An inventory of nanotechnology applications in the agricultural, feed and food sector

EFSA EXTERNAL SCIENTIFIC REPORT - CFT/EFSA/FEED/2012/01
Hubert Rauscher, Karin Aschberger
European Commission – Joint Research Centre

4. FachDialog
Nanotechnologie im Lebensmittelbereich
Berlin, 15 June 2015

Serving society
Stimulating innovation
Supporting legislation
Plant production chain

Plant protection substances - Nano-pesticides:
Organic nanoparticles (encapsulations) or combinations of organic-inorganic
Fertilisers: Ammonia released from buckyballs
Water purification: Aluminium oxide nanofibres;
Soil remediation: Nano iron powders
Veterinary drugs; Antibiotics: Silver, aluminium, zinc oxide nanoparticles
Feed additives; Uptake and co-migration of nutrients: nano minerals
Binders for contaminants (mycotoxins): Nanoclays
Packaging materials/surfaces: Nanocomposites (nanoclays) in bottles, nanosilver in plastics (as antimicrobial)

Additives (anti-caking, colorant): Silica (E551), titanium dioxide (E171), iron oxides (E172), metallic silver (E174), metallic gold (E175)
How safe is nanofood? What is on the market?

Tiny particles may pose big risk

Some nanoparticles commonly added to consumer products can significantly damage DNA.

Foods Contain...

- Nano food 2040
- Million
- TINY INGREDIENTS
- BIG RISKS
- About 13 million
- 2012, according to this week.
- This is despite nanoparticles'...

4: FachDialog, Berlin, 15/06/2015
The EFSA Scientific Network for Risk Assessment of nanotechnologies in Food and Feed identified a need for up-to-date information on the state of the art of nanotechnology applications for the food sector. EFSA launched a call for tender for an

**Inventory of nanotechnology applications in the agriculture/food/feed sector**

**RIKILT – STICHTING DLO, Wageningen, NL**

**JRC-Institute for Health and Consumer Protection – Nanobiosciences; Ispra, IT**

(Final report: July 2014)
Tasks in the project

1. Perform an **extensive literature search** of nanomaterials in the agri/feed/food sector

2. Produce **inventory lists** for applications of nanomaterials in the agri/feed/food sector

3. Provide detailed **descriptions** of the nanomaterials in (future) applications in the agri/feed/food sector

4. Review existing **legislation** for nanomaterials in non-EU countries
Sources of information: Nanoinventory

- Extensive literature search (bibliographic databases)
- Additional literature searches
- EFSA Nano Inventory
- Questionnaires
- Company websites
## Search Results
(see search strategy and exclusion criteria)

<table>
<thead>
<tr>
<th>Bibliographic database</th>
<th>Identified hits</th>
<th>Selected relevant records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scopus</td>
<td>4184</td>
<td>393</td>
</tr>
<tr>
<td>Web of Science</td>
<td>+ 2338</td>
<td>+134</td>
</tr>
<tr>
<td>PubMed Central</td>
<td>+ 1698</td>
<td>+64</td>
</tr>
<tr>
<td>NANOnet Base</td>
<td>+ 12</td>
<td>+4</td>
</tr>
<tr>
<td>SciFinder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scholar</td>
<td>+ 736</td>
<td>+55</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8968</strong></td>
<td><strong>662</strong></td>
</tr>
</tbody>
</table>
Task 2: Nano Inventory

- Developed in Microsoft Access environment to facilitate collection, storage and extraction of data
- 3 predefined queries to generate inventory lists
  - Application
  - Toxicological data
  - Risk assessment status

Application fields

- **AGRI**
  - Pesticide
  - Fertiliser

- **FOOD**
  - Food additive
  - Food contact material
  - Novel food
  - Flavouring
  - Enzyme
  - Supplement
  - Food ingredient (not specified)

- **FEED**
  - Feed additive
  - Enzyme
  - Supplement

- **OTHER**
  - Veterinary drug
  - Biocide

Currently used

Foreseeable for future use

EFSA supporting publication 2014:EN-621 (adapted)
Task 2: Analysis of Nano Inventory

Year of publication (2013 not complete)

