An Overview of Opportunities and Challenges of Food Nanoscience/Technology

CIFST
Ontario Section
Fall Technical Session
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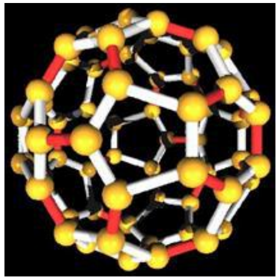
Word is relatively new but the concept is not

- Creation of the word/field is relatively “new”
  - Richard Feynman 1959 talk “There’s Plenty of Room at the Bottom” - "nano-scale" machines
  - Nori Taniguchi 1974 “Nano-technology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or by one molecule.”

    On the Basic Concept of 'Nano-Technology

    Proc. Intl. Conf. Prod. London, Part II British Society of Precision Engineering
- Concept is old:

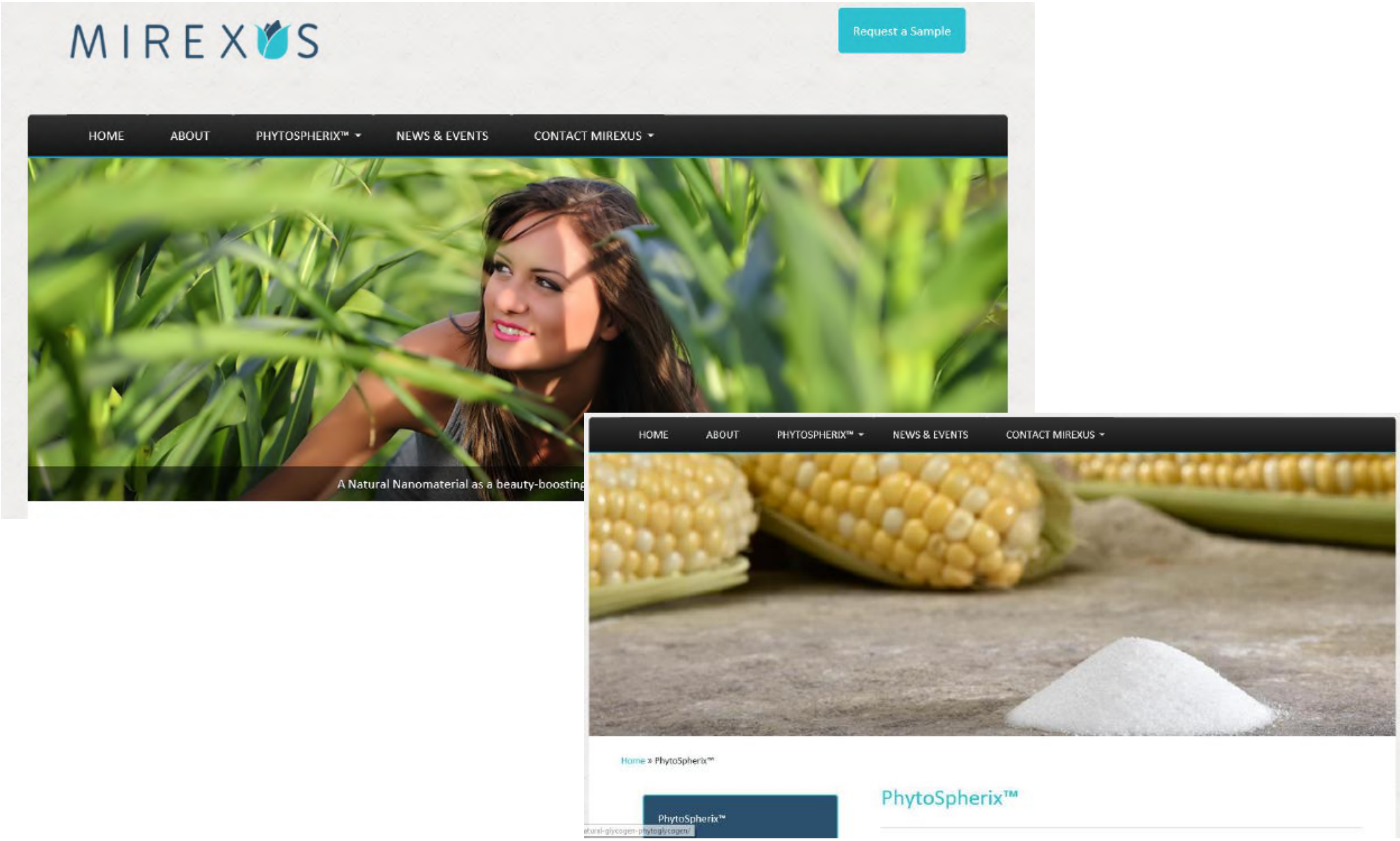
The Lycurgus Cup (Rome) is an example of dichroic glass; colloidal gold and silver in the glass allow it to look opaque green when lit from outside but translucent red when light shines through the inside.
http://www.nano.gov/nanotech-101/timeline



Richard Smalley discovered the Buckminsterfullerene (C60), more commonly known as the buckyball, which is a molecule resembling a soccerball in shape and composed entirely of carbon, as are graphite and diamond.
http://www.nano.gov/nanotech-101/timeline

Nano, nano everywhere!

