Nanofood

By Gregor Wolbring[i]

This is an extended and updated version of my Nanofood column(*1*) published in July 2006 by innovationwatch.com. This brief focuses on food and not on agricultural practices although both are targeted and impacted by nanotechnologies.

The debate around the safety, usefulness, distribution and regulation of GM Food and GM based nutraceuticals and functional food is still in full swing with a less than clear outcome (see resource list at end of paper) and already the next technology (nanotechnology) for food modification and production (Nanofood) is deployed and developed.

A recent OECD and Allianz report(*2*) stated:" Nanotechnology will not only change how every step of the food chain operates but also who is involved. At stake is the world's $3 trillion food retail market, agricultural export markets valued at $544 billion, the livelihoods of farmers and the well-being of the rest of us. Converging technologies could reinvigorate the battered agrochemical and agbiotech industries, possibly igniting a still more intense debate – this time over "atomically-modified" foods."

In a recent survey (*3*) about the 'top 10 nanotechnology applications for Developing Countries', agricultural productivity enhancement was in second place and food processing and storage was in sixth place.

Nanofood Market

According to the consultant group Kaiser which worked for many years on nanotechnology issues "more than 180 applications are in different developing stages and a few of them are on the market already. The nanofood market is expected to surge from USD 2.6 bn. [2003] to 7.0 bn. US dollars in 2006 and to 20.4 bn. US dollars in 2010. More than 200 companies around the world are today active in research and development. USA is the leader followed by Japan and China. By 2010 Asian with more than 50 percent of the world population will be the biggest market for nanofood with the leading of China." Cientifica another consulting group which worked on nanotechnology since 2000 wrote in their blog and in a recent report(*4*) that Nanotechnologies in the food industry will grow from $410 million in 2006 to be worth $5.8 billion by 2012. Cientifica sees the following Challenges & Drivers of Nanotechnology Applications in the Food Industry (*4*)

- Food related diseases
- The aging population
- . Lessening the risk of local and global climate change on food production
- .Life-style requirements
- .Sustainability of food production and processing
- .Food safety and quality
- .Analysis and impact of consumer, technology and globalization related drivers

It is particularly interesting that Cientifica believes that molecular manufacturing the design of material atom by atom might be used for food after 2012 "Unlike a few of the other reports we have seen on nanotech and food, and as regular readers would expect, we don't see desktop nanofactories churning out unlimited free food before 2012. "(*4*)

The Woodrow Wilson International Center for Scholars Project on Emerging Nanotechnologies has published recently a report on anticipated applications of nanotechnology in agriculture and food production (*5*) and on nano food and agriculture products. a database listing activities in Agrifood Nanotechnology Research and Development(*6*).

What is Nanotechnology?

The term 'nanotechnology was first used to describe the manufacturing of products from the bottom up atom by atom (like the food replicator in many science fiction films where one says for example coffee and the machine builds, synthesizes the coffee molecule by molecule). However due to sales pitch strategies by companies and others the term nanotechnology is used today to mean 'nanoscale technology' and nanoscale sciences covering 'nanotechnology' research and development products, ideas and processes with controlled size below 300nm. Many Nano-Taxonomies exist, which show the numerous fields, processes and products covered under Nano today. (*7*)

The original meaning of the term nanotechnology is now generally known as molecular manufacturing or molecular nanotechnology.

Nanotechnology in all its meanings allows among others for the manipulation of materials on an atomic or molecular scale and enables a new paradigm of science and technology which sees different technologies converging at the nanoscale namely (a) nanoscience and nanotechnology; (b) biotechnology and biomedicine, including genetic engineering; (c) information technology, including advanced computing and communications; (d) cognitive science (neuro engineering) ("NBIC" (nano-bio-info-cogno) and (e) synthetic biology which is the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes. (*8*) (NBICS)

The National Nanotech Initiative (USA) envisions applications for NBIC products in areas such as the environment, energy, water, weapons and other military applications, globalization, agriculture, health (more efficient diagnostics and genetic testing, cognitive enhancement; life extension and enhancing human performances in general). (*9*) Others such as the social group of transhumanist believe that advances in NBICS hold the key for extreme life extension to the level of immortality and the achievement of morphological (*10*), 'full reproductive' and genomic freedom. (*11*)