EFSA supporting publication 2014:EN-621
Task 2: Analysis of Nano Inventory

Distribution of NM applications that are already marketed, in development or with unclear status over the most relevant application fields.
Overview of nanomaterial type mentioned in 633 records of the Nano Inventory (filtered with the query “current and future applications”)
Overview of the most often mentioned NM types and applications in the literature sources

Task 2: Analysis of Nano Inventory

- **Metals**
  - Ag
  - Au
  - Fe
  - Cu
  - Se

- **Metal oxides**
  - TiO₂
  - ZnO
  - SAS
  - SiO₂

- **Full carbon materials**
  - Nanotubes
  - Fullerenes
  - Carbon black

- **Clay and surface-modified clay**
  - Clay
  - Surface modified clay

- **Nano encapsulates, etc.**
  - Nano encapsulates

Peters et al. in preparation
Task 2: Analysis of Nano Inventory

available on the market

→ trend from inorganic materials towards organic materials

in development

EFSA supporting publication 2014:EN-621
Task 3: Nano-applications in agricultural production

Increase efficacy of agro-chemicals compared to conventional formulations

- Pesticides - Plant growth promoters - Animal feed additives
- Organic: encapsulations and solid lipid nanoparticles
- Inorganic: titanium dioxide, silver, silica, alumina
- Commercialised products: Nanocid®(Ag), Chitosan (Chitin based polymer), PrimoMaxx (plant growth regulator), Nano-E (electrostatic atomized water particles)
- Naturally occurring: ashes, metals, nanoclay (fertilizer)
- Agri-waste management, water, soil cleaning

http://www.nanocid.com
Task 3: Nano-applications in food (1)

Most applications as food additives to improve product quality (texture, taste), solubility or bioavailability of nutrients

SAS – precipitated or fumed silica; surface coating, clearing of beverages, anti-caking agent, etc.

Other anti-caking agents: calcium silicate, sodium aluminosilicate, dicalcium phosphate, sodium ferrocyanide and microcrystalline cellulose; → nano?

TiO$_2$ as white pigment (parts in nano-size range), nanoform as antimicrobial

Nickel oxide, cobalt - inactivation of foodborne pathogens

Iron oxide: food colorant

TEM images of Aerosil 200F (a), Aerosil 380F; Dekkers et al. Nanotoxicology, 2011; 5(3): 393–405,
Task 3: Nano-applications in food (2)

Nano-encapsulations and nanodelivery systems

Incorporation, adsorption or dispersion of bioactive compounds (vitamins, isoflavones, omegs-3 FA) in nano-sized vesicles

Improved stability, and solubility (hydro-lipophilic), increased bioavailability and delivery to cells/tissues

Lycovit™ (Lycopene), LifePak Nano™ (carotenoids, CoQ10), MicroHydrin™ (antioxidant)
Task 3: Nano-applications in food contact materials

Coatings of machinery in food production, surfaces, kitchenware/equipment, nano-sieves, active and intelligent food packaging

Improved quality, freshness and storage time of food

UV-protection, anti-microbials, improved gas-exchange barrier of packaging, contaminant sensors for food monitoring

Improved mechanical and heat resistance (e.g. biodegradable composites)

Nanoparticles of silver, titanium dioxide, magnesium oxide, zinc oxide, nanocomposites, chitosan, nisin
Focus on agri-food application

Physico-chemical characterisation not always well reported – difficult to draw conclusions
Main source: open literature

Difficult to get full risk assessments
Task 4: Review of EU legislation

- General Food Law
  Regulation (EC) No 178/2002
- Novel foods and novel foods ingredients
  Regulation (EC) No 258/97 (proposal for revision)
- Food additives
  Directive 89/107/EEC
- Food shall not be placed on the market if it is unsafe
- Addition of vitamins and minerals
  Regulation (EC) 1925/2006
- Feed legislation
  various Directives and Regulations
- Food contact materials (FCM)
  Regulation (EC) No 10/2011
- Regulation on the Provisions of Food Information to Consumers (EC) No 1169/2011
  Definition, Labelling

Specific legislations apply, depending on types of food ingredients or FCM
Task 4: Review of EU legislation