David Hawxhurst
Woodrow Wilson International Center for Scholars



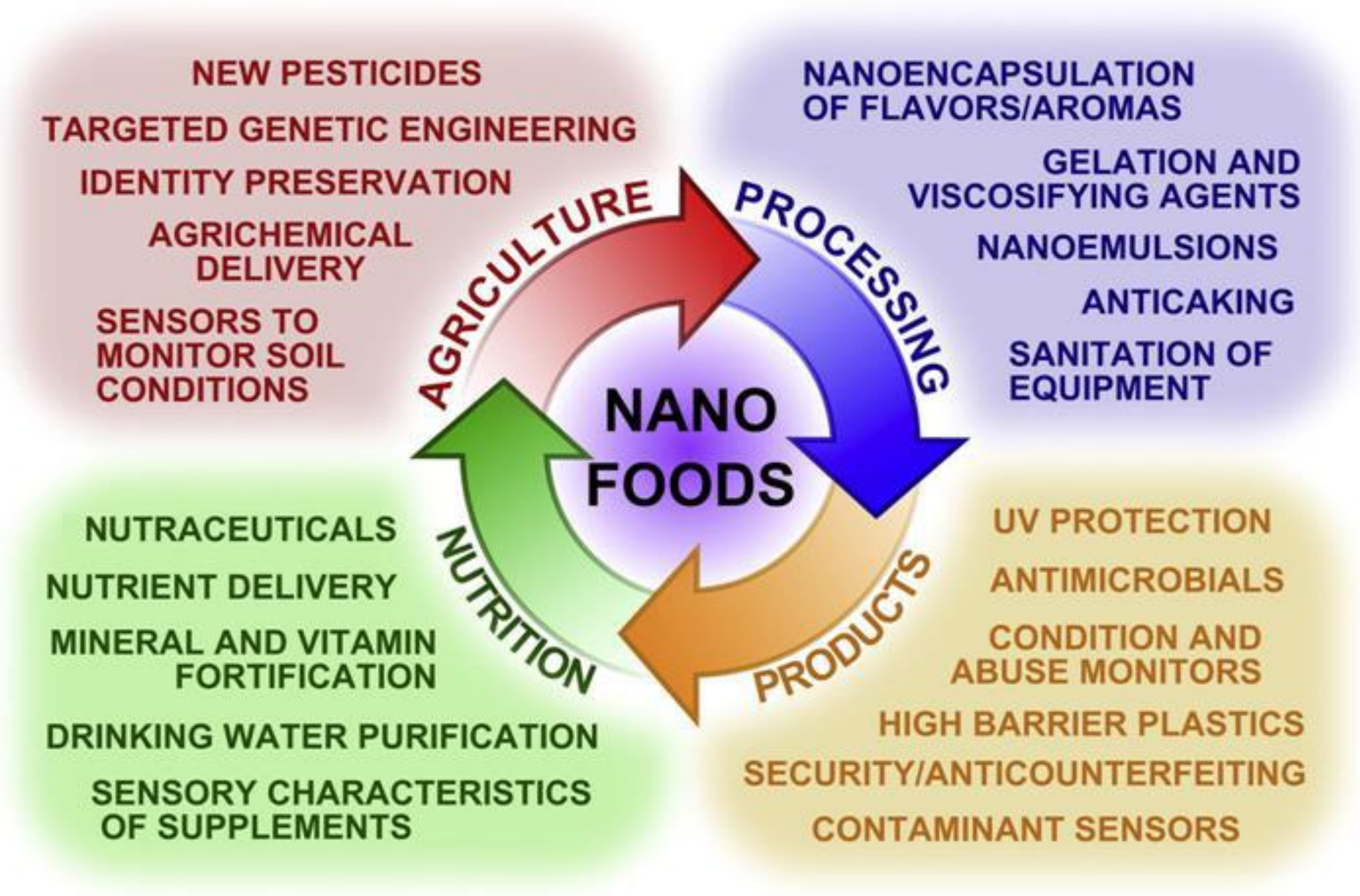
http://mirexus.com/phytospherix/

Terminology and Nomenclature

Defining Nanotech

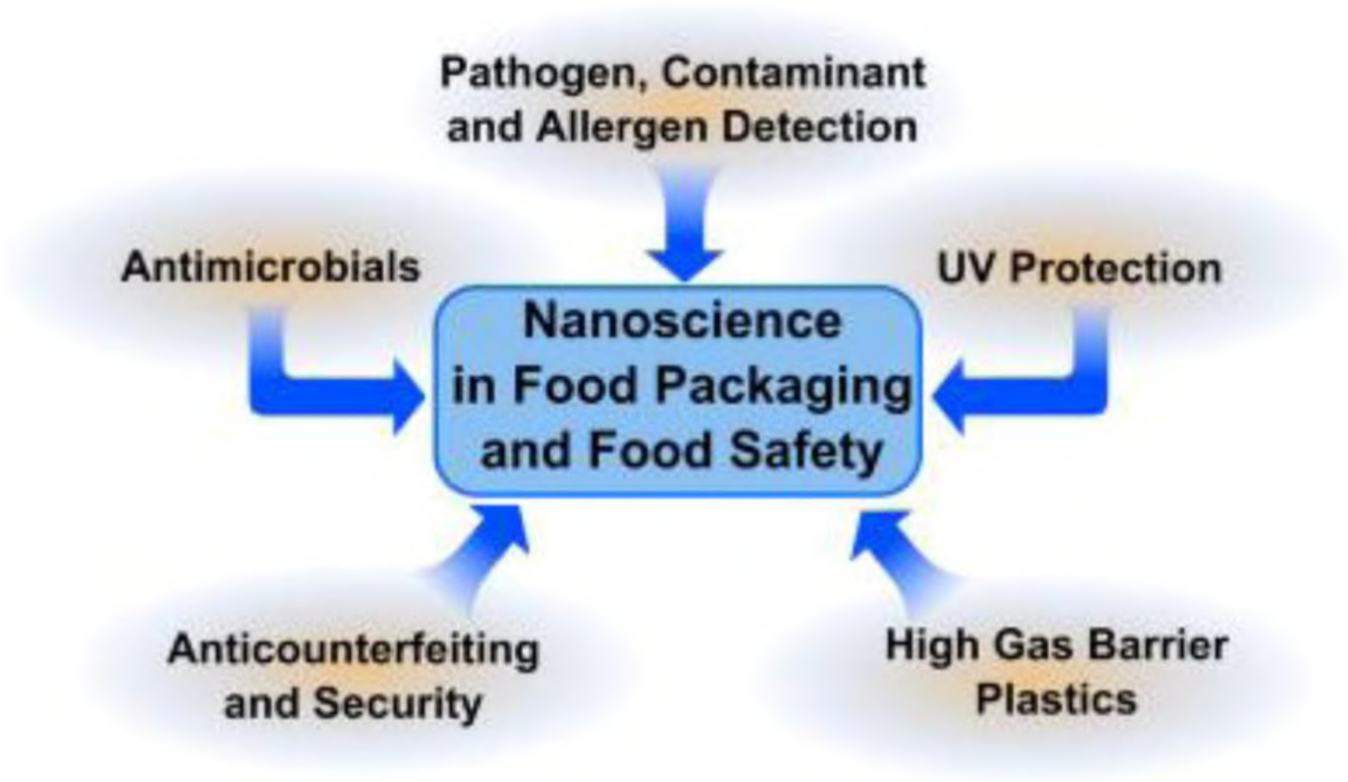
- Two principal parts to defining what is to be considered nanotechnology:
- (i) **Scale** <u>and</u> (ii) **Uniqueness**/novelty
- Nanotechnology is the understanding and control of matter….
  - (i) … at dimensions between approximately 1 nm to 100 nm
  - (ii) … where unique phenomena enable novel applications

Nano in Agri-Food



Duncan,T (2011) J Colloid Interface Science 363(1):1-24

Nano – Food Packaging



Duncan,T (2011) J Colloid Interface Science 363(1):1-24

Diffusion of Fluorescently Labeled Bacteriocin from Edible Nanomaterials and Embedded Nano-Bioactive Coatings

- Assess release rates of fluorescently labeled antimicrobial peptide nisin (lantibiotic/biopreservative) from liposomal nanocarriers
- Lanthionine-containing peptides (lantibiotics) are promising antimicrobial agents being investigated as substitutes for current antibiotics
- Pore formation in cell membranes
- Lantibiotics are effective against food-borne microbes including *Listeria monocytogenes* and *Clostridium botulinum*

Imran et al. ACS Applied Materials & Interfaces 8 (2016): 21618-21631

Diffusion of Fluorescently Labeled Bacteriocin from Edible Nanomaterials and Embedded Nano-Bioactive Coatings

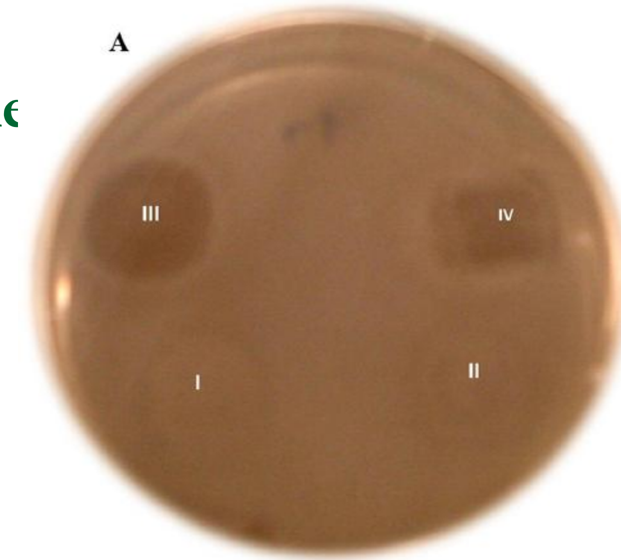
Antimicrobial activity of biodegradable hydroxypropyl methylcellulose (HPMC) coatings against *L. monocytogenes*

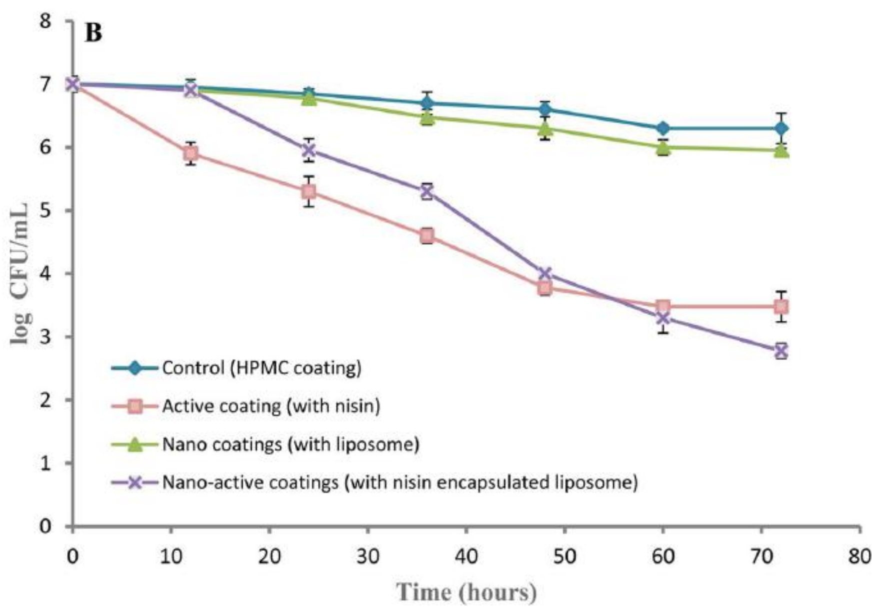
A:

- (I control) coatings without nisin
- (II control) coatings embedded with empty nanoliposomes
- (III) active coatings containing nisin
- (IV) nanoactive coatings containing nanoliposomes encapsulated nisin

B:

Quantitative anti-listerial activity assessment of active and nano-active coatings





http://pubs.acs.org/doi/full/10.1021/acsami.6b04621

Nano-Sensors

- Potential Applications:
  - Pathogen detection (bacteria, viruses)
  - Toxin and pesticide detection
  - Spoilage detection
  - Authenticity and traceability
  - Quality control

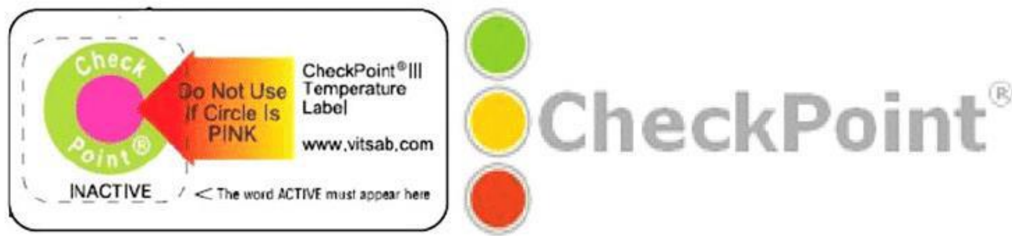
Nano-Sensors

- UV activated, oxygen sensitive, colored ink based on titanium dioxide.
- Changes color in presence/absence of oxygen.

Photographs of oxygen indicator ink printed on a MAPed food package. Left: Before UV activation. Middle: After UV activation. Right: On opening the package. (Photographs: David Hazafy, University of Strathclyde)

Intelligent inks - now you see them, now you don't   http://www.nanowerk.com/spotlight/spotid=4104.php

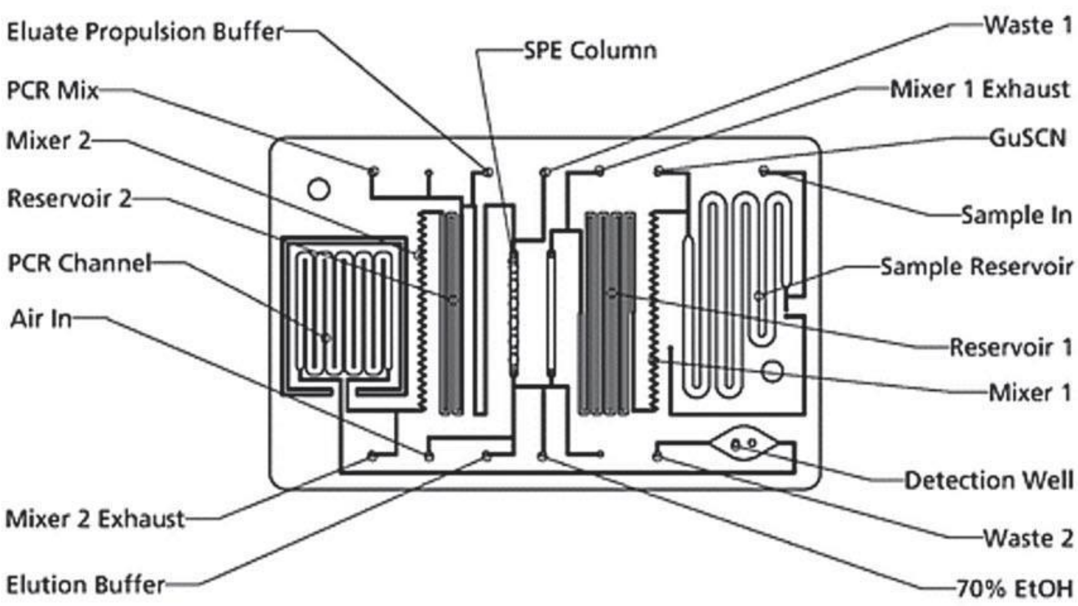
Nano-sensors

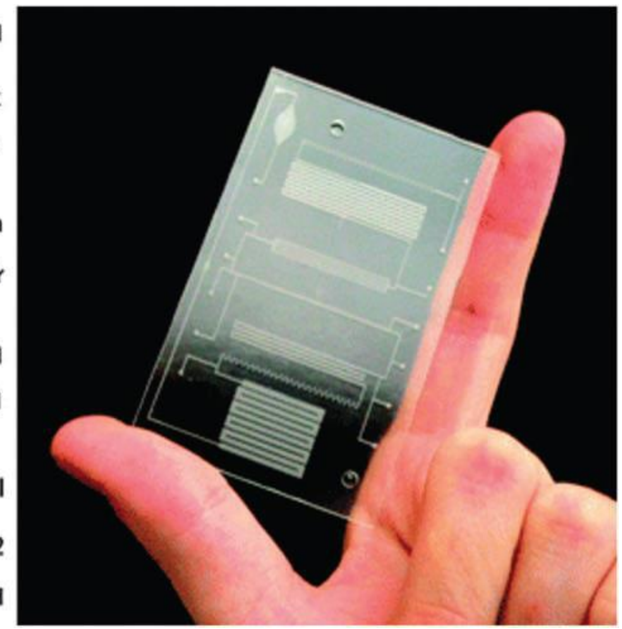


https://www.researchgate.net/profile/Bambang_Kuswandi/publication/225471060/viewer/AS:104182438694918@1401850437774/background/8.png