Nanofunding

The U.S. government spent nearly twice as much on nanotechnology in 2004 as it did on the Human Genome Project (HGP) in its peak year. Predictions are that expenditures in Nanotechnology will soon outstrip investments to date in Genomics and Biotechnology (*12*). "By the end of 2005 governments had sunk eighteen billion dollars (US$18 billion) of taxpayers money into nanotechnology R&D. With an additional six billion dollars (US$6 billion) forecast for 2006, nanotechnologies will then have received the same level of funding in absolute dollar terms as the entire Apollo program." (*13*) Many countries including middle and low-income countries are getting increasingly involved in NBICS. (*14*)

What is Nanofood:

The European group Nanoforum believes that food can be classified as nanofood as when "nanotechnology techniques or tools are used during cultivation, production, processing, or packaging of the food. It does not mean atomically modified food or food produced by nanomachines." Nanofood definition should include atomically modified food or food produced by nanomachines, although this application is quite a few years away and might never appear but if it appears one can not say this is not nanofood (maybe it will be called molecular manufactured food). However although the definition of the nanoforum seems to be artificially narrow with this exclusion, it still gives a good idea of how much food will be nanofood in the future and how broad a circle of people will be affected by nanofood. Most people very likely will never have heard of Nanofood or might think this is the future talking however this future is here now.

Nanoapplication for Food

"Five out of ten of the world's largest food companies, including Heinz, Nestlé, Unilever and Kraft, are aggressively exploring the potential of nanotechnology for better packaging, improved food safety and better nutritional content."(*15*)
The second nano food conference the Nano4Food Conference, just took place in Atlanta, USA, October 12-13, 2006. According to the conference webpage, nanotechnology will be able to solve a variety of problems in the food industry by enabling increases in productivity and cost-effectiveness; providing better food processing, packaging and logistics; helping in the design of new healthier and tastier products; and providing better food safety and quality assurance.

Envisioned applications are nanoscale biosensors for pathogen detection and diagnosis; nano-delivery of bioactive/nutrient ingredients in foodstuffs through improved knowledge of food materials at the nanoscale; and nanoscale filtration systems for improved texture modification.

Nanotechnology is envisioned to be used in food production, processing, preservation, flavor and color improvement, hygiene, safety and packaging. Nanomaterials include nanocomposites, nanoclays, nanotubes and others. Nanosensors, nanoimaging and nanochips will be used, as will nanofilters. Nano delivery systems will use nanocapsules, nanocochleates, nanoballs, nanodevices, nanomachines and nanorobots.

Cientifica list in a recent report (*4*) a variety of Nanotechnology Applications in Food Packaging, Food Processing, Food Ingredients/Food Additives, Food Safety and Quality.

Scientists at the University of Kent in the UK have received euro;800,000 to study ways how nanotechnology can improve the safety and quality of chilled and frozen foods(*16*).

In a recent timesonline article(*15*) one finds the following "Many of the applications of nanotechnology as applied to food are not controversial. The use of "nanofilters" is already ensuring that viruses and bacteria are removed completely from liquids such as milk, improving safety and giving longer shelf life. Equally, there is little controversy over new techniques of attaching nanoscale-sensing devices to food products and packaging, so that the sources of food ingredients can be traced back to origin ; something that food campaigners have long been demanding.

There is also much excitement around the potential of nanotechnology to make food safer. Campylobacter, for example, is a bacterium that does not harm chickens but causes illness in human beings and even death in the vulnerable. A nanoparticle to go into chicken feed is being developed at Clemson University, South Carolina, which would latch on to Campylobacter, ensuring that it is excreted by chickens, so making the bird safer to eat.

And nanoscale silica spheres filled with molecules of a fluorescent dye have been developed to go into meat packaging, where they will detect the presence of the deadly E. coli 0157 bacteria. The surface of the spheres are covered with antibodies that search out and stick to the antigens found on the surface of the E. coli bacteriuma. When contact is made, the spheres literally light up, resulting in a change in packaging colour. Nanomaterials added to PVC films can also prevent spoilage by UV light."

