ICoMST – Copenhagen August 2009

The Food and Environment Research Agency

Applications of Nanoparticles for the Food Industry and Potential Safety Issues

Dr. Qasim Chaudhry

The Food and Environment Research Agency

York, United Kingdom

Nanotechnology Applications for Food Sector

The Food and Environment Research Agency

- What is nanotechnology?
- Current and projected applications for the food sector
  - Likely benefits
  - Potential risks
  - A possible way forward

A Brief Introduction

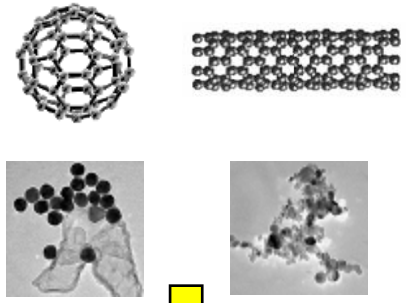
The Food and Environment Research Agency

- Nanotechnology involves the manufacture, processing, and application of materials that have **one or more dimensions** of the order of **100 nanometers (nm) or less** [BBSI PAS 71:2005)]

1 nm = 1 billionth of a meter

Nanomaterials and Nanoparticles

- 1/5,000,000 the size of an ant
- 1/80,000 of the diameter of a human hair
- 1/90 the size of HIV virus



- Uniform (spherical and tubular)
- Irregular (clusters, aggregates)
- Bound (embedded) forms
- Free nanoparticulates

- **Novel materials, applications and consumer / industrial products**

Novel Properties of Nanomaterials

The Food and Environment Research Agency

- Normal physicochemical rules do not apply well at the nano-scale:
  - nanomaterials may behave differently from ‘parent’ materials
  - extremely small size = very large surface area
  - novel properties of materials = novel products
- Fast growing application of nanomaterials in a variety of consumer products

Nanotechnology Applications

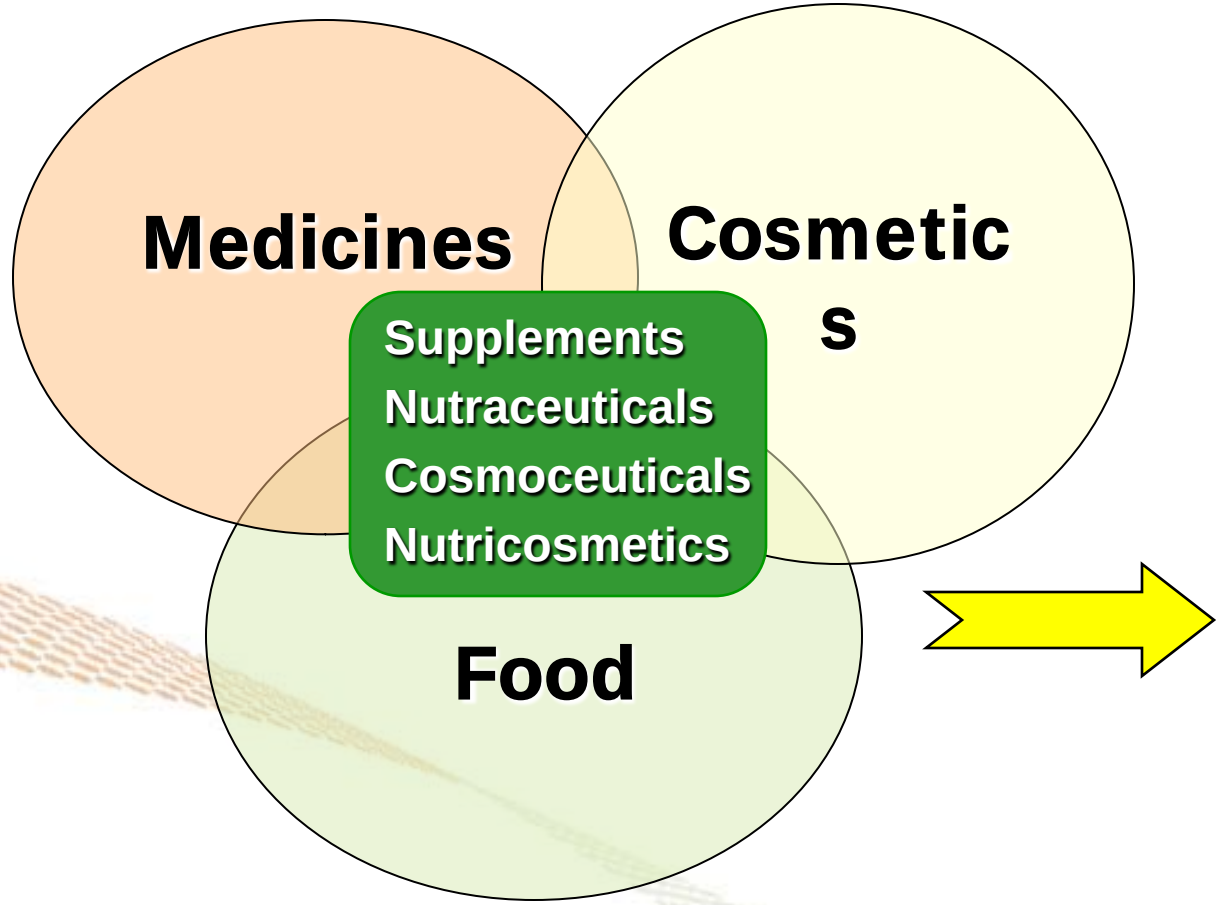
The Food and Environment Research Agency