Microfluidic SERS for "lab-on-a-chip" device of detection of foodborne pathogens

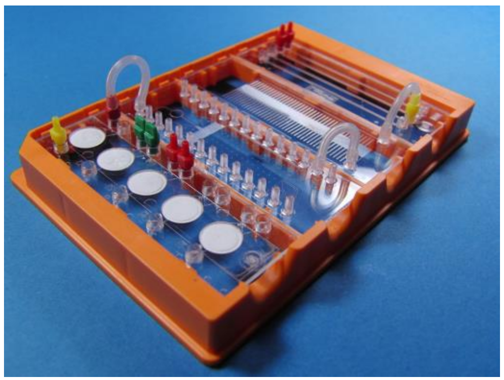
- The "lab-on-a-chip" systems allow the integration of sample preparation, manipulation, separation and detection to achieve a high and fast throughput.

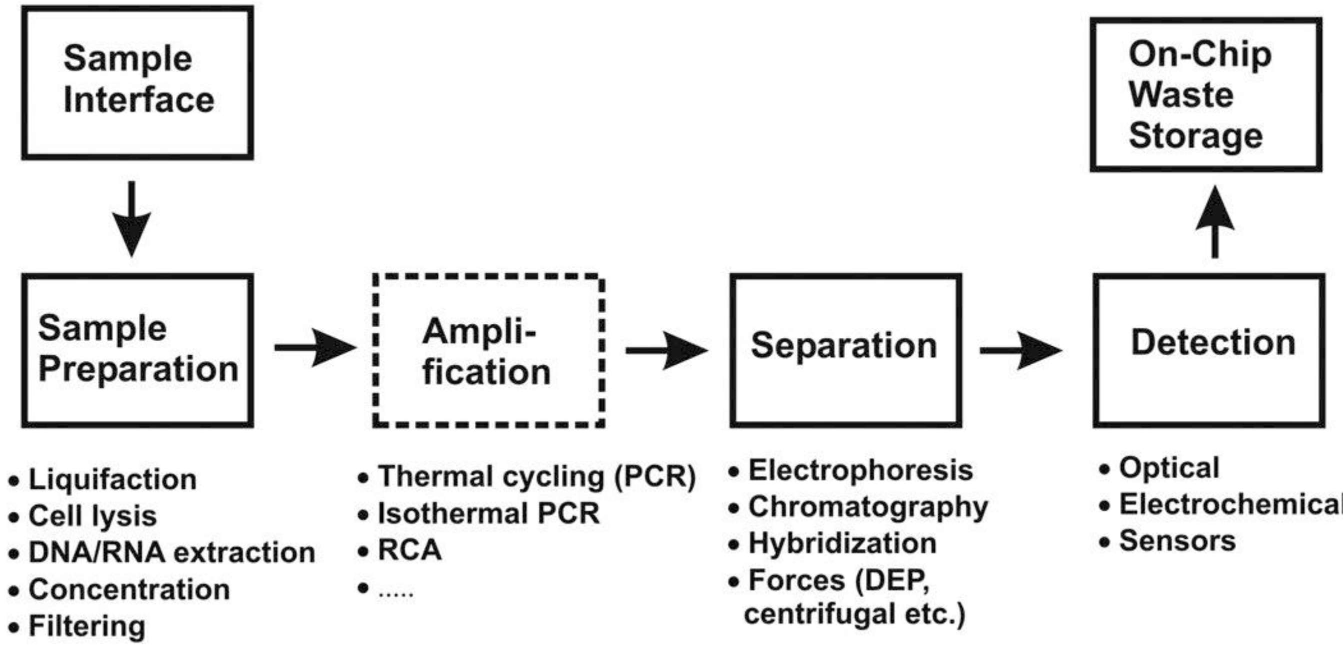




Courtesy of Dr. Xiaonan Lu, UBC

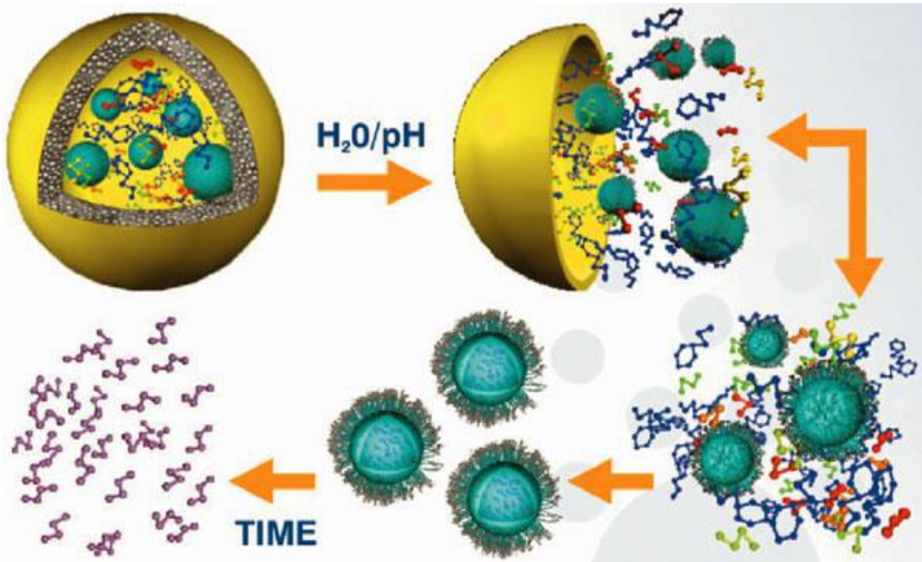
Overview: Microfluidic "Lab-on-a-Chip"

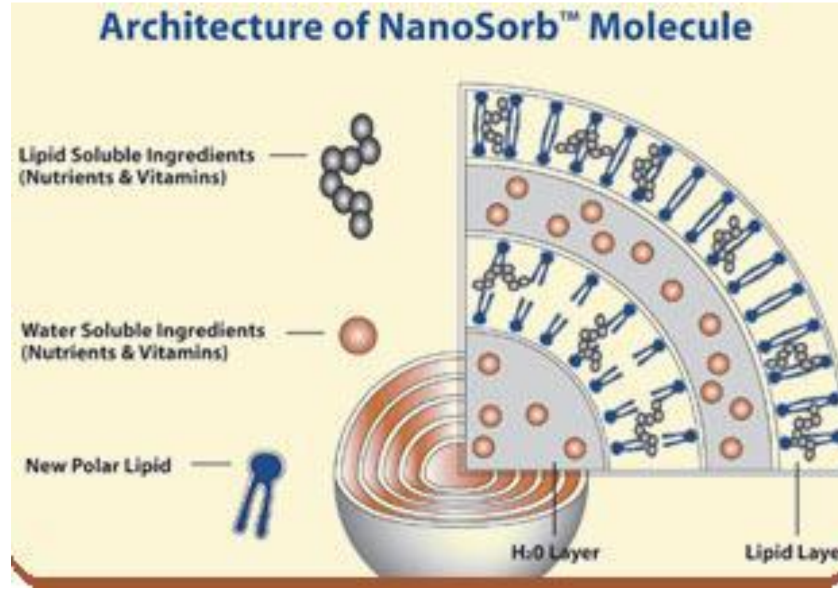




Xu et al., 2013, *Appl. Phys. Lett.*, 102, 023702
Guo and Lu, 2015. *Trends Food Sci. Technol.*, 46, 252-263.

Nanoencapsulation - nanoemulsions





Shefer,A. (2005) www.foodtech-international.com/papers/images/application-nano/fig1

http://nanogreensinfo.com

- Functional ingredients are essential components in many foods
  - e.g., vitamins, colours, flavours, preservatives, antimicrobials, etc.)
- Usually need some sort of delivery system to optimize activity.
- Pay load substantially decreased

Nanoencapsulation - nanoemulsions

- A number of potential advantages of using nanoemulsions rather than conventional emulsions for this purpose:
  - Carry the ingredient to the desired site of action
  - Control the release of the ingredient (e.g., release rate) in response an external trigger (e.g., pH, temperature, ionic strength, enzymes, etc.)
  - Greatly increase the bioavailability of lipophilic substances
  - Scatter light weakly and so can be incorporated into optically transparent products
  - Can be used to modulate the product texture
  - A high stability to particle aggregation and gravitational separation
  - Protect the ingredient from chemical or biological degradation
  - Must be compatible with the food attributes (e.g., appearance, texture, taste/flavour)

D.J .McClements (2011), Edible nanoemulsions: fabrication, properties, and functional performance, Soft Matter, 7, 2297-2316; J.Weiss (2007) IFT Annual Meeting

Various Nano Applications

Table 1 Summary of research and application for micro/nano–emulsion loaded functional compounds.