In a recent foodproductiondaily article(*17*) one reads "A plastic container that uses silver nanoparticles to keep foods fresher longer, points the way forward for processors looking to incorporate the technology into their packaging.The technology is attractive to the food industry as it promises to yield new solutions to key challenges. Research and development underway includes the development of functional food, nutrient delivery systems and methods for optimizing food appearance, such as colour, flavour and consistency.In the food-packaging arena, nanomaterials are being developed with enhanced mechanical and thermal properties to ensure better protection of foods from exterior mechanical, thermal, chemical or microbiological effects. The new containers, being marketed to consumers by Sharper Image in the US, are infused with naturally antibacterial silver nanoparticles. This keeps foods fresher three or even four times longer than normal, Sharper Image claims. The containers can be used to store fruits, vegetables, herbs, breads, cheeses, soups, sauces and meats while maintaining color, flavor and nutritional values much longer. Silver is naturally anti-germ, anti-mold and anti-fungus. In tests comparing Fresher Longer to conventional containers, the 24-hour growth of bacteria inside Fresher Longer containers was reduced by over 98 percent because of the silver nanoparticles, the company claimed."

If one searches the Nanotechnology Consumer Products Inventory[1] set up by the Woodrow Wilson International Center for Scholars in the US for food one finds 38 hits which include Antibacterial tableware which with nano silver coating, nanotech antioxidant system for essential oils and flavours, nanotechnological–based supplements specifically targeted for professional and amateur athletes, Nano-sized self assembled structured liquids) for Canola Active oil,nano calcium/magnesium, nano B12 vitamin.

Two annexes to the report **Down on the Farm by ETC** give further ideas of where nanofood is heading: Annex 1: Nanotech R&D at Major Food and Beverage Corporations; and Annex 2: Nano Patents for Food and Food Packaging .

Nano-Nutraceuticals and Nano-Functional Food

Nutraceuticals and functional foods according to Agri-Food Canada "are food components that provide demonstrated physiological benefits or reduce the risk of chronic disease, above and beyond their basic nutritional functions. A functional food is similar to a conventional food, while a nutraceutical is isolated from a food and sold in dosage form, in both cases the active components occur naturally in the food."

Biofortified" foods (fortified with vitamins, minerals, etc.) are another development Bio-engineering and genetics have so far been envisioned by many as tools to produce more nutritious and functional food a vision which is questioned by many. The jury is still out as to the outcome of this discourse around GE based nutritious and functional food and along comes already the next technology. Nanotechnology is moving fast into this area. The **Nanoforum report on food** gives many examples of Nan-Nutraceuticals and Nano-functional foods.

Nanocapsules -- "Nanocapsules containing tuna fish oil (a source of omega 3 fatty acids) in "Tip-Top" Up bread."

Nano-sized Self-assembled Liquid Structures -- "The Israeli Company Nutralease, utilises Nano-sized Self-assembled Liquid Structures (NSSL) technology to deliver nutrients in nanosized particles to cells. Nutraceuticals that have been incorporated in the carriers include lycopene, beta-carotene, lutein, phytosterols, CoQ10 and DHA/EPA." "The technology has already been adopted and marketed by Shemen Industries to deliver Canola Activa oil."

Nanocochleates -- "Biodelivery Sciences International have developed nanocochleates, which are 50 nm coiled nanoparticles and can be used to deliver nutrients such as vitamins, lycopene, and omega fatty acids more efficiently to cells, without affecting the colour or taste of food."

Interactive and Smart Foods -- "Kraft foods have established a consortium of research groups from 15 universities to look into the applications of nanotechnology to produce interactive foods. These will allow the consumer to choose between different flavours and colours. The consortium also has plans to develop smart foods which

[1] http://www.nanotechproject.org/index.php?id=44

will release nutrients in response to deficiencies detected by nanosensors, and nanocapsules which will be ingested with food, but remain dormant until activated. All these new developments will make the concept of super foodstuffs a reality, and these are expected to offer many different potential benefits including increased energy, improved cognitive functions, better immune function, and antiaging benefits."

