Nutritional Outlook October 2006

Nanotechnology Nudges into Nutrition

By: Berna Magnuson, PhD, and George Burdock, PhD

The worldwide nanotechnology food market could reach $20.4 billion by 2010, according to one estimate.

Nanotechnology is moving out of the realm of science fiction and into our buildings, drugs, clothing, cosmetics, and yes, even nudging into our foods, beverages, and dietary supplements. For those of you who are still not really sure what nanotechnology means, the next paragraph will give a short introduction. If you are already "nano-savvy" and just want to know what's "nano-new" in the food and nutrition world, you can skip to the third paragraph.

Nanotechnology can be defined in a variety of ways, but the one common component is that it is technology that deals with materials smaller than 100 nanometers (especially with the manipulation of individual molecules). One definition states that nanotechnology is the art and science of manipulating matter at the nanoscale to create new and unique materials and products. How small is a nanometer? Really, really small—too small to see, even with a light microscope or basic electron microscope. One comparison is that a nanometer is to a meter as the diameter of a dime is to the diameter of the earth. Another is that a nanometer is 1/100,000 the width of a human hair. Nanotechnology has produced a variety of nanomaterials, including nanocomposites used in building materials, nanocrystals used in solar panels and semiconductors, nanoparticles used in stain-repellent clothing and sunscreens, nanotubes used in tennis rackets, and nanocatalysts used in novel drug development.

The rapid development of new nanomaterials and potential applications is at least partially the result of the research support from the National Nanotechnology Initiative (NNI), a federal research and development (R&D) program established to coordinate the multiagency efforts in nanoscale science, engineering, and technology. These nanomaterials are often composed of compounds that have been used for many years, such as carbon, gold, lead, and various other metals. However, once these materials are reduced in size to below 100 nanometers (nm), they begin to display novel characteristics based on the quantum mechanical forces that are exhibited at this level. These quantum mechanical forces may make the material stronger, more conductive, better able to transfer heat, absorb light, have altered solubility properties, etc. The change in properties that occurs with the change in size is creating new potential applications for traditional materials, but also may create new health hazards.

Nanotechnology advocates suggest that nanotechnology will provide the next new wave of food products, with promises of food that can adjust its color, flavor, or nutrient content to accommodate each person's taste or health needs. It offers packaging that can sense when food contents are spoiling and alert consumers. One estimate is that the worldwide nanotechnology food market will be $20.4 billion by 2010, and that five out of 10 of the world's largest food and beverage companies are currently investing in nanotechnology R&D.

To assess the trends in the development of consumer products using nanotechnology, the Woodrow Wilson International Center for Scholars (Washington, DC) has compiled an international inventory of commercially available consumer products. More than 20 food and beverage products in this inventory as consumer products claim to be produced with nanotechnology, including teas, oils, vitamin supplements, and nutraceuticals. Nanotea (a dark green tea grown in a selenium-rich area of Fujian Province in China) relies on nano-pulverization to particulate the tea to a nano-level of fineness. The resulting tea, with its inherent antioxidants and high selenium content, is claimed to be able to "release effectively all the excellent essences of the tea, thus boosting the adsorption (adsorbing viruses, free radicals, cholesterol, and blood fat) and annihilation of viruses through penetration so that a good supplement of selenium can be achieved and the selenium supplement function can be increased by 10 times." Interestingly, even the name of the tea company, Qinhuangdao Taiji Ring Nano-Products Company, Ltd., taps into the nano hot button.

Canola Active oil from Israel claims to utilize a proprietary manufacturing process to prepare nano-sized lipid micelles, termed 'nanodrops.' These lipid micelles have improved solubility and absorption in the gastrointestinal tract and are designed to carry beneficial canola-derived phytosterols. These nanodrops are competitively taken up by the large bile-derived micelles that normally carry cholesterol, thus inhibiting the uptake and transportation of cholesterol from the digestive system. By nano-sizing the phytosterols, there is a fourfold reduction in cholesterol uptake over the use of traditional plant-based sterol esters.