- 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/

Nanotchnology Applications for Food/ Feed Sectors

The Food and Environment Research Agency



- ✓ New tastes, flavours, and textures of food
- ✓ Less amount of fat, salt, sugar and preservatives
- ✓ Enhanced uptake and bioavailability of nutrients and supplements
- ✓ Increased nutritional value
- ✓ Maintenance of food quality and freshness,
- ✓ 'Improved', 'Active', 'Intelligent', and 'Smart' packaging
- ✓ Better traceability and safety of food

Current Status of Food Applications

The Food and Environment Research Agency

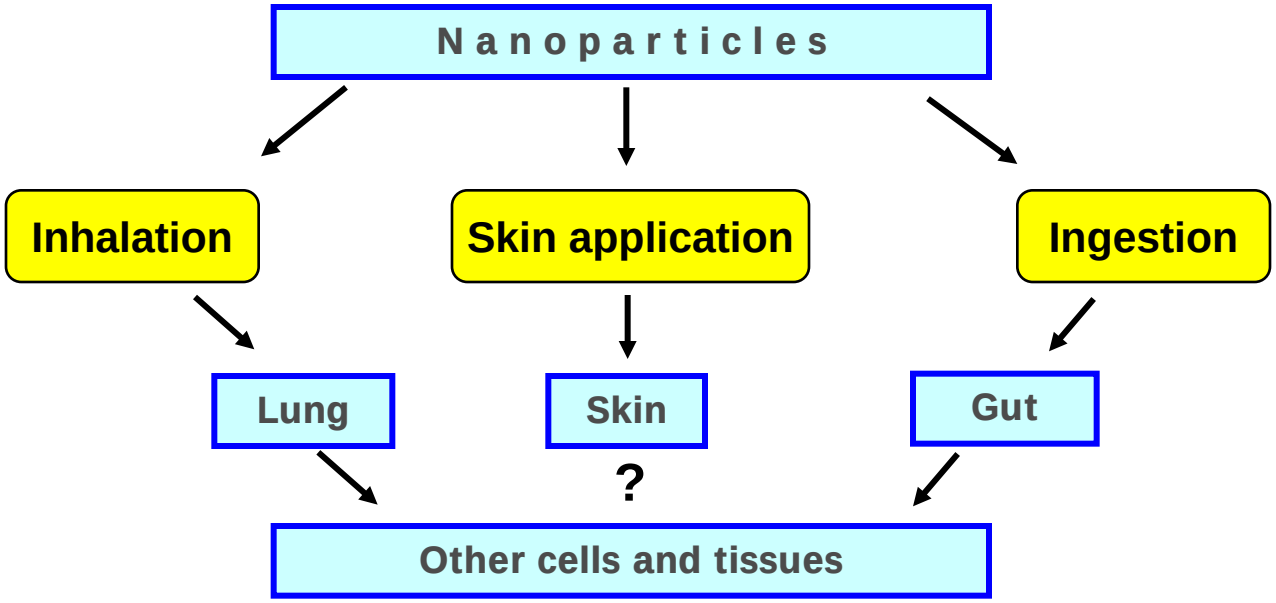
- Increasing applications of nanotechnology for food and related sectors worldwide;
- Potential impacts on plant and animal food production, food processing, food storage, transportation, consumption;
- Most applications are outside Europe, only some supplements and food packaging materials are currently available in the EU;
- Global food applications (including packaging) estimated at US$4 million in 2006, predicted to range between US$6 billion by 2012 and >20 billion by 2010