Nano-carriers -- "The German company Aquanova has developed a new technology which combines two active substances for fat reduction and satiety into a single nano-carrier (micelles of average 30 nm diameter), an innovation said to be a new approach to intelligent weight management. Called NovaSOL Sustain, it uses CoQ1O to address fat reduction and alpha-lipoic acid for satiety. The NovaSol technology has also been used to create a vitamin E preparation that does not cloud liquids, called SoluE, and a vitamin C preparation called SoluC. The NovaSOL product can be used to introduce other dietary supplements as it protects contents from stomach acids. In a different strategy, Unilever is developing low fat ice creams by decreasing the size of emulsion particles that give ice-cream its texture. By doing so it hopes to use up to 90% less of the emulsion and decrease fat content from 16% to about 1%."

A recent timesonline article(*15*) states "One of the reasons food manufacturers are taking such an interest in nanoscale products is that they can cross cell membranes. Encapsulating nutrients in nanoscale spheres could enhance the biological activity of dietary supplements — or "nutraceuticals" as they are sometimes called — by feeding them directly into cells. A dozen or so dietary supplements of this sort are on the market in the US and have been embraced enthusiastically by health and fitness enthusiasts. Dr Qasim Chaudhry leads the nanotechnology team at the Central Science Laboratory, an agency of Defra (the Department for Environment, Food and Rural Affairs), and is undertaking the FSA-sponsored research on nanotechnology. He points out that such products may have unanticipated effects, far greater absorption than intended or altered uptake of other nutrients, but little, if anything, is known currently."

According the **report Down on the Farm by ETC**, BASF produces a nano-scale version of carotenoids, a class of food additives which it sells to major food and beverage companies worldwide for use in lemonades, fruit juices and margarines.

Taste Nanology and StabilEase are two recent examples of products developed by the flavor technology company **Blue Pacific Flavors**.

Questions Raised

Nano versus low tech/no tech solutions:

As the **report Down on the Farm by ETC** and others show (see Resources) the issue is not simple. Questions have to be asked, such as: Are high-tech solutions the best option or are low-tech or no-tech solutions available, possible, and more feasible and effective? Golden rice which is GE rice to contain Vitamin A was often and sometimes still is used as an example for a high-tech solution to vitamin A deficiency but aren't there other -- maybe better and cheaper -- ways available to deal with vitamin A deficiency? It is not self-evident or a forgone conclusion that high

technology is the best or only solution for poverty, hunger and malnutrition. The UN press release **UN report finds Sub-Saharan Africa improving on vitamin, mineral deficiencies** from 2004 (*18*) states: "Many countries in sub-Saharan Africa are fighting back in the battle against vitamin and mineral deficiencies, saving millions of people from death or illness through relatively cheap programmes, according to a report jointly authored by United Nations agencies and non-governmental organizations (NGOs). The report(*19*) finds that millions of other people, especially children, could be helped if the programmes and strategies - which include iodizing salt and giving vitamin A supplements to children - are extended to every country in Africa. Some 25 nations in the region now reach 70 per cent or more of their children with one vitamin A capsule every year, and 11 have recently achieved much higher rates of iodized salt coverage, the report states. Many governments are also adding iron and folic acid to wheat flour or fortifying staples such as sugar, margarine and cooking oils with vitamins and minerals. UNICEF Deputy Executive Director Kul Gautum said Africa has an important opportunity to advance its human development in a relatively short space of time. "We have the right strategies - food fortification, supplementation and basic nutritional education - and the right partnerships to implement them. The challenge is simply our will to reach out to every child," he said. The report was prepared by UNICEF, the World Health Organization"

Who is involved?

It also raises the question as to who is involved. Women in particular in developing countries, indigenous people, disabled people, people with little disposable income farmers are all impacted inn particular ways by the debate around food production, food security, food consumption which makes it essential that they are involved in the nanofood debate. So far nano-food is not on the agenda of many of the groups working in food security or GM Food. In regards to Women and development The Association for Women's Rights in Development (AWID) has some nano content on their webpage however very few groups working in development in general or food and development are covering nanofood as of yet. The keyword combination 'Nanofood' and indigenous people' only generates 10 hits Only 11 hits are generated with "disabled people" and nanofood and only 543 hits are generated with women and nanofood. The Conferences: Asia-Pacific Peoples Convention on Food Sovereignty Peoples' Statement of the Asia Pacific Convention on Food Sovereignty mentions nano as does the Dhaka Declaration Globalize the hope! Globalize the struggle! South Asian Peasants' Assembly 29 and 30 July 2003, Dhaka, Bangladesh**.** However very little action on nanofood seem to have evolved from the declaration and statements at least if I look at Google..

