

House of Lords Select Committee on Science and Technology inquiry into Nanotechnologies and Food

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1. The emerging debate about nanotechnology and food

The subject of applications of nanotechnologies in food is rising in media profile. This is being driven, on the one hand, by publications from promoters of nanotechnology pointing to substantial potential benefits and quoting very large projected future markets (see, for example, [1]), and on the other hand concern from NGO's and consumer organisations (most recently, Friends of the Earth, who published a report on the subject last year [2]). The debate is compromised, in my view, by a lack of clarity about the scope of the various technologies that are being lumped together as nanotechnology.

2. What is nanotechnology?

Most people's definitions are something along the lines of "*the purposeful creation of structures with length scales of 100 nm or less to achieve new effects by virtue of those length-scales*". But when one attempts to apply this definition in practise one runs into difficulties, particularly for food. It is this ambiguity that lies behind the difference of opinion about how widespread the use of nanotechnology in foods is already. On the one hand, Friends of the Earth says they know of 104 nanofood products on the market already (and some analysts suggest the number may be more than 600). On the other hand, the CIAA (the Confederation of Food and Drink Industries of the EU) maintains that, while active research in the area is going on, no actual nanofood products are yet on the market. In fact, both parties are, in their different ways, right; the problem is the ambiguity of definition.

2. The naturally nanostructured nature of most food

The issue is that food is naturally nano-structured, so that too wide a definition ends up encompassing much of modern food science, and indeed, if you stretch it further, some aspects of traditional food processing. Consider the case of "nano-ice cream": the FoE report [2] states that "Nestlé and Unilever are reported to be developing a nano- emulsion based ice cream with a lower fat content that retains a fatty texture and flavour". Without knowing the details of this research, what one can be sure of is that it will involve essentially conventional food processing technology in order to control fat globule structure and size on the nanoscale. If the processing technology is conventional (and the economics of the food industry dictates that it must be), what makes this nanotechnology, if anything does, is the fact that analytical tools are available to observe the nanoscale structural changes that lead to the desirable properties. What makes this nanotechnology, then, is simply knowledge. In the light of the new knowledge that new techniques give

us, we could even argue that some traditional processes, which it now turns out involve manipulation of the structure on the nanoscale to achieve some desirable effects, would constitute nanotechnology if it was defined this widely. For example, traditional whey cheeses like ricotta are made by creating the conditions for the whey proteins to aggregate into protein nanoparticles. These subsequently aggregate to form the particulate gels that give the cheese its desirable texture. The distinction between “natural” food nanoparticles and structures and ones that have been deliberately engineered is potentially very problematic. For example, the recent European Food Standards Agency scientific opinion [3] concentrates on ‘*engineered nanomaterials*’, but goes on to add that “*Natural nanoscale materials (e.g. micelles) will be considered if they have been deliberately used e.g. to encapsulate bioactive compounds or further engineered to retain their nanoscale properties. “Natural” nanoscale components present as emulsions (e.g. in homogenized milk, mayonnaise, etc.) will not be considered.*’ This places the emphasis on whether the manipulation of the nanostructure has been done on purpose. Of course, in the hypothetical case that a particular nanostructure developed during processing did have potentially harmful effects, then the potential danger it might pose would not be affected by whether its introduction was intentional or not.

3. Different types of nanotechnologies have quite different risk profiles

It should be clear, then, that there isn’t a single thing one can call “nanotechnology” – there are many different technologies, producing many different kinds of nano-materials. One makes materials and structures at the nanoscale in order to access new properties - and these new properties in principle could bring new risks. But there are a number of quite different classes of properties that going to the nanoscale unlocks, and it is this variety of different types of nanoscale behaviour that makes it impossible to precisely specify a size range that constitutes the nanoscale. Different properties are affected by size in different ways, and it is only a general sense that many such properties start to be dramatically affected below sizes of a few hundred nanometers that underlies the adoption of definitions such as that which defines 100 nm as the upper limit of the nanoscale. One class of properties is affected by the simple issue of the larger surface to volume ratio of small particles; this affects issues such as solubility and catalytic effectiveness. Another important class of properties arises from the interaction of the physical dimensions of a nano-object with the wavelength of some kind of radiation. This includes the well-known transparency of small dielectric particles such as nanoscale titanium dioxide and the colour changes of gold colloids, and the quantum confinement effects that arise in semiconductor nanoparticles (quantum dots). Finally there are a number of properties that arise due to the importance of Brownian motion and strong surface forces at the nanoscale, in particular the phenomenon of self-assembly, which underlies, for example, the formation of nanoscale surfactant micelles, and is of great importance in biological processes at the nanoscale.