Safety Concerns

The Food and Environment Research Agency

- Some concern over safety of nanotechnologies have been raised by:
  - Greenpeace
  - The ETC Group
  - Friends of the Earth
  - The Soil Association
  - Which?
  - The Royal Commission on Environmental Pollution

Consumer Safety Concerns



- Properties of nanoparticles may differ widely from ‘conventional’ forms
- Growing scientific evidence indicates that:
  - free nanoparticles can cross cellular barriers, and may reach those targets in the body where larger equivalents could have not reached
  - exposure to some ENPs can increase production of oxyradicals that may lead to oxidative damage and inflammatory reactions

- Geiser et al. (2005) Ultrafine particles cross cellular membranes by nonphagocytic mechanisms in lungs and in cultured cells, Environmental Health Perspectives 113 (11): 1555-1560.
- Li et al. (2003) Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage, Environmental Health Perspectives 111(4): 455-460.

GI Uptake and Translocation of Nanoparticles

- Particles diffusion rate through GI mucus depends on size, charge (Szentkuti, 1997), and surface coating (Lai et al., 2007)
- Translocation of ENPs is greater than larger particles (Desai et al., 1996; Des Rieux et al., 2006)
- Smaller ENPs cross the mucus layer faster than the larger ones (Hoet et al., 2004)
- Translocation of smaller ENPs is greater than the larger ones (Hillyer and Albrecht, 2001)
- The rate of GI uptake of ENPs is 2-200 times greater in Peyer's Patches (only ~1% of the total intestinal surface area) compared with the enterocytes (Des Rieux et al., 2006)
- Contradicting results on the association of dietary particulates (micro or nano-sized) with the initiation or exacerbation of gut diseases such as Crohen's or irritable bowel syndrome
- Translocation to different organs following oral administration of:
  - smaller sized gold ENPs (Hillyer and Albrecht, 2001)
  - nanosilver (Kim et al., 2008).
  - magnetic ENPs (Kwon et al., 2008).

Nano-sized Ingredients/ Additives

Technology

- Processed nano-structures in food
- Use of nano-sized ingredients & additives

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)
- Lycopene, Nano-salt, WOW Mayonnaise

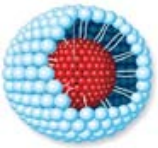
Concerns

- Need to ensure nanostructures are solubilised/ digested in the gut – i.e. they do not carry insoluble biopersistent materials to the circulatory system

Delivery Systems for Supplements/ Nutraceuticals

Technology

- Nanoencapsulation of ingredients, additives and supplements
- Based on micelles & liposomes



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, lutein, omega-3 fatty acids, coenzyme-Q10)

Concerns

- Need to ensure that greater bioavailability does not lead to increased health risks
- Tissue distribution is not different from that of conventional forms

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

Engineered Nanoparticulate (ENP) Additives

Technology

- Manufactured nanoparticle forms of additives and supplements

Benefits

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

Examples

- Mineral supplements (calcium, magnesium, iron, zinc, silica, diatomaceous earth, silver, gold)
- Nano-tea; “slim-shake chocolate”

Concerns

- Possible exposure to insoluble free ENPs, inside and outside the gut
- Toxicological properties of most ENPs are not yet known

Food Packaging Applications

- **Improved nano-composites**
  - Polymers incorporating nanomaterials to improve flexibility, durability, temperature/ moisture stability, barrier properties
- **‘Active’ nano-composites**
  - Plastic polymers incorporating nanomaterials with antimicrobial properties
- **‘Intelligent’ & ‘Smart’ packaging**
  - Packaging incorporating nanosensors to monitor condition of the food

Examples




Concerns

- Potential risks due to migration of ENPs into food and drinks

Nanomaterial Migration in FCMs

The Food and Environment Research Agency

Two nanotech food contact materials 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.