Nanofood and impact on farmers and low income countries.

The prediction by Cientifica that we might see molecular manufacturing of food after 2012 highlight one consequence for farmers in general and particularly in low income countries. If a machine can generate food atom by atom that must have an impact on the demand for nature-based commodities such as food. It must have an impact on the export capabilities of food by especially low income countries. Even before 2012 and the may be appearance of the molecular manufacturing of food the changes of food design, production, manufacturing and selling through nanotechnologies such as nanoceuticals, the nanoformulation of pesticides and the envisioned change of

agriculture through nanotechnology will impact farmers especially poor farmers especially in the south who can not respond quickly to nanotechnology driven agricultural, food production and demand changes and who might never .be able to afford the new technologies and adapt or influence the deployment and usage of nanotechnologies.

Nano approaches replacing GE approaches?

Another interesting question is whether Nano approaches to nutraceutical and functioning food make GE approaches to nutraceutical and functioning food obsolete or whether nanotechnology will be used to increase the usability of GE or whether these two will complement each others .

Regulation:

UK
According to the **UK food regulator, 'gaps' in regulating nanotechnology** exist.[2]

THE ROYAL SOCIETY AND ROYAL ACADEMY OF ENGINEERING REPORT (UK) on Nanotechnology in 2004 has a variety of recommendations (R1-15) which could be applied to nanofood [3] The UK government has published a response[4] to the Royal Society and Royal Academy of Engineering Nanotech report however as a Royal Academy press release stated "The Royal Society and the Royal Academy of Engineering have expressed serious concern at the Government's lack of progress in improving the understanding of the potential health and environmental impacts of free nanoparticles in a new report published today (Tuesday, 24 October 2006)."[5]

The Institute of Food Science & Technology **IFST Information sheet on nanotechnology and Food** from February 2006[6] highlights a variety of concerns in regards to the properties and human medical health and environmental safety of Nanoparticle and highlights that it is legal in the UK to sell materials for use in foods, based on safety data for the macroscopic material that there is no requirement to label foods nanoparticles.

The IFST concludes in the fact sheet that:

"new developments, the management of potential risks is not the sole responsibility of politicians and legislators. Scientists and technologists have a primary responsibility to ensure the safety of the products that they develop. Consumers are entitled to expect any changes in Nanotechnology food composition or packaging materials that involve nanotechnology to be necessary and safe, the appropriate toxicity testing to have been done and the results to be freely available in the public domain. A cautious approach to the introduction of products of nanotechnology into food structure, manufacture and production will be very important. Appropriate risk-benefit analyses

[2] http://www.foodnavigator.com/news/ng.asp?id=67935
[3] http://www.nanotec.org.uk/
[4] http://www.royalsoc.ac.uk/page.asp?id=3190
[5] http://www.royalsoc.ac.uk/news.asp?id=5455
[6] http://www.ifst.org/uploadedfiles/cms/store/ATTACHMENTS/Nanotechnology.pdf

should therefore be performed and used, if necessary, to underpin new controls or, as appropriate, legislation on the permitted types and levels of use of these materials."

USA

The FDA Regulation of Nanotechnology Products[7] section on the FDA webpage gives an idea as to the thought of the FDA towards nanotechnology product regulations. In short it does not feel like that the FDA sees a need to change their ways

A recent workshop in the USA addressed among others nano standards issues likely to be relevant for the agrifood sector.[8]

