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Analysis of Early Stage Agrifood Nanotechnology Research and Development

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Project on
Emerging Nanotechnologies
at the Woodrow Wilson International Center for Scholars

The **Project on Emerging Nanotechnologies** is an initiative launched by the Wilson Center and The Pew Charitable Trusts in 2005. It is dedicated to helping business, government and the public anticipate and manage possible health and environmental implications of nanotechnology.

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Introduction

Nanotechnology has the potential to revolutionize agricultural and food (agrifood) production. Potential applications of the technology include controlled, nutraceutical delivery systems for food; on-farm applications to deliver drugs or pesticides to livestock or crops; and smart-sensing devices for agriculture-environment interactions. The most prominent agrifood nanoproducts currently on the U.S. market are nanocomposites for food packaging. These nanomaterials provide barriers to oxygen and carbon dioxide, thus protecting food quality.[1]

A recent report by Helmut Kaiser Consultancy indicates that worldwide sales of nanotechnology products to the food and beverage packaging sector were US$860 million in 2004, up significantly from US$150 million in 2002.[2] Products for nutraceutical delivery in foods are on the market in other countries.[3] Five out of ten of the world's largest food and beverage companies invest in some form of nanotechnology research. For example, Kraft Foods funds research at several universities and national labs through its "NanoteK" consortium.[4] Despite the attention to agrifood nanotechnology in industry, there have been few, if any, systematic publicly-available evaluations of research and development (R&D) in this area, and the field of agrifood nanotechnology remains largely unexplored in the public domain.

Nevertheless, the public is aware of the potential for improving food via nanotechnology. One study designed to investigate the public perceptions of nanotechnology found that 6% of respondents listed "safer and better food" as one of the main expected benefits from the technology. This benefit was the 5th most cited. However, a similar degree of concern was also raised, as 7% of respondents cited worries associated with "nanotechnology's use in food products, packaging, and agriculture."[5] This concern was the 6th most cited.

We created a new, publicly accessible of largely U.S. government-funded research projects in agrifood nanotechnology. This inventory is important for many reasons, including public access to information about this emerging area and future, in-depth work

[1] For example, nanoclays dispersed in polymer matricies, such as Nanomer® nanoclays produced by Nanocor®

[2] The webpage for the Helmut Kaiser