tastes and textures, improved bioavailability of nutrients and supplements, longer shelf life, better traceability and safety of packaged food products
- **Gradual but far-reaching changes**
  Probably not any major step-change applications – at least not in the short term
- **Regulatory controls**
  Stringent regulations are in place to ensure consumer safety
- **Major challenges**
  Detection/characterisation, quality assurance, health and environmental safety, regulatory compliance