Germany

"Germany's food safety risk assessment agency has commissioned a study on the potential health effects of nanotechnologies used in products.(*20*) The German Federal Institute of Risk Assessment (BfR) has commissioned the University of Stuttgart to conduct the survey on the risks of nanotechnological applications in food, cosmetics and other everyday items, according to a report by the Nanoforum. The survey will be performed by ZIRN (Centre of Interdisciplinary Risk-science and Sustainable Development of Technology) which will involve about 100 experts from science, industry, public authorities and non-governmental organisations.A questionnaire will focus on questions relating to current and future applications and potential risks. This information will be debated further in two workshops before being consolidated into a "risk-barometer" to be used to better inform public authorities.BfR is responsible for identifying and assessing potential risks to consumers from foods, feedstuffs, chemicals and consumer products. It is also responsible for proposing risk reduction measures to political circles and informing the general public about them. For the food and drink industry anything that involves food contact, to say nothing of actual ingestion, will be subject to a lot of scrutiny for at least the next three years, as regulatory bodies like the Food and Drug Administration get preliminary studies done and rules written."

Global

The International Organization for Standardization[9] has a variety of technical committees and standards such as ISO/TC 223, *Societal security*[10] *and ISO/TC229*[11] *on Nanotechnology, the* ISO 22000 series on food safety management systems,[12] the

---

[7] http://www.fda.gov/nanotechnology/regulation.html

[8] Institute for Food and Agricultural Standards, 2007. An Issues Landscape for Nanotechnology Standards: Report of a Workshop. Cowles House, 11-12 September, 2006. East Lansing, MI: Institute for Food and Agricultural Standards, Michigan State University http://ifas.msu.edu/NSWorkshopReport.pdf

[9] http://www.iso.org/iso/en/aboutiso/introduction/index.html

[10] http://www.iso.org/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeDetailPage.TechnicalCommitteeDetail?COMMID=5366

[11] http://www.iso.org/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeDetailPage.TechnicalCommitteeDetail?COMMID=5932

[12] http://www.iso.ch/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=35466

ISO 14000 [13]environmental management standards the work of ISO/TC 207, *Environmental management*[14] has developed standards for environmental management systems, environmental auditing and performance evaluation, product labeling, life cycle assessment, greenhouse gas reporting and others. It works on International Standard providing guidelines for social responsibility (SR).The guidance standard will be published in 2008 as ISO 26000 [15]
I am not sure whether stakeholders are involved in a broad enough way within ISO, whether NGO stakeholders use the language available in ISO documents which might be useful to themselves in a sufficient way and whether they are even aware enough of ISO and its work.

What's Next:

We haven't even started to address the regulatory issues around Nanotechnology and food and synthetic biology(*8*) is another scientific field developing steam and one can foresee that one will use the field to generate and design organism which might produce food or be involved in agriculture and food production.
Another area which one should monitor is the area of 'in vitro meet where one uses stem cells and other procedures to grow meat. New Harvest is a non-profit organization which has been created in the United States to bring cultivated meat closer to reality.[16] My column covering this topic will come out April 30, 2007.[17]

Conclusion:
Its time that nano and synthetic biology and other techno approaches to food and agriculture applications are covered extensively by a public discourse. Its not enough to focus just on GM.

Further Reading/Resources:

Many articles on nanofood can be found on http://**www.foodnavigator.com** and **http://www.foodproductiondaily.com**

References

1. Wolbring, G, Nanofood, http://www.innovationwatch.com/choiceisyours/choiceisyours.2006.07.31.htm , 2006.,Innovationwatch.com webpage

[13] http://www.iso.org/iso/en/iso9000-14000/index.html
[14] http://www.tc207.org/
[15] http://isotc.iso.org/livelink/livelink/fetch/2000/2122/830949/3934883/3935096/home.html?nodeid=4451259&vernum=0
[16] http://www.new-harvest.org/
[17] In vitro meat live 30 April at http://www.innovationwatch.com/choiceisyours/choiceisyours-2007-0l-30.htm

2. Christoph Lauterwasser. Small sizes that matter: Opportunities and risks of Nanotechnologies , 2006, http://www.oecd.org/dataoecd/4/38/35081968.pdf,

3. Salamanca-Buentello, F., Persad, D. L., Court EB, Martin, D. K., Daar, A. S., and Singer, P. A.Nanotechnology and the developing world (2005) *PLOS Med 2*, 5 e97, http://medicine.plosjournals.org/perlserv?request=get-document&doi=10.1371/journal.pmed.0020097 ,