Products produced in the United States include: OilFresh, a catalytic device "powered by nanotechnology" to slow cooking oil deterioration, nanospray vitamin supplements to improve vitamin absorption, and a variety of NanoCeuticals, including Artichoke Nanoclusters. The development of new food and drug products using nanotechnology prompted the formation of an internal FDA Nanotechnology Task Force on August 9, 2006. The new task force is charged with determining regulatory approaches that encourage the continued development of innovative, safe, and effective FDA-regulated products that use nanotechnology materials and processes.

How the application of nanotechnology to nutrients and food compounds will alter their chemical and biological properties is not well known at this time. The ability to alter the solubility of functional lipids is an attractive application, as the poor water solubility of lipids makes them problematic in food formulations. Tan and Nakajima described in a 2005 issue of Food Chemistry the preparation of beta-carotene nanodispersions for improved solubility and bioavailability. However, the beta-carotene in the nanodispersions was chemically unstable, and the authors showed that the degradation was dependent upon the mean particle diameter. Thus a change in size altered the chemical stability. Similarly, a change in size alters the biological properties of materials. Drug companies are doing a great deal of research on the altered properties of nano-sized lipids. Lipid nanoparticles and nanolipid-drug conjugates have improved solubility and absorption rates, due to greater ability to cross membranes or pass through interstitial spaces, resulting in increases in bioavailability from 5 to over 80% in some cases. What are the potential effects of the application of this approach to food components or nutrients? Benefits can be quickly identified—new food formulations, the ability to fortify water-based beverages with functional lipids, the ability to add less of a nutrient to a food to achieve the same level of a biological function, and so on.

The potential downsides are perhaps not so obvious. For example, it is known that some lipid-soluble vitamins are potentially toxic if absorbed rapidly or completely (currently, in some cases only a fraction of the dose is absorbed); therefore, does improving uptake of lipid-soluble vitamins present a potential problem? Will we need new Recommended Dietary Allowances and Upper Limits for nanoformulations of vitamins and minerals, because so much more is absorbed? How does this affect labeling? Will we need new Percent Daily Values on food labels for nanonutrients versus conventionally delivered nutrients?

In addition to absorption, it is possible that nano-sized materials will have altered distribution, metabolism, and excretion properties, all of which may also alter functionality and even inherent toxicity of a substance. For example, if the toxicity of a substance is dependent on physical contact with a cell, what happens when particle diameters are reduced to 10 nm or less, and when the surface area is exponentially increased compared with an equal mass of the same substance at micro dimensions? Paracelsus, the world's first toxicologist, concluded that "the dose makes the poison," which has served the toxicology community for centuries. But now, that might have to be changed to, "the dose, as a function of the surface area, makes the poison." Thus a new field of science is emerging along with nanotechnology—the field of nanotoxicology.

In a recent report, the lack of research on the safety of oral exposure of nanotechnology-derived materials was clearly demonstrated. It is of utmost importance that the food and nutrition professions begin to investigate the possible adverse effects of exposure to nanoparticles incorporated in food and nutritional products before they arrive on the market shelves. There is tremendous promise for this new technology to solve many health problems and improve the disease-preventive activity of food compounds, but this must not blind us to the potential for harm as well. Public trust is fragile, easily broken with news of an adverse event, and very difficult to rebuild. Now is the time, while product development is still under way, for product safety evaluation and for documentation of that evaluation to be initiated. Nanotoxicology needs to nudge into nutrition as quickly as nanotechnology is, to ensure the application of this technology into nutritional applications is safe, beneficial, and accepted by consumers.

George A. Burdock, PhD, is a principal in the toxicology consulting firm of the Burdock Group (Vero Beach, FL; and Washington, DC). Dr. Burdock is an internationally recognized authority on the safety of food ingredients, personal care products, and dietary supplements, and has more than 20 years of experience dealing with regulatory issues related to product safety and risk assessment.

Bernadene Magnuson, PhD, has expertise in evaluation of food compounds for cancer prevention and efficacy data for dietary health claims. Dr. Magnuson holds degrees in food science, nutrition, and toxicology, and has worked in the food industry and academia. As part of the Burdock Group scientific team, she reviews toxicology and safety data on natural and synthetic food compounds, dietary supplements, and food contaminants.