Functional Compounds	Benefits	Applications	Reference
α–Tocopherol	Antioxidant	Medicine/Food	5
β–Carotene	Antioxidants/Vitamin A precursor	Food color	6
Curcumin	Antioxidant/Anti–inflammatory/ Anticancer	Food color	7
Phytosterol	Cholesterol absorption inhibitor	Medicine/Cosmetic/Food additive	8
Lycopene	Antioxidant/Anticancer	Food color	9
Lidocaine	Local anesthetic/Antiarrhythmic drug	Medicine	10
Itraconazole	Antifungal	Medicine	11
Carbamazepine	Anticonvulsant	Medicine	12
Quercetin	Antioxidants/Anti–inflammatory	Medicine/Food	13
Cisplatin	Anticancer	Medicine	14
Thalidomide	Immunomodulatory agent	Medicine	15
Polyunsaturated fatty acids (PUFA)	Anti–inflammatory	Food/Medicine	16
Oleuropein	Antioxidant	Food	17

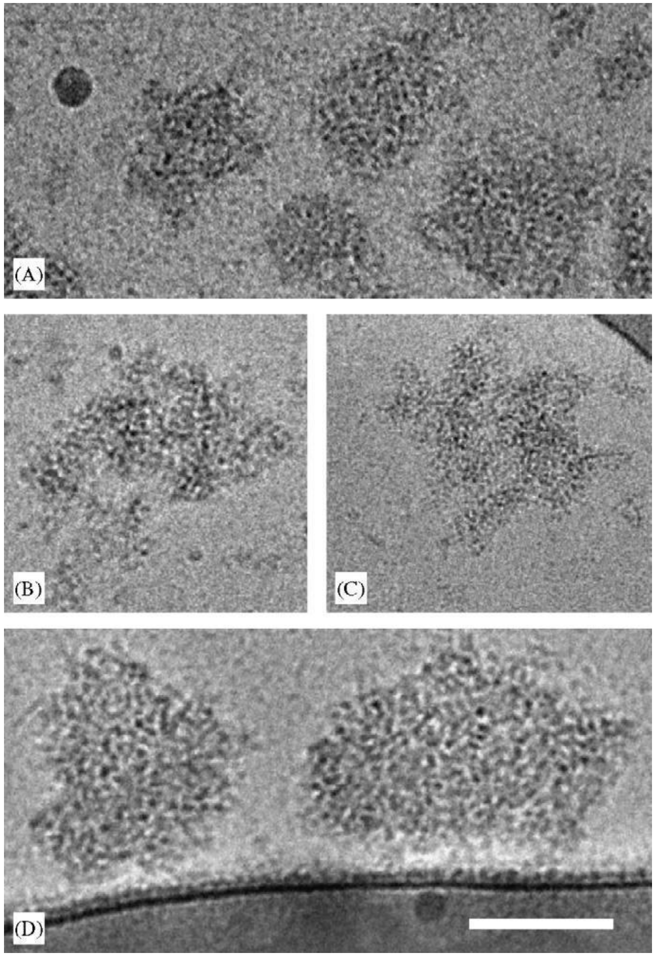
5) X. Li, Biomaterials, 34, 481-491 (2013).
6) A. Trentin, J. Food Eng.,106, 267-274 (2011).
7) K. Ahmed, Food Chem., 132,799-807 (2012).
8) F. Liu, J. Agric. Food Chem., 62, 5133-5141 (2014).
9) R. Bou, Eur. J. Lipid Sci. Technol., 113, 724-729(2011).
10) Y. S. Rhee, Int. J. Pharm., 398, 21-27 (2010).
11) P. Deveda, Int. J. Pharm. Pharm. Sci., 2, 104-112 (2010).
12) C. R. Kokare, Indian J. Pharm. Edu.Res., 47, 172-177 (2013).
13) Y. Zhu, Q.. Adv. J.Food Sci. Technol., 5, 1238-1243 (2013).
14) T. Beppu, Anticancer Res., 32, 4923-4930 (2012).
15) F. A. Araújo, Eur. J.Pharm. Sci., 42, 238-245 (2011).
16) M. A. Neves, Ind. Eng. Chem. Res., 47, 6405-6411 (2008).
17) S. Souilem, Food Res. Int., 62, 467-475 (2014).

Wang et al. Japan Journal of Food Engineering 16.4 (2015): 263-276.

Value added versus commodities

Casein nanoparticles as nano-vehicles

- **Casein micelles**
  - Nano-capsules created by nature to deliver nutrients (calcium, phosphate, protein) to the neonate
  - Natural self-assembly tendency of bovine caseins
  - Morphology and average diameter of re-assembled micelles similar to those naturally occurring
  - Useful nano-vehicles for entrapment, protection and delivery of sensitive hydrophobic nutraceuticals within food products, e.g., vitamin D2



Cryo-TEM images of (A) naturally occurring CM in skim milk; (B) and (C) re-assembled CM; (D) D2- re-assembled CM. The bar on the bottom right is 100nm long. (The dark area on the bottom is the perforated carbon film holding the sample.)

Semo et al. (2007) Casein micelle as a natural nano-capsular vehicle for nutraceuticals, Food Hydrocolloids, 21(5–6): 936-942. 10.1016/j.foodhyd.2006.09.006

Nano-encapsulation of saffron extract through double-layered multiple emulsions of pectin and whey protein concentrate

- Saffron used in foods, pharmaceuticals and cosmetics
- Natural colorant, antioxidant and therapeutic properties
- Crocin (color)
- Picrocrocin (aroma)
- Saffranal (flavor)
- These compounds are unstable
  - Processing temperature
  - Storage temperature
  - pH
  - Light
  - Oxygen
  - Enzymes
  - Proteins
  - Metallic ions

Saffron

Esfanjani et al. Journal of Food Engineering 165 (2015): 149-155.

Nano-encapsulation of saffron extract through double-layered multiple emulsions of pectin and whey protein concentrate

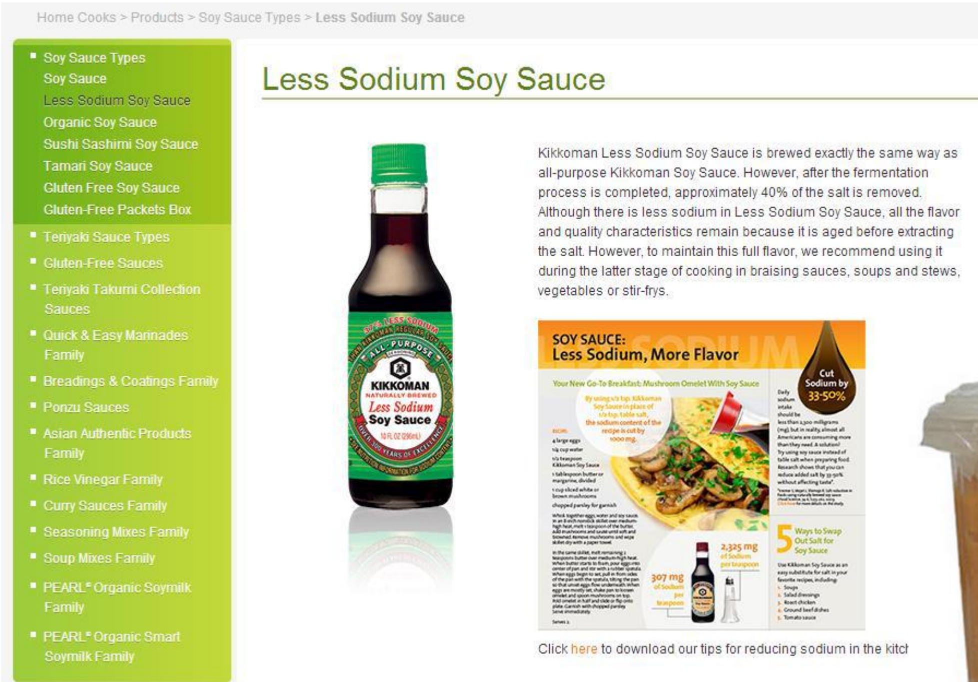
- Nano-encapsulation of saffron extract by spray drying was performed successfully
- Encapsulated double-layer W/O/W emulsions had the maximum encapsulation efficiency
- Powder particles of W/O/W emulsions had:
  - smooth surfaces
  - no pores
  - no wrinkles

Esfanjani et al. Journal of Food Engineering 165 (2015): 149-155.

Health issues

- Diabetes
- Obesity
- Cardiovascular diseases
- Micronutrient deficiencies

Sodium

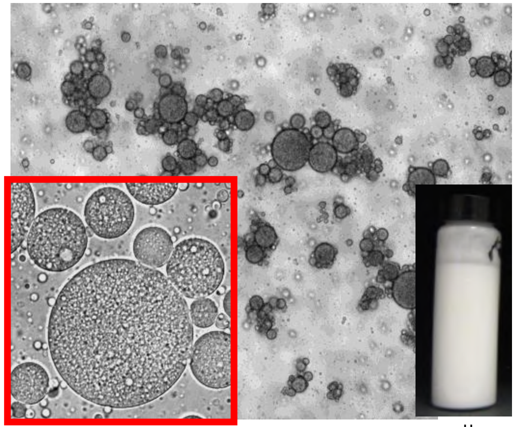


http://www.kikkomanusa.com/homecooks/products/products_hc_details.php?pf=10102&fam=101

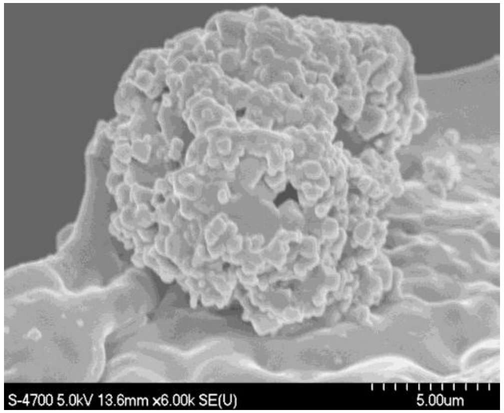
http://www.asianfoodgrocer.com/product/honzokuri-low-salt-miso-26-4-oz

Bio-molecular carriers

- <u>Double emulsions (W/O/W)</u>
  - Inner phase comprised of nano-sized droplets w/ NaCl.
  - Liquid foods - soups



- <u>Biopolymer-based nanoparticles</u>
  - pH-sensitive protein-polysaccharide carriers
  - Proprietary polysaccharide carriers
  - Solid foods – cheese



Nutragenomics

https://www.nutrigenomix.com/about-us

Ethical Issue?

POLICYFORUM

SCIENCE AND REGULATION

Regulating Direct-to-Consumer Personal Genome Testing

International cooperation and postmarket regulation are needed for Internet-based direct-to-consumer genome tests.

