FAPC-139

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Nanotechnology and Opportunities for Agriculture and Food Systems

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Nanotechnology has emerged as one of the most innovative scientific fields in decades. Nanotechnology involves use of materials on an extremely small scale, usually 0.1 to 200 nanometers. One nanometer is equal to one thousandth of a micrometer or one millionth of a millimeter. For comparison, a living cell has dimensions of microns (thousands of nanometers). Nanotechnology allows scientists to create materials and structures at the molecular level. The National Nanotechnology Initiative (NNI), was formed in 2000 and involves 17 federal departments and agencies. The U.S. Department of Agriculture, a partner agency in the Federal NNI held a national planning workshop, "Nanoscale Science and Engineering for Agriculture and Food Systems", in Washington, D.C. on Nov. 18-19, 2002. Leading nanotechnology researchers and administrators from Land Grant Universities and nanotechnology program leaders from other federal agencies were among the participants of this workshop. The objective of the workshop was to identify nanotechnology opportunities with the potential to revolutionize agriculture and food systems and to develop a strategic plan with recommendations for implementation of a new program in nanotechnologies within the USDA. Nucleic acid bioengineering, smart treatment delivery systems, nanobioprocessing, bioanalytical nanosensors, nanomaterials and bioselective surfaces were identified as some of the potential research areas that would have a significant impact on agriculture. In 2003, USDA created a new program, "Nanoscale Science and Engineering for Agriculture and Food Systems," under the National Research Initiative Program (NRI). Since then, a number of research proposals relevant to agriculture and food systems have been funded by the NRI program.

The food industry also is very interested in nanotechnology. In 2000, Kraft Foods, with headquarters in Chicago, Ill., began sponsoring the NanoteK Consortium. The members of the Consortium include researchers from 15 universities, three national labs and three start-up companies. Harvard University, the University of Nebraska, the University of Connecticut, Los Alamos and Argonne National Laboratories, the Universities of Seville and Malaga in Spain and Uppsala University in Sweden are some of the institutions involved in this collaboration. Some of the research areas identified by the consortium members are development of low cost sensors that detect the presence of foodborne pathogens, filters for removing undesirable compounds from foods and beverages and nanoparticles to store flavors and nutrients inside food and release them at designated organs in the body when they are needed. Nestle's research center in Switzerland assigned a group of scientists to investigate the potential benefits of nanotechnology for food systems. The European Union (EU) is coordinating a research program, EU Nanoforum, so that food companies can take rapid advantage of new developments. The Nanoforum brings together existing national and regional networks and shares information on how researchers and businesses can access national, EU-wide and venture capital funding to boost nanotechnology. The latest annual report from the EU Nanoforum indicates that Greece, Ireland and Netherlands are leading the research efforts that could eventually be of commercial use to the food processors in Europe. NanoNed is a program that is supported by the Dutch government and covers investments in experimental facilities. This program includes a virtual laboratory called "Nanolab," consisting

of the existing nanotechnology research infrastructure in Groningen (BioMade and MSC-plus at the University of Groningen), and Twente (MESA and University of Twente research center). The Danish-Swedish dairy group Arla Foods, Danish sugar and food ingredients group Danisco, Danish meat producers Danish Crown, Danish vegetable oils and specialty fats producer Aarhus United and several academic institutions in the Aarhus region of Denmark also formed an alliance to establish a center called Nanofood Consortium with the objective of developing healthier, safer and more nutritious food products.

Nanotechnology has the potential to improve food quality and safety significantly. Currently a lot of work is being carried out on nanosensors targeting improved pathogen detection in food systems. Many electronic companies have been investigating electrically conducting polymers. These same materials can also be used to manufacture sensors that can detect very low levels of molecular signals of spoilage and foodborne pathogens within minutes of exposure. Scientists at the Kopelman Laboratory at the University of Michigan are working on non-invasive bioanalytical nanosensors that could perhaps placed in an animal's (i.e. cow's) saliva gland to detect a single virus before it has had a chance to multiply and develop disease symptoms. Researchers at the University of Connecticut are working on an "electronic tongue" that detects minute amounts of a huge range of chemicals. This sensor uses tiny electrodes coated with a conductive polymer. According to the researchers involved in the project, this device can detect parts per trillion and costs about 50 cents to produce. It is also expected that the tongue technology could potentially be incorporated into food packages, such as meat wrappings, and would change color when the meat starting to spoil. According to nutraingredients.com, scientists at the University of Bonn in Germany are working on nanoscale level dirt-repellent coatings. This concept could have important applications at food production sites, in particular abattoirs and meat processing plants. Nanoscale monitors could be linked to recording and tracking devices to monitor temperature changes and detect pesticides and genetically modified crops within the food system. It is expected that such machines/sensors will appear on production lines within four years.

A recent study from Helmut Kaiser Consultancy, which looked into nanotechnology in the food industry, estimates that nanofood market will expand from $2.6 billion to $20.4 billion by 2010. According to the same source, worldwide sales of nanotechnology products to the food and beverage packaging sector jumped to $860 million in 2004 from $150 million in 2002. It is believed that about 200 companies around the world are active in research and development in nanotechnology. It is expected that nanotechnology is going to change the whole packaging industry. Nanotechnology enables designers to alter the structure of packaging materials at the molecular level. For example, plastics can be manufactured with different nanostructures to gain various gas and moisture permeabilities to fit the requirements of specific products such as fruits, vegetables, beverage and wine. As a result, shelf-life and flavor and color preservation of the products can be improved. Nanostructured films and packaging materials can prevent the invasion of pathogens and other microorganisms and ensure food safety. Nanosensors embedded in food packages will allow the determination of whether food has gone bad or show its nutrient content. By adding certain nanoparticles into packaging material and bottles, food packages can be made more light- and fire-resistant, with stronger mechanical and thermal performance and controlled gas absorption.

Nanotechnology is still an emerging technology. Experiences from the genetically modified organism debate clearly indicate that public support and consumer acceptance of this technology will depend on the behavior of institutions responsible for development and regulation of technological innovations and risk assessment. One way to secure public support for this technology is to dedicate resources to further research on widely shared goals, such as clean and renewable energy and public health intervention to ensure development of healthy and nutritious foods and crops. Distribution of expertise and benefits and availability of choices worldwide would help public acceptance of the technical innovations derived from nanotechnology and nanoscience. Currently, there are a number of on-going studies that attempt to detail, analyze and assess the potential problems and benefits, pitfalls and known and unknown issues related to developments in nanoscience and technology. However, health, environmental and workers health risk analyses, and a regulatory framework for nanotechnology and nanoscience are some of the issues that have to be addressed as the technology matures.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Robert E. Whitson, Director of Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Dean of the Division of Agricultural Sciences and Natural Resources and has been prepared and distributed at a cost of 74 cents per copy. 0710