- Some reassurance from the limited tests available so far, but more materials need testing.

Smart Packaging Concepts

The Food and Environment Research Agency

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

Developments at R&D stage

The Food and Environment Research Agency

- Nano(bio)sensors for monitoring food product for microbial and environmental safety and traceability
- Smart labels incorporating Radio Frequency Identification Display (RFID) to enable tracking of food products during transport and distribution
- Nano(bio)sensors for disease monitoring in farmed animals
- Nano-veterinary medicines for animal health
- Feed ingredients and supplements for animal nutrition and health – e.g. Nano-additives that can bind and inactivate toxins in animal feed

Regulatory Aspects

The Food and Environment Research Agency

- Food Standards Agency (draft) Review (2006): www.food.gov.uk/multimedia/pdfs/nanotech.pdf
- Defra Review by Chaudhry et al. (2006): www.defra.gov.uk/science/Project_Data/DocumentLibrary/CB01075/CB01075_3373_FRP.doc
- Chaudhry et al. (2007): Potential use of nanomaterials as food additives or food ingredients and implications for consumer safety and regulatory controls, Final Report on Project A01057, Food Standards Agency London.
- Chaudhry et al. (2008): Potential applications of nanotechnology for food contact materials and implcations for consumer safety and regulatory controls, Final Report on Project A03063, Food Standards Agency London www.food.gov.uk/science/research/researchinfo/contaminantsresearch/contactmaterials/a03prog/a03projlist/a03063/.

Regulatory Aspects

The Food and Environment Research Agency

- Most nanotechnology applications would come under some approval process:
- The existing models for risk assessment should be applicable; but certain modifications would be needed in testing methodologies
- There are major gaps in knowledge in relation to:
  - the effects of ENPs on human health
  - agreed dose units for hazard and exposure assessments
  - reliable and validated methods for measurement and characterisation of ENPs in complex food matrices

Regulatory Aspects -Food

The Food and Environment Research Agency

- General Food Law (Regulation 178/2002) sets out the general principles and requirements of food law within the EU, including setting up of EFSA – **Food placed on the market is not unsafe**
- Food Additives (Framework Directive 89/107) and the subordinate legislation – **Only approved additives are used in food**
- **Novel Foods** and Novel Food Ingredients (Regulation (EC) 258/97):
  - Article 1 of Regulation 258/97 defines a 'novel' food as a food or food ingredient not having a significant history of human consumption within the Community prior to May 1997 and which falls within certain defined categories; e.g.:
  - 'foods and food ingredients to which has been applied a production process not currently used, where that process gives rise to significant changes in the composition or structure of the foods or food ingredients which affect their nutritional value, metabolism or level of undesirable substances' (Article 1(f) Regulation 258/97).

Regulatory Aspects - Packaging

The Food and Environment Research Agency

- The main statutory instrument is Regulation (EC) No.1935/2004 on materials and articles intended to come into contact with food
- Directive 2002/72/EC (as amended) - plastic materials and articles intended to come into contact with foodstuffs
- Commission Directive 2005/31/EC amending Council Directive 84/500/EEC - ceramic articles intended to come into contact with foodstuffs.

New Regulatory Proposals

The Food and Environment Research Agency

Food Additives

- A set of 4 proposed Regulations published by the EC, as likely replacement of Food Additives Framework Directive by a common authorisation system, to provide a common basis of controls on food additives (Regulation EC 7/2008), food enzymes (Regulation EC 8/2008), and food flavourings (Regulation EC 9/2008).
- The most relevant aspect to nano- food additives in the proposed Regulation is the **re-evaluation** of safety assessment, which would ensure that food additives, once permitted, are kept under continuous observation and re-evaluation.