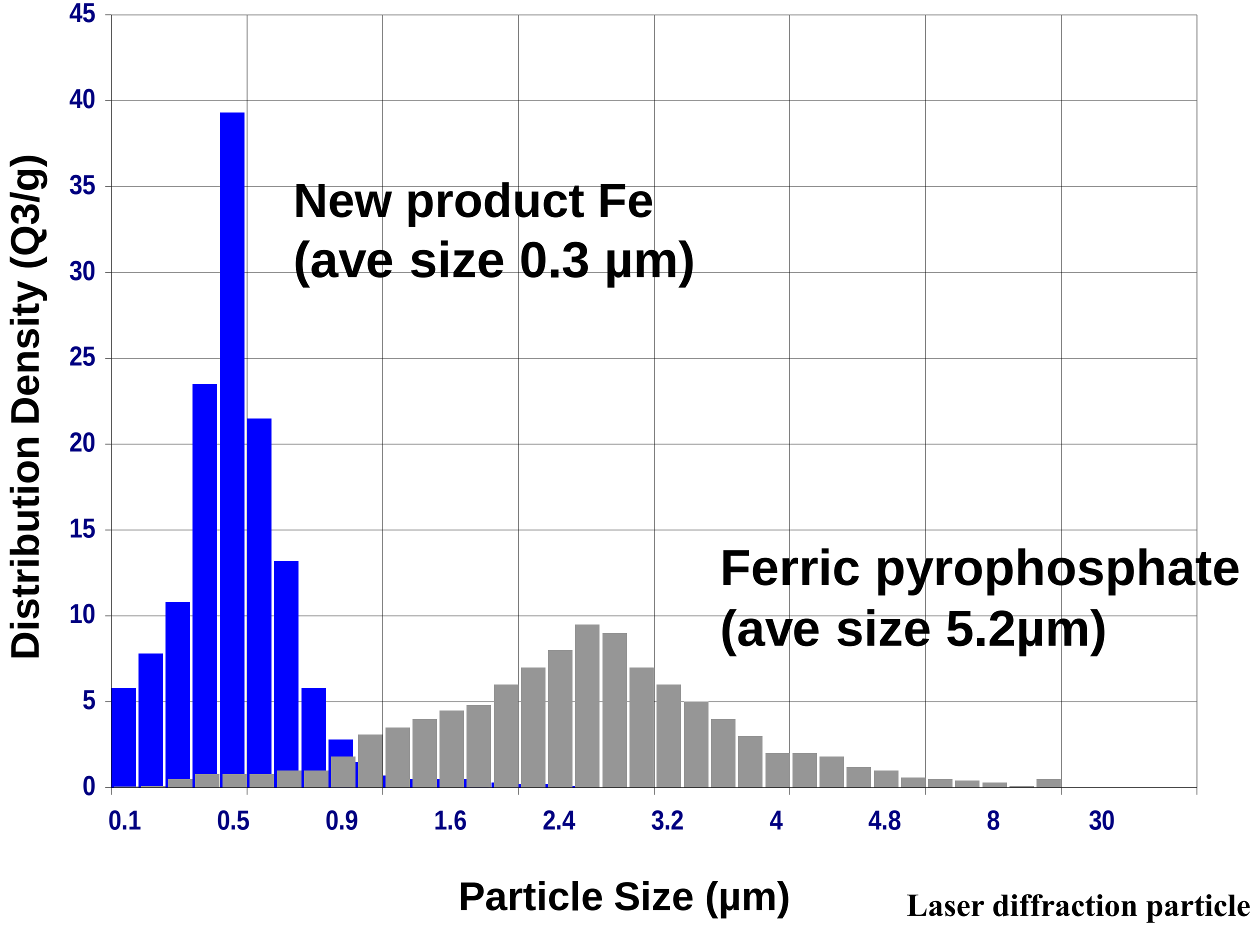
Amy L. McGuire,[1*] Barbara J. Evans,[2] Timothy Caulfield,[3] Wylie Burke[4]

SCIENCE VOL 330 8 OCTOBER 2010

Courtesy Dr. Ahmed El-Sohemy

Problems with iron fortification

- Unpleasant taste and color
- Instability, precipitation
- Toxicity, nausea, vomiting, poor appetite, diarrhea and constipation
- Poor bio-availability



Laser diffraction particle counter
Supersonic wave: 2 min.

Courtesy of Dr. Lekh Juenja

Stability of Iron Sources

Nano Fe	Ferric pyrophosphate	Ferrous sulfate	Sodium ferrous citrate
Clear	White precipitation	Brown precipitation	Yellowish-brown

5 mg Fe / 100 ml, pH 7.0, stored at 40°C under dark conditions
Storage time: Nano Fe for 3 months, all others 2 days

Courtesy of Dr. Lekh Juneja

What is DNA Barcoding?

A method of species identification based on DNA sequences derived from standard marker genes for animals (COI), plants (rbcL and matK) and fungi (ITS)

The hypothesis is that, for that gene segment, every species will have a unique sequence (or a unique assemblage of closely related sequences).

✓This sequence is termed a ‘barcode’. For example:

Species A: CCTAAGCTTACGTTTCC

Species B: CCTAGGCTTACGTTACC

Courtesy of Drs. Bob Hanner and Steve Newmaster, Univ. of Guelph

Authenticity/Traceability

STUDY » YOU THOUGHT YOU ORDERED SEA BASS

Fishy business

You say tuna, I say tilapia: DNA testing shows that one-quarter of fish is mislabeled

BY REBECCA DUBE

Before you bite into that fish and chips or spend $30 on halibut at the supermarket, you may want to take a second look: 25 per cent of fish is mislabelled, according to a University of Guelph study published today that used DNA analysis to determine the true identity of fish sold in Toronto and New York.

One sample sold as tuna turned out to be tilapia; halibut was really hake; and red snapper was, on different occasions, lavender jobfish, Labrador redfish, perch and cod.

"There's not a lot of regulation around fin fish; it's basically been ignored," says study co-author Robert Hanner, associate director for the Canadian Barcode of Life Network and an assistant professor of biology at the University of Guelph.

"Now that we have the tool to do it, we probably have an obligation to start testing."

He and co-author Eugene Wong tested 96 samples of fish from grocery stores, markets and restaurants in New York and Toronto. They analyzed the DNA of each fish and compared it with a global database of species. They intended simply to test the database, which performed well, identifying each piece of fish they found. Discovering so much fish fraud was a surprise.

» SEE 'FISH' PAGE 3

> ***There's not a lot of regulation around fin fish; it's basically been ignored.***
>
> Robert Hanner, study co-author

PHOTO ILLUSTRATION/THE GLOBE AND MAIL

Food Safety – Traceability: DNA –Plant Material - Herbals

That herbal supplement may not be what you think it is, scientists find

HELEN BRANSWELL
TORONTO — The Canadian Press
Published Friday, Oct. 11 2013, 8:25 AM EDT
Last updated Friday, Oct. 11 2013, 8:56 AM EDT

DNA doesn't lie.

And when scientists from the University of Guelph scoured the DNA in a number of herbal products, they found that many times the labels on the merchandise didn't accurately reflect what was in the container.

Some products contained fillers like wheat or rice that were not listed on the label. Some were contaminated with other plant species that could have caused toxicity or triggered allergic reactions. And still others contained no trace of the substance the bottle purported to contain.

http://www.theglobeandmail.com/news/national/that-herbal-supplement-may-not-be-what-you-think-it-is/article14825662/

Challenges

- Regulatory challenge
- Consumer attitude/acceptance

Regulatory Challenges

efsa
European Food Safety Authority

Supporting Publications 2012:EN-

TECHNICAL REPORT

EFSA Scientific Network of Risk Assessment of Nanotechnologies in Food and Feed[1]

European Food Safety Authority[2, 3]

European Food Safety Authority (EFSA), Parma, Italy

SUMMARY

EFSA is closely following developments in the area of nanotechnologies in food and feed in order
address the need to provide further spe
stronger co-operation with the Membe
institutional partners (EU and internatio
formulated by EFSA's Management Boa
networking with Member States[4], the Sci
Food and Feed (hereafter referred to as "
first meeting in February 2011, one meeti

The main overall goals of the Nano N
mutual understanding of risk assessmen
scientific assessments carried out in EU;
among Member States and EFSA. In
assessments developed in EU.

The network is currently composed of
addition to this Network Observers repr
and Turkey. The first meeting in Februar
States organisations and from EU Candi
Panel or Working Group Experts and 3 E

[1] On request from EFSA, Question No EFSA-Q-2
[2] Correspondence: scientific.committee@efsa.eur
[3] Acknowledgement: EFSA wishes to thank the M
of Nanotechnologies in Food and Feed: Austrian A
Research Centre (VAR), (Belgium); University
Republic NMP NCP (Czech Republic), National
Agriculture (Estonia); Finnish Food Safety Author
AFSSA (France); BfR Bundesinstitut für Risikobe
Physical Chemistry, NCSR DEMOKRITOS (Gr
Authority of Ireland (Ireland); Istituto Superiore
Veterinary Risk Assessment Institute (Lithuania);
Norwegian Scientific Committee for Food Safety
of Porto (Portugal); Slovak Medical University (Sl
(Slovenia); University of Barcelona (Spain); Food
of the Scientific Network for Risk Assessment o
Ministry of Health - (Former Yugoslav Republic of
[4] http://www.efsa.europa.eu/en/mb061219/docs/mb061219-ax6.pdf

Suggested citation: European Food Safety Authority; EFSA Scientific Network for Risk Assessment of Nanotechnologies in Food and Feed. Supporting Publications 2012:EN-246. [10 pp.]. Available online: www.efsa.europa.eu/publications

http://www.efsa.europa.eu/en/search/doc/246e.pdf

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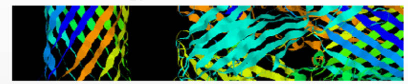
Nanotechnology



The U.S. Food and Drug Administration (FDA) regulates a wide range of products, including foods, cosmetics, drugs, devices, veterinary products, and tobacco products some of which may utilize nanotechnology or contain nanomaterials. Nanotechnology allows scientists to create, explore, and manipulate materials measured in nanometers (billionths of a meter). Such materials can have chemical, physical, and biological properties that differ from those of their larger counterparts.

Spotlight
- FDA Continues Dialogue on 'Nano' Regulation
- FDA's Approach to Regulation of Nanotechnology Products
- Article by FDA Commissioner Magaret A. Hamburg in Science, April 2012
- Nanotechnology Regulatory Science Research Plan

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NanoRegulations

Nanomaterials are being regulated in Canada under existing legislation including the Canadian Environmental Protection Act, 1999, the Pest Control Products Act, the Fertilizers Act, the Feeds Act and the Food and Drugs Act. It is recognized that, due to the unique properties associated with nanomaterials, the science surrounding the risk assessment of these substances needs to be developed further. To that end, the Federal Government is funding nanomaterial health and safety research within Canada, and actively participating in international efforts to study, quantify and understand the behaviour and toxicity of nanomaterials.