In the same way that the new properties that arise at the nanoscale can have their origin in quite different physical phenomenon, so the new potential risk profiles of such materials will be very different, and it will be impossible to generalise across these categories. To

give a few examples, cadmium selenide quantum dots, titanium dioxide nanoparticles, sheets of exfoliated clay, fullerenes like C60, casein micelles and phospholipid nanosomes will all have quite distinct profiles of risk and uncertainty and it is likely to be very misleading to generalise from any one of these to a wider class of nanomaterials.

4. Engineered nanoparticles versus self-assembled nanostructures

To begin to make sense of the different types of nanomaterial that might be present in food, there is one very useful distinction. This is between engineered nanoparticles and self-assembled nanostructures. Engineered nanoparticles are covalently bonded, and thus are persistent and generally rather robust, though they may have important surface properties such as catalysis, and they may be prone to aggregate. Examples of engineered nanoparticles include titanium dioxide nanoparticles and fullerenes.

In self-assembled nanostructures, though, molecules are held together by weak forces, such as hydrogen bonds and the hydrophobic interaction. The weakness of these forces renders them mutable and transient; examples include soap micelles, protein aggregates (for example the casein micelles formed in milk), liposomes and nanosomes and the microcapsules and nanocapsules made from biopolymers such as starch.

5. Varieties of food nanotechnology

Some potentially important areas of application of nanotechnology in food include the following:

- *Food science at the nanoscale.* This is about using a combination of fairly conventional food processing techniques supported by the use of nanoscale analytical techniques to achieve desirable properties. A major driver here will be the use of sophisticated food structuring to achieve palatable products with low fat contents.
- *Encapsulating ingredients and additives.* The encapsulation of flavours and aromas at the microscale to protect delicate molecules and enable their triggered or otherwise controlled release is already widespread, and it is possible that decreasing the lengthscale of these systems to the nanoscale might be advantageous in some cases. We are also likely to see a range of “nutriceutical” molecules come into more general use.
- *Water dispersible preparations of fat-soluble ingredients.* Many food ingredients are fat-soluble; as a way of incorporating these in food and drink without fat manufacturers have developed stable colloidal dispersions of these materials in water, with particle sizes in the range of hundreds of nanometers. For example, the substance lycopene, which is familiar as the molecule that makes tomatoes red and which is believed to offer substantial health benefits, is marketed in this form by the German company BASF.

6. Nanotechnology in packaging and food contact materials

Nanotechnology will also find applications in packaging and food contact materials. Again, there are some important distinctions.

- *Essentially passive nanostructures.* These will be typically used to control barrier properties (e.g. controlling gas diffusion for plastic beer bottles), and examples will be the use of exfoliated clay coatings and composites.

- *Nanomaterials which release active ingredients.* For example nanosilver may be incorporated in packaging materials for anti-microbial properties.

- *Active devices* - from sensors to detect spoilage, through to "intelligent packaging".

One issue is worth mentioning in this context. These ideas for incorporating nanotechnology in packaging all, in different ways, tend towards increased material complexity, which does go counter to some other trends, particularly the drive to minimise waste and make things recyclable.

7. Clarity and shared understanding must underlie real dialogue

What is important in this discussion is clarity – definitions are important. There are large discrepancies between estimates of how widespread food nanotechnology is in the marketplace now, and these discrepancies lead to unnecessary misunderstanding and distrust. Clarity about what we are talking about, and a recognition of the diversity of technologies we are talking about, can help remove this misunderstanding and give us a sound basis for public dialogue.

[1] *Nanotechnology in Agriculture and Food*, Nanoforum, May 2006
<http://www.nanoforum.org/dateien/temp/nanotec%20hnology%20in%20agriculture%20and%20food.pdf>

[2] *Out of the Laboratory and on to our Plates: Nanotechnology in Food & Agriculture*, Friends of the Earth, March 2008,
http://www.foeeurope.org/activities/nanotechnology/Documents/Nano_food_report.pdf
(accessed 12/3/09)

[3] *The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety*, The EFSA Journal (2009) 958, 1-39