Novel Foods

- A proposal by the European Parliament for a new Regulation on novel foods (2008/0002 (COD)), which would repeal Regulation (EC) No. 258/97 - includes in the Preamble 'foods modified by new production processes, such as nanotechnology and nanoscience, which may have an impact on food' as novel foods

Summary

The Food and Environment Research Agency

- **Early days for the new technology**
  More products are in the R&D pipeline, and are likely to be available in the near future;
- **Potential benefits**
  Maintenance of quality and freshness, improved tastes, flavours, textures, nutritional value, shelf life, traceability and safety, less use of additives, improved animal nutrition and health;
- **Safety concerns**
  Concerns over potential health effects of food products that may contain insoluble, indigestible, and biopersistent nanoparticles.
- **Consumers information**
  Consumer information/ involvement/ education is a must for the success of nanofoods

A Way Forward

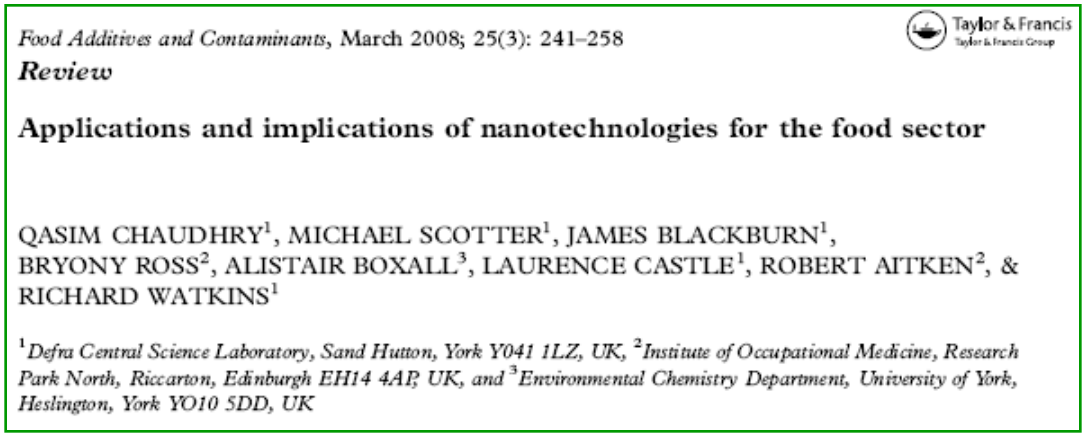
The Food and Environment Research Agency

- Industry needs to show due diligence when using nanofood/ feed products, in that:
  - there are clear advantages in the use of nanotechnology over other available technologies
  - the benefits outweigh any risks, and the risks are acceptable
- Assure product quality, promote research to fill knowledge gaps:
  - ensure regulatory compliance
  - case-by-case assessment of the potential risks
  - consumer information in regard to benefits as well as possible risks

Sources of Information

The Food and Environment Research Agency

- Recent studies into the application and implications of nanotechnology for food ingredients, additives & food packaging
- EFSA opinion on the potential risks of nanotechnology in food and feed