In the 2008 report, Small is Different: A Science Perspective on the Regulatory Challenges of the Nanoscale, the Council of Canadian Academies found that "existing regulatory approaches and risk management strategies are appropriate for the challenges presented by nanomaterials," however, it recommended that more investment be made in strategic risk assessment research.

http://nanoportal.gc.ca/default.asp?lang=en&n=23410D1F-1

One of the challenges of regulation in Canada – many agencies

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Regulation and Standards

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http://nanoportal.gc.ca/default.asp?lang=En&n=23410d1f-1

Canada:

- Health Canada http://nanoportal.gc.ca/default.asp?lang=En&n=23410d1f-1
  - Food and Drugs Act
  - Cosmetic Regulations
  - Food Additive Regulations
  - Food and Drug Regulations
  - Medical Devices Regulations
  - Natural Health Products Regulations
  - New Substances Program Advisory Note 2007-06 http://nanoportal.gc.ca/default.asp?lang=En&n=9B5AA83F-1
  - Interim Policy Statement on Health Canada's Working Definition for Nanomaterials http://www.hc-sc.gc.ca/sr-sr/consult/_2010/nanomater/index-eng.php
- Food and Food Packaging, Assessments of New Substances Found in Novel Foods, Food Additives and Food Packaging under Canadian Environmental Protection Act, 1999 (CEPA, 1999) http://www.hc-sc.gc.ca/sr-sr/tech/nanotech/food-alimentation-eng.php
- Environment Canada
  - Regulating Nanomaterials under the Canadian Environmental Protection Act http://www.pollutionprobe.org/wp-content/uploads/Regulating-Nanomaterials-under-the-Canadian-Environmental-Protection-Act-Myriam-Hill.pdf

United States Food and Drug Agency

- FDA's approach http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/ucm301114.htm
  - Regulation and oversight https://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/nanotechnology-regulation-and-oversight-principles.pdf
  - Regulatory Science Research Plan http://www.fda.gov/ScienceResearch/SpecialTopics/Nanotechnology/ucm273325.htm

United States Food & Drug Authority

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FDA News Release

FDA issues guidance to support the responsible development of nanotechnology products

For Immediate Release June 24, 2014

Release

Today, three final guidances and one draft guidance were issued by the U.S. Food and Drug Administration providing greater regulatory clarity for industry on the use of nanotechnology in FDA-regulated products.

One final guidance addresses the agency's overall approach for all products that it regulates, while the two additional final guidances and the new draft guidance provide specific guidance for the areas of foods, cosmetics and food for animals, respectively.

Nanotechnology is an emerging technology that allows scientists to create, explore and manipulate materials on a scale measured in nanometers—particles so small that they cannot be seen with a regular microscope. The technology has a broad range of potential applications, such as improving the packaging of food and altering the look and feel of cosmetics.

"Our goal remains to ensure transparent and predictable regulatory pathways, grounded in the best available science, in support of the responsible development of nanotechnology products," said FDA Commissioner Margaret A. Hamburg, M.D. "We are taking a prudent scientific approach to assess each product on its own merits and are not making broad, general assumptions about the safety of nanotechnology products."

The three final guidance documents reflect the FDA's current thinking on these issues after taking into account public comment received on the corresponding draft guidance documents previously issued (draft agency guidance in 2011; and draft cosmetics and foods guidances in 2012).

The FDA does not make a categorical judgment that nanotechnology is inherently safe or harmful, and will continue to consider the specific characteristics of individual products. All four guidance documents encourage manufacturers to consult with the agency before taking their products to market. Consultations with the FDA early in the product development process help to facilitate a mutual understanding about specific scientific and regulatory issues relevant to the nanotechnology product, and help address questions related to safety, effectiveness, public health impact and/or regulatory status of the product.

http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm402499.htm

European Food Safety Authority

- European Food Safety Authority https://www.efsa.europa.eu/en/topics/topic/nanotechnology
  - Inventory of Nanotechnology applications in the agricultural, feed and food sector http://www.efsa.europa.eu/en/supporting/pub/621e
  - Nano inventory PDF presentation http://www.oekopol.de/wp-content/uploads/03_Rauscher_EFSA-Bericht-Nanoinventory.pdf

FSANZ

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Te Mana Kounga Kai – Ahitereiria me Aotearoa

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- Food issues
- Genetically modified foods
- Imported foods
- Labelling
- Nutrition and fortification

Nanotechnology and Food

(Last updated January 2014)

The term nanotechnology is used to describe engineered matter that is generally less than 100 nanometres (nm) in size in one dimension. One nm is one billionth of a metre.

Food and water are naturally made up of nm-scale particles. For example, proteins are in the nanoscale size range and milk is an emulsion of nanoscale fat droplets.

Humans are also exposed to ultrafine and nm scale particles such as smoke, dust, ash, and fine clays through the air, food and water. Scientists estimate that in urban air we may inhale millions of nanoscale particles in every breath.

Any new foods manufactured using nanotechnologies that may present safety concerns will have to undergo a comprehensive scientific safety assessment before they can be legally supplied in Australia and New Zealand.

Using the best available scientific evidence, FSANZ has adopted a range of strategies to continually review and manage potential risks associated with nanotechnologies in foods to ensure the public are not exposed to any health or safety issues.

These strategies include:

- amending the FSANZ Application Handbook to support new food regulations and ensure applicants provide all the necessary information to help FSANZ conduct a risk assessment
- advising the food industry about the amendments to the Application Handbook involving nanotechnology and asking industry for information about proposed nanotechnology applications
- engaging with other national and international regulatory agencies, industry and the public to outline FSANZ's regulatory responses.

FSANZ has not received any applications to approve new or novel nanoscale particles for food use.

Find out more about nanotechnology on the Department of Industry website.

More information

Regulation of Nanotechnologies in Food in Australia and New Zealand

RELATED LINKS

- National Enabling Technologies Strategy
- Australian Nanotechnology Network
- NanoSafe Australia
- US Food and Drug Administration
- Health Canada
- Woodrow Wilson Nanotechnology Project
- Rice Uni - Int Council for Nanotechnology

http://www.foodstandards.gov.au/consumer/foodtech/nanotech/Pages/default.aspx

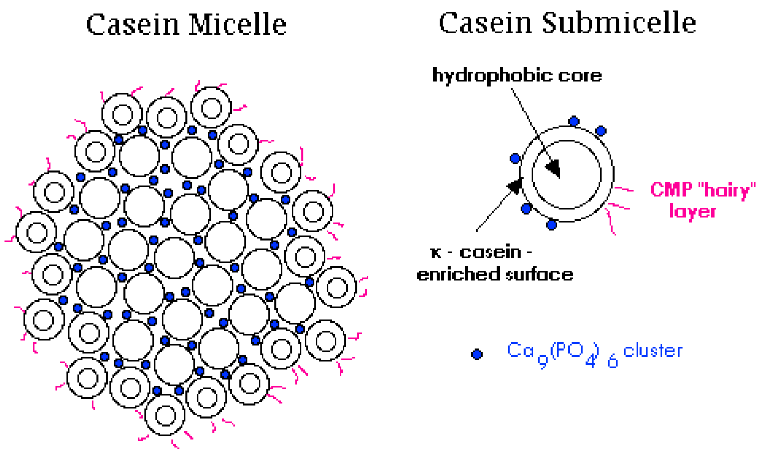
International organizations

- OECD Working Party on Nanotechnology (WPN) http://www.oecd.org/sti/nano/oecdworkingpartyonnanotechnologywpnvisionstatement.htm
  - Working Party on Manufactured Nanomaterials (WPMN, subsidiary to the Chemicals Committee) http://www.oecd.org/env/ehs/nanosafety/
  - Working Party on Biotechnology (WPB) http://www.oecd.org/sti/biotech/
  - National Experts for Scientific and Technological Indicators (NESTI) and their parent committees http://www.oecd.org/sti/nano/
- International Cooperation on Cosmetic Regulation (ICCR) http://www.iccrnet.org/

When talking about nanoscience/technology are all objects/particles synthesized (Engineered Nano Materials)?

- NO!!

Scientific American Jan. 18 2008



P. Walstra and R. Jenness In: P. Walstra and R. Jenness, Editors, *Dairy chemistry and physics*, Wiley, New York (1984)
http://www.foodscience.uoguelph.ca/deicon/casein.html

Science, Philosophy Debates

- Is the debate around nanotechnology similar to the debate around genetically modified organisms (GMO)?

In Pursuit of Nanoethics

The International Library of Ethics, Law and Technology Volume 10, 2014, pp 39-57

GM Food and Nanotechnology

Ronald Sandler

Abstract

In matters characterized by a high degree of complexity or uncertainty, such as the social and ethical dimensions of an emerging technology, it is often useful to begin with historical analogies (Steinbruner 2002). In the case of nanotechnology, one of the favored analogs is genetically modified (GM) foods. Even a cursory read of the first generation of social and ethical issues (SEI) literature on nanotechnology reveals that the GM food analogy plays prominently in motivating and framing the discourse, if not the agenda of SEI research. This chapter offers critical reflections on the comparisons between nanotechnology and GM foods. The aim is to identify the respects in which the comparisons are helpful in clarifying and responding to the SEI associated with emerging nanotechnologies, as well as the respects in which the comparisons are unhelpful or misleading. After reviewing several similarities and dissimilarities between the two types of technologies, three potential lessons from the GM food experience for emerging nanotechnologies are evaluated: a lesson on public engagement; a lesson on technological fixes; and a lesson on case by case assessment.

http://link.springer.com/chapter/10.1007/978-1-4020-6817-1_4

Consumer/Public Issues

- What are some of the issues consumers/public concerned about?
  - Transparency and inclusivity
  - Fear of the unknown
  - Can we guarantee zero risk?
  - Is science static?

BFJ
118,5

1254

Consumer attitudes towards nanotechnology in food products: an attribute-based analysis

Nigel D. Steenis and Arnout R.H. Fischer
Department of Marketing and Consumer Behaviour, Wageningen University, Wageningen, The Netherlands

Received 22 September 2015
Accepted 16 February 2016

Abstract

Purpose – Nanotechnology is a technology that holds much promise for food production. It is, however not clear to what extent consumers will accept different types of nanotechnologies in food products. The purpose of this paper is to research consumer attitudes towards differing applications of food nanotechnologies.

http://www.emeraldinsight.com/doi/pdfplus/
10.1108/BFJ-09-2015-0330

How much do consumers really know about nanotechnology?