4. Cientifica. Nanotech and Food - The Real Numbers, 2006, http://www.cientifica.com/blog/mt/2006/08/nanotech_and_food_the_real_num.html, http://www.cientifica.com/www/summarys/Nano4FoodBrochure.pdf ,

5. Kuzma, J and VerHage, P. NANOTECHNOLOGY IN AGRICULTURE AND FOOD PRODUCTION: ANTICIPATED APPLICATIONS, 2006, http://www.nanotechproject.org/file_download/94,

6. Woodrow Wilson International Center for Scholars, Agrifood Nanotechnology Research and Development Database, http://www.nanotechproject.org/50, 2007.,Woodrow Wilson International Center for Scholars

7. Wolbring, G, From Nanotech to Nanoscale Technology and Sciences, http://www.innovationwatch.com/choiceisyours/choiceisyours.2006.07.15.htm , 2006.,The Choice is Yours Column at Innovationwatch.com

8. Wolbring, G, Synthetic Biology 2.0, http://www.innovationwatch.com/choiceisyours/choiceisyours.2006.05.30.htm , 2006.,The Choice is Yours Column at Innovationwatch.com

9. M.Roco, W. B. e. Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science. 2003. http://www.wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf. Kluwer Academic Publishers, Dordrecht Hardbound.

10. Anders Sandberg. Morphological Freedom -- Why We not just Want it, but Need it. 2001. http://www.nada.kth.se/~asa/Texts/MorphologicalFreedom.htm.

11. Wolbring, G., (2003) in *Living with the Genie* (Lightman, A. S. D. D. C., Ed.) pp 139-157, Island Press,

12. Lux Research. The Nanotech Report 2004 (TNR 2004) , 2004, https://www.globalsalespartners.com/lux/# ,

13. Cientifica. Where has the money gone?, 2006, http://www.cientifica.com/www/details.php?id=340,

14. Maclurcan, D.Nanotechnology and Developing Countries, Part 2: What Realities? (2005) *AZoNano - Online Journal of Nanotechnology*, http://www.azonano.com/Details.asp?ArticleID=1429,

15. Vivienne Parry. Food fight on a tiny scale, 2006, http://www.timesonline.co.uk/article/0,,8123-2412344,00.html,

16. Ahmed ElAmin, Scientists research nanotechnology use for chilled, frozen sectors, http://www.foodproductiondaily.com/news/ng.asp?id=69045-nanotechnology-chilled-frozen, 2006.,foodproductiondaily.com

17. staff reporter, Container uses nanoparticles to extend shelf life, http://www.foodproductiondaily-usa.com/news/ng.asp?n=67672-nanotechnology-plastic, 2006.,foodproductiondaily.com

18. UN News Servivce, UN REPORT FINDS SUB-SAHARAN AFRICA IMPROVING ON VITAMIN, MINERAL DEFICIENCIES, http://www.un.org/apps/news/story.asp?NewsID=12171&Cr=vitamin&Cr1=, 2004.,UN News Service

19. UNICEF. VITAMIN AND MINERAL DEFICIENCY in Sub-Saharan Africa, 2004, http://www.unicef.org/media/files/Africa_DAR.pdf ,

20. staff reporter, Germany begins risk survey on nanotechnology, http://www.foodproductiondaily.com/news/ng.asp?n=68637-nanotechnology-risk-germanyPrint, 2006.,foodproductiondaily.com

---

[i] Dr Wolbring is based at the University of Calgary. He is a health researcher, a ability/disability studies scholar, a governance of science and technology researcher, a bioethicist, a science and technology ethicist, , and a biochemist. He is based at the University of Calgary, Faculty of Medicine Calgary, Alberta, Canada; Founding Member and Affiliated Scholar, Center for Nanotechnology and Society at Arizona State University, USA; Part Time Professor, Faculty of Law, University of Ottawa, Canada. His webpage is www.bioethicsanddisability.org/start.hml ; His biweekly column is at http://www.innovationwatch.com/commentary_choiceisyours.htm
His blog Nano, Bio, Info, Cogno, Synthetic bio, NBICS is at http://wolbring.wordpress.com/