- Pre-market approval required for many agri/feed/food applications, Risk assessment (implicitly) covers nanomaterials (food/feed additives, novel food, pesticides, etc.)
- NMs explicitly addressed by some Regulations e.g.: plastic FCM, Novel Food revision, Food Information to Consumer, Biocides, Active and intelligent materials and articles
- NM Definition: 1169/2011 (FIC); EC Recommendation 2011/696/EU
- Need to label NM in food applications (from Dec 2014)
- Re-evaluation of some materials of historical use (CaCO₃, SAS)
- EFSA guidance on risk assessment of nano-applications available
- NM as chemical substance regulated by REACH, C&L; ECHA guidance available
## Task 4: Review of EU legislation

<table>
<thead>
<tr>
<th>Application</th>
<th>Authorisation</th>
<th>Nano-Definition</th>
<th>Nano-Label</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture - Pesticides</strong></td>
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<tr>
<td>Plant protection products</td>
<td>(EC) No 1107/2009</td>
<td>No</td>
<td>No</td>
<td>EFSA guidance</td>
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<td></td>
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<tr>
<td><strong>Food/Feed</strong></td>
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<td></td>
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<tr>
<td>Food additives</td>
<td>(EC) 1333/2008</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Enzymes</td>
<td>(EC) 1332/2008</td>
<td>No</td>
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<td>EFSA guidance</td>
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<td>Flavourings</td>
<td>(EC) 1334/2008</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Food supplements</td>
<td>Dir 2002/46/EC</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Feed ((EC) 767/2009)</td>
<td>Not required</td>
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<td></td>
<td></td>
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<td>Feed additives</td>
<td>(EC) 1831/2003</td>
<td>No</td>
<td>No</td>
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<tr>
<td><strong>Food contact materials</strong></td>
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<tr>
<td>Food contact materials</td>
<td>(EC) 1935/2004</td>
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<td>Plastic food contact materials</td>
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<td>Active and Intelligent Materials and Articles</td>
<td>(EC) 450/2009</td>
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<td><strong>Biocides/Chemicals</strong></td>
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<td>Biocides</td>
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<td>(EU) No 528/2013</td>
<td>(EU) No 528/2013</td>
<td>Pending (information requirements)</td>
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<td>Chemical substances</td>
<td>(EC) 1907/2006 (REACH) (authorization required for certain hazardous substances)</td>
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<td>No</td>
<td>ECHA guidance</td>
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</tbody>
</table>

Amenta et al. (in preparation)
Main findings

- Many activities ongoing in several countries: mainly USA, Australia/New Zealand (FSANZ), Canada, China, Japan, Malaysia, Korea, Switzerland
- EU candidate states (e.g. Turkey) – similar approaches as EU
- Nanomaterials definitions: not legally binding recommendations/guidance; beside size other specific properties considered (e.g. US)
- Nano-specific legislation for agri/feed/food not available, case-by-case approach for risk assessment often recommended (e.g. USA)
- System for certifying products in Taiwan, Iran, Thailand
# Summary on food legislation for some selected non-EU OECD countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Responsible organisation</th>
<th>Existing legislation</th>
<th>Sources</th>
</tr>
</thead>
</table>
| USA     | US Food and Drug Administration (FDA)  
Environmental Protection Agency (EPA) | Federal Food, Drug, and Cosmetic Act (FFDCA)  
[http://www.fda.gov/Food/default.htm](http://www.fda.gov/Food/default.htm)  
[http://www.epa.gov/oecaagct/lfra.html](http://www.epa.gov/oecaagct/lfra.html) |
| Canada  | Canadian Food Inspection Agency (CFIA)  
| Korea   | Food Sanitation Act | Ministry of Food and Drug Safety (MFDS)  
Korean food and Drug Administration (KFDA)  
Conclusions

- nano-encapsulates, silver, and titanium dioxide are the most often mentioned nanomaterials in the literature
- food additives and food contact materials are the most often mentioned current applications
- future developments are expected for nano-encapsulates and nano-composites in applications such as novel food, food/feed additives, biocides, pesticides and food contact materials
- most toxicological data, was found for silica, titanium dioxide, and silver
- EU: binding NM definitions and specific provision for some applications
- non-EU countries: broader approach, mainly built on guidance
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