International Journal of Consumer Studies

International Journal of Consumer Studies ISSN 1470-6423

'Better safe than sorry': consumer perceptions of and deliberations on nanotechnologies

Lucia A. Reisch[1], Gerd Scholl[2] and Sabine Bietz[3]

Abstract

Although nanotechnologies are considered key technologies that can drive growthgenerating innovations in well-saturated markets, worldwide investment in nanotechnologies has to date focused largely on technology-related development programmes and little effort has been expended to research associated risks. As a result, even though prior discourses have sensitized western consumers to potential health-related dangers, solid knowledge on, for example, the toxicological and eco-toxicological risks and unintended side effects of nanotechnology are scarce. This paper therefore presents an overview of the current evidence on consumer knowledge and perceptions of nanotechnology and public engagement with it, with a focus on the US, the UK and Germany. Overall, even though survey data suggest that awareness of the term 'nanotechnology' has risen slightly, today's consumers are generally ill informed about its nature and its applications in consumer related products. Hence, based on our analysis of these data, we argue that early political engagement in the nanotechnology issue – for example, consumer policy options that support consumer interest in the marketing of 'nanos' – would facilitate objective public discourse.

Reisch, Lucia A., Gerd Scholl, and Sabine Bietz. "'Better safe than sorry': consumer perceptions of and deliberations on nanotechnologies." *International Journal of Consumer Studies* 35.6 (2011): 644-654.

Science Communication
2014, Vol. 36(3) 352–378

DOI: 10.1177/1075547014529093
scx.sagepub.com
SAGE

Inequalities in Scientific Understanding: Differentiating Between Factual and Perceived Knowledge Gaps

Leona Yi-Fan Su[1], Michael A. Cacciatore[2], Dietram A. Scheufele[1], Dominique Brossard[1], and Michael A. Xenos[1]

Abstract

This study assesses two key types of knowledge assessments, factual and perceived knowledge, in the study of knowledge gaps. In addition, we distinguish between communication channels in exploring the phenomenon, examining nanotechnology knowledge gaps based on levels of attention to traditional media, science blog use, and the frequency of interpersonal discussion. Using regression analysis, we find that how researchers measure knowledge can significantly affect the discovery of gaps. We also find differential effects based on communication channels, including evidence that the direction of perceived gaps in knowledge can be reversed as media consumption increases. Implications of these findings are discussed.

Su, Leona Yi-Fan, et al. "Inequalities in Scientific Understanding Differentiating Between Factual and Perceived Knowledge Gaps." *Science Communication* 36.3 (2014): 352-378. doi: 10.1177/1075547014529093

Undergraduate Students' Risk Perception and Argumentation Concerning Nanomaterials in Consumer Products

Authors: Karlsson, Caroline; Enghag, Margareta; Wester, Misse; Schenk, Linda

Source: Journal of Nano Education, Volume 6, Number 1, June 2014, pp. 50-62(13)

Publisher: American Scientific Publishers

Abstract:

In the present paper we combine two analytical frameworks in order to extend our understanding of how students reason about a socio-scientific issue, namely, nanomaterials in consumer products. Using the results from two focus group discussions including seven students each, we first thematically explored undergraduate engineering students' risk perception. Two main themes were found in this analysis: "Exploring the concept of nanotechnology" and "Handling risks with nanotechnology." Second, we analyzed the nature of students' arguments using the SEE-SEP model, which is a coding scheme based on the subject areas Sociology/Culture, Environment, Economy, Science, Ethics/Morality, and Policy, intertwining the three aspects Knowledge, Values, and Personal experience. According to this analysis, 55% of the participants' arguments were based on values, 25% on knowledge, and 20% on personal experiences. Despite the absence of specific knowledge, however, the students could conduct a complex argumentation about nanomaterials and actively examined the paradox of new opportunities but unresolved risks. The students' reasoning reveals that arguments in favor and arguments against the use of nanomaterials in different products do not cross each other out, but co-exist. The results indicate that the risk perception was influenced to some degree by the area of use, such as skin care products or car treatment. It was also found that when lacking specific knowledge, our participants turned to analogies to other technology developments. Implications for education on nanotechnology are discussed.

http://www.ingentaconnect.com/content/asp/jne/2014/00000006/00000001/art00006

Educating the public, especially the young

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For K-12 Students

No matter how old or you are, learning about nanotechnology can be fun and exciting. All around the country, we have found new ways to learn about nanotechnology. There are museum exhibits with hands-on experiments and exhibits, and even if you can't get there, you can watch the experiments and visit the museums online. There are magazines with cool stories and games about nanotechnology. Check out the nanotechnology bus that drives around the country and find out when it's coming to your town. There's even a program to learn about nanotechnology by playing with Legos®!

Here you will see that nanotechnology is not just one thing. It is chemistry, physics, biology and materials science at the molecular level. After all, every one of us is made of atoms!

Students learn about nanoscience and nanotechnology at the NanoDays event hosted by the University of Nebraska-Lincoln. Visit nisenet.org for this year's dates and locations. Image: UNL

Check out these links to learn more about the fun and interesting ways you can learn about nanotechnology. (You may need to install the latest version of Flash to play some of the games.)

Nanooze is an online and print science magazine created by Cornell University as part of the education programs of the NNIN--the National Nanotechnology Infrastructure Network. It has online games, articles, and a blog, and you can view it in English, Spanish, and Portuguese.

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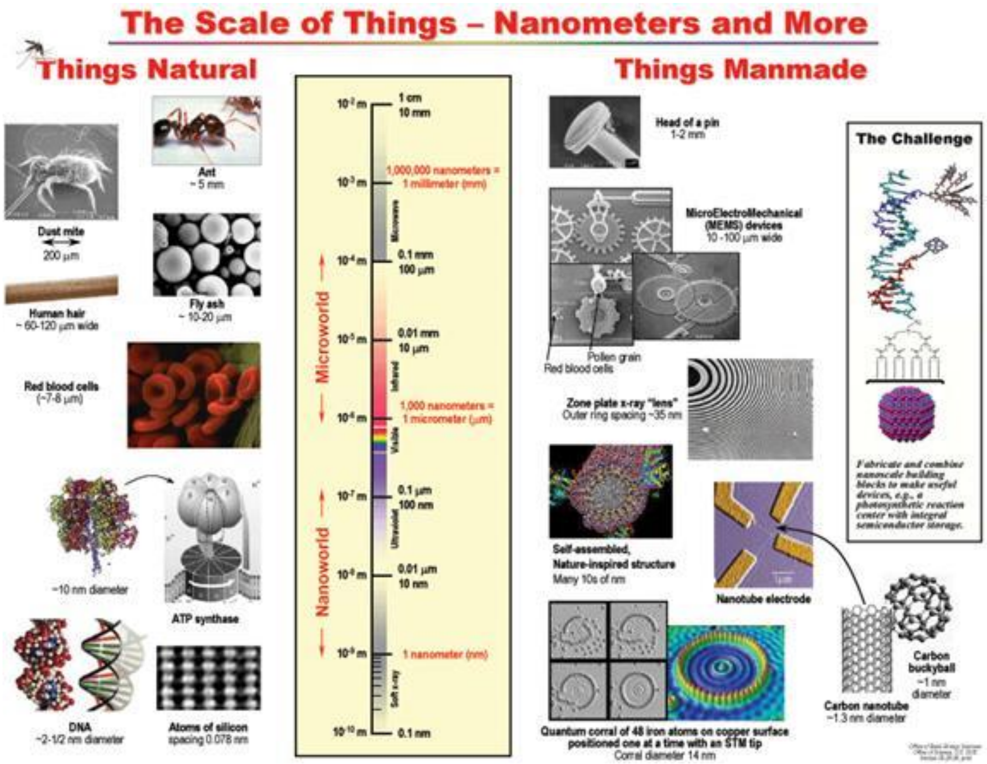
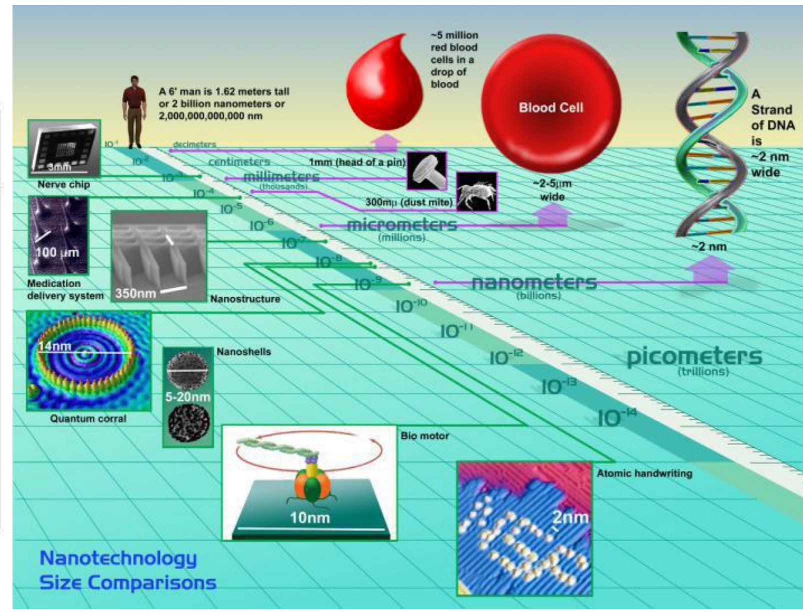
http://www.nano.gov/education-training/k12

Helping the public understand nanotechnology





http://www.umt.edu/ethics/debatingscienceresourcecenter/nanotechnology/NanoODC/default.aspx

http://www.understandingnano.com/introduction.html

Educating the public, especially the young

http://www.nanooze.org/english/nanooze_newsletters.html

Effective in touch with people to improve perception

Courtesy of Dr. Hongda Chen, USDA, NIFA

Education - Websites

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Fax: 519-823-2808

Teacher Resources

A growing list of resources to help teach about nanoscience.

Potential Careers

* Nanofluidics Process Manager
* Nanomaterials Designer

http://www.nano.uoguelph.ca/

Scientific Challenges

- Identification and characterisation of nanoparticles within the food matrix
- Uptake and absorption
- Safety

Some current references

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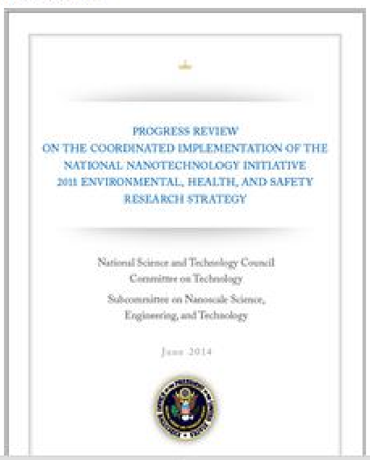
Progress Review on the Coordinated Implementation of the National Nanotechnology Initiative 2011 Environmental, Health, and Safety Research Strategy

Subject Area:
NNI Publications and Reports
NNI Strategic Documents
EHS-related Documents
Author: CoT/NSET/NEHI
Publication Date: Jun. 25 2014

Description:



Executive Summary

This document provides an overview of progress on the implementation and coordination of the 2011 NNI Environmental, Health, and Safety (EHS) Research Strategy that was developed by the Nanoscale Science, Engineering, and Technology Subcommittee's Nanotechnology Environmental and Health Implications (NEHI) Working Group. Consistent with the adaptive management process described in this strategy, the NEHI Working Group has made significant progress through the use of various evaluation tools to understand the current status of nanotechnology-related EHS (nanoEHS) research and the Federal nanoEHS research investment.