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

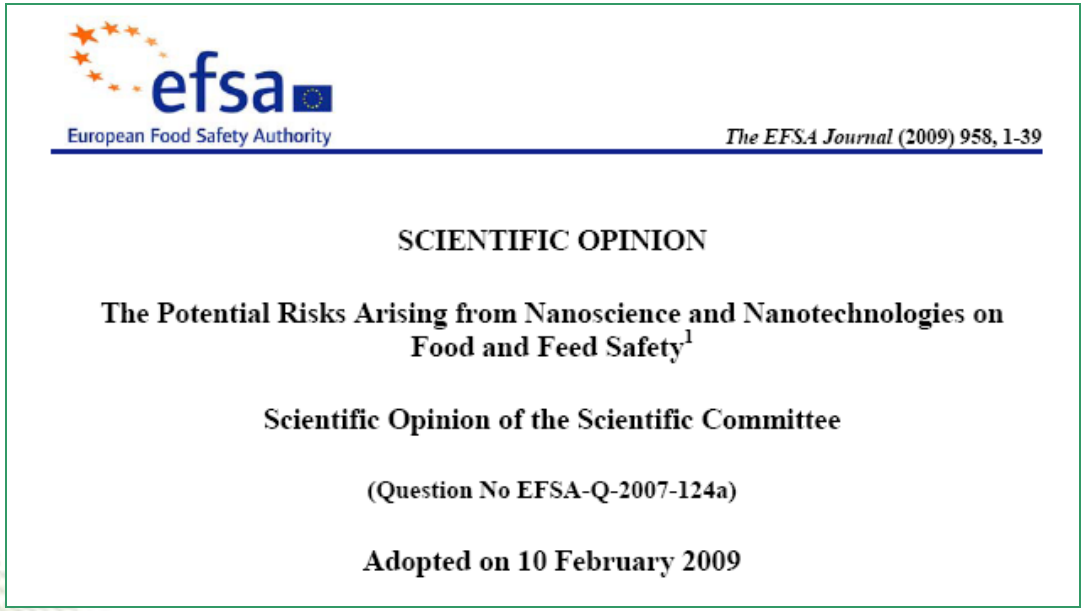
Taylor & Francis

Review

Applications and implications of nanotechnologies for the food sector

QASIM CHAUDHRY[1], MICHAEL SCOTTER[1], JAMES BLACKBURN[1], BRYONY ROSS[2], ALISTAIR BOXALL[3], LAURENCE CASTLE[1], ROBERT AITKEN[2], & RICHARD WATKINS[1]

[1]*Defra Central Science Laboratory, Sand Hutton, York Y041 1LZ, UK,* [2]*Institute of Occupational Medicine, Research Park North, Riccarton, Edinburgh EH14 4AP, UK, and* [3]*Environmental Chemistry Department, University of York, Heslington, York YO10 5DD, UK*



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

Further Information

fera
The Food and Environment Research Agency

Food Additives and Contaminants
2008, 1–27, iFirst

Taylor & Francis
Taylor & Francis Group

REVIEW

Detection and characterization of engineered nanoparticles in food and the environment

Karen Tiede[ae*], Alistair BA Boxall[ae], Steven P Tear[b], John Lewis[a], Helen David[c] and Martin Hassellöv[d]

[a]*Central Science Laboratory, Sand Hutton, York YO41 1LZ, UK;* [b]*Department of Physics, University of York, York, UK;* [c]*Unilever Colworth, Safety and Environmental Assurance Centre, Bedford, UK;* [d]*Department of Chemistry, University of Gothenburg, Gothenburg, Sweden;* [e]*Environment Department, University of York, Heslington, York, Y010 5DD, UK*

(*Received 16 November 2007; final version received 18 February 2008*)

Journal of Food and Nutrition Research Vol. 47, 2008, No. 3, pp. 105–113

Migration of engineered nanoparticles from polymer packaging to food – a physicochemical view

PETER ŠIMON – QASIM CHAUDHRY – DUŠAN BAKOŠ

Summary
A physicochemical perspective on the potential migration of engineered nanoparticles (ENPs) from packaging to food is presented, based on evaluation of the average distance travelled by ENPs in the polymer matrix. The study has taken into account physicochemical properties of both ENPs and packaging polymers. From the properties, some general characteristics underpinning ENP migration can be predicted. The results indicate that any detectable migration of ENPs from packaging to food will take place in the case of very small ENPs with a radius in the order of 1 nm, from polymer matrices that have a relatively low dynamic viscosity, and that do not interact with the ENPs. These conditions are likely to be met in the case of nanocomposites of silver with polyolefines (LDPE, HDPE, PP). It can also be predicted that there will not be any appreciable migration in the case of bigger ENPs, that are bound in polymer matrices with a relatively high dynamic viscosity such as polystyrene and polyethylene terephtalate.

RSC Nanoscience & Nanotechnology

Edited by Qasim Chaudhry, Laurence Castle and Richard Watkins

Nanotechnologies in Food

RSC Publishing