Most notably, the participating agencies reported to the NEHI Working Group examples of ongoing, completed, and anticipated EHS research (from FY 2009 through FY 2012) relevant to implementation of the 2011 NNI EHS Research

http://nano.gov/node/1157

Terms of Use

Measurement of Nanomaterials in Foods: Integrative Consideration of Challenges and Future Prospects

Christopher Szakal,† Stephen M. Roberts,‡ Paul Westerhoff,§ Andrew Bartholomaeus,⊥,∥ Neil Buck,¶ Ian Illuminato,# Richard Canady,▲ and Michael Rogers▽,*

Abstract

The risks and benefits of nanomaterials in foods and food contact materials receive conflicting international attention across expert stakeholder groups as well as in news media coverage and published research. Current nanomaterial characterization is complicated by the lack of accepted approaches to measure exposure-relevant occurrences of suspected nanomaterials in food and by broad definitions related to food processing and additive materials. Therefore, to improve understanding of risk and benefit, analytical methods are needed to identify what materials, new or traditional, are "nanorelevant" with respect to biological interaction and/or uptake during alimentary tract transit. Challenges to method development in this arena include heterogeneity in nanomaterial composition and morphology, food matrix complexity, alimentary tract diversity, and analytical method limitations. Clear problem formulation is required to overcome these and other challenges and to improve understanding of biological fate in facilitating the assessment of nanomaterial safety or benefit, including sampling strategies relevant to food production/consumption and alimentary tract transit. In this Perspective, we discuss critical knowledge gaps that must be addressed so that measurement methods can better inform risk management and public policy.

ACS Nano, 2014, 8 (4), pp 3128–3135 DOI: 10.1021/nn501108g

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25 JUN 2014

Towards reference materials for nanoparticles in food

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The JRC-IRMM combined its competence in the measurement of nanomaterials with its proficiency in the production of reference materials to develop a soup reference material spiked with silica nanoparticles.

A set of four reference materials for the detection and quantification of silica nanoparticles in tomato soup were produced. These materials aim to support the challenging work of verifying the correct labelling of nanomaterials in complex matrices such as food and consumer products.

Silica, e.g. labelled as E551, is already an approved food additive in the EU and can be used as anti-caking agent in soup powders and similar foodstuff. It may contain nanoparticles and Regulation 1169/2011 stipulates that from December 2014 on, consumers must be informed whether ingredients are present in their nano-form. Without suitable methods to check the correctness of statements, the implementation of such legislation will not be possible. To improve the availability of reliable and validated methods, the EU Project NanoLyse developed and validated analytical methods for the detection and quantification of nanomaterials in food. A second aspect of this project was the development of the first reference materials for nanoparticles in food matrices worldwide.

In close collaboration with the other project partners[1], homogeneity and stability of the material were assessed and first steps towards a value assignment were made. The data obtained demonstrate that the production of a certified reference material should be feasible.

Read more in: R. Grombe et al., Production of reference materials for the detection and size determination of silica nanoparticles in tomato soup, Anal. Bioanal. Chem. (2014) 406:3895–3907, doi:10.1007/s00216-013-7554-1

https://ec.europa.eu/jrc/en/news/towards-reference-materials-nanoparticles-food

Comprehensive
REVIEWS
in Food Science and Food Safety

Measurement Methods to Evaluate Engineered Nanomaterial Release from Food Contact Materials

Gregory O. Noonan, Andrew J. Whelton, David Carlander, and Timothy V. Duncan

Abstract: This article is one of a series of 4 that report on a task of the NanoRelease Food Additive project of the Intl. Life Science Inst. Center for Risk Science Innovation and Application to identify, evaluate, and develop methods that are needed to confidently detect, characterize, and quantify intentionally produced engineered nanomaterials (ENMs) released from food along the alimentary tract. This particular article focuses on the problem of detecting ENMs that become released into food indirectly from food contact materials. In this review, an in-depth analysis of the release literature is presented and relevant release mechanisms are discussed. The literature review includes discussion of articles related to the release phenomenon in general, as experimental methods to detect ENMs migrating from plastic materials into other (nonfood) complex matrices were determined to be relevant to the focus problem of food safety. From the survey of the literature, several "control points" were identified where characterization data on ENMs and materials may be most valuable. The article concludes with a summary of findings and a discussion of potential knowledge gaps and targets for method development in this area.

Keywords: characterization, detection, food contact materials, food safety, measurement methods, migration, nanotechnology, release

Comprehensive Reviews in Food Science and Food Safety Volume 13, Issue 4, Article first published online: 21 JUN 2014 http://onlinelibrary.wiley.com/doi/10.1111/1541-4337.12079/pdf

Comprehensive REVIEWS in Food Science and Food Safety

Measurement Methods for the Oral Uptake of Engineered Nanomaterials from Human Dietary Sources: Summary and Outlook

Christopher Szakal, Lyubov Tsytsikova, David Carlander, and Timothy V. Duncan

Abstract: This article is one of a series of 4 that report on a task of the NanoRelease Food Additive (NRFA) project of the International. Life Science Institute Center for Risk Science Innovation and Application. The project aims are to identify, evaluate, and develop methods that are needed to confidently detect, characterize, and quantify intentionally produced engineered nanomaterials (ENMs) released from food along the alimentary tract. This particular article offers an overview of the NRFA project, describing the project scope and goals, as well as the strategy by which the task group sought to achieve these goals. A condensed description of the general challenge of detecting ENMs in foods and a brief review of available and emerging methods for ENM detection is provided here, paying particular attention to the kind of information that might be desired from an analysis and the strengths and weaknesses of the various approaches that might be used to attain this information. The article concludes with an executive summary of the task group's broad findings related to the 3 topic areas, which are covered in more detail in 3 subsequent articles in this series. The end result is a thorough evaluation of the state of ENM measurement science specifically as it applies to oral uptake of ENMs from human dietary sources.

Keywords: characterization, detection, food safety, measurement methods, nanomaterials, nanotechnology, nanotoxicology

Comprehensive Reviews in Food Science and Food Safety Volume 13, Issue 4, Article first published online: 21 JUN 2014 http://onlinelibrary.wiley.com/doi/10.1111/1541-4337.12080/pdf

Comprehensive REVIEWS in Food Science and Food Safety

Engineered Nanoscale Food Ingredients: Evaluation of Current Knowledge on Material Characteristics Relevant to Uptake from the Gastrointestinal Tract

Rickey Y. Yada, Neil Buck, Richard Canady, Chris DeMerlis, Timothy Duncan, Gemma Janer, Lekh Juneja, Mengshi Lin, Julian McClements, Gregory Noonan, James Oxley, Cristina Sabliov, Lyubov Tsytsikova, Socorro Vázquez-Campos, Jeff Yourick, Qixin Zhong, and Scott Thurmond

Abstract: The NanoRelease Food Additive project developed a catalog to identify potential engineered nanomaterials (ENMs) used as ingredients, using various food-related databases. To avoid ongoing debate on defining the term *nanomaterial*, NanoRelease did not use any specific definition other than the ingredient is not naturally part of the food chain, and its dimensions are measured in the nanoscale. Potential nanomaterials were categorized based on physical similarity; analysis indicated that the range of ENMs declared as being in the food chain was limited. Much of the catalog's information was obtained from product labeling, likely resulting in both underreporting (inconsistent or absent requirements for labeling) and/or overreporting (inability to validate entries, or the term *nano* was used, although no ENM material was present). Three categories of ingredients were identified: emulsions, dispersions, and their water-soluble powdered preparations (including lipid-based structures); solid encapsulates (solid structures containing an active material); and metallic or other inorganic particles. Although much is known regarding the physical/chemical properties for these ingredient categories, it is critical to understand whether these properties undergo changes following their interaction with food matrices during preparation and storage. It is also important to determine whether free ENMs are likely to be present within the gastrointestinal tract and whether uptake of ENMs may occur in their nanoform physical state. A practical decision-making scheme was developed to help manage testing requirements.

Keywords: bioavailability, food ingredient, nanotechnology

Comprehensive Reviews in Food Science and Food Safety Volume 13, Issue 4, Article first published online: 21 JUN 2014 http://onlinelibrary.wiley.com/doi/10.1111/1541-4337.12076/pdf

Comprehensive REVIEWS in Food Science and Food Safety

Methods to Evaluate Uptake of Engineered Nanomaterials by the Alimentary Tract

Heather Alger, Dragan Momcilovic, David Carlander, and Timothy V. Duncan

Abstract: This article is one of a series of 4 that report on a task of the NanoRelease Food Additive project of the International Life Science Institute Center for Risk Science Innovation and Application to identify, evaluate, and develop methods that are needed to confidently detect, characterize, and quantify intentionally produced engineered nanomaterials (ENMs) released from food along the alimentary tract. This particular article focuses on the problem of detecting and characterizing ENMs in the various compartments of the alimentary tract after they have been ingested from dietary sources. An in depth analysis of the literature related to oral toxicity of ENMs is presented, paying particular attention to analytical methodology and sample preparation. The review includes a discussion of model systems that can be used to study oral uptake of ENMs in the absence of human toxicological data or other live-animal studies. The strengths and weaknesses of various analytical and sample preparation techniques are discussed. The article concludes with a summary of findings and a discussion of potential knowledge gaps and targets for method development in this area.

Keywords: alimentary tract, characterization, detection, food safety, measurement methods, nanotechnology, nanotoxicology

Comprehensive Reviews in Food Science and Food Safety Volume 13, Issue 4, Article first published online: 21 JUN 2014 http://onlinelibrary.wiley.com/doi/10.1111/1541-4337.12077/pdf

Issues – moving forward

- Many potential benefits but must also identify any potential risks
- Various governments/agencies are in the process of developing policies/regulations
- Need to educate consumers/public to avoid a repeat of the discussion involving Genetically Modified Organisms

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- Advanced Foods and Materials Canada
- NANOLYSE and NanoRelease Projects
- IUFoST

Some nanofood for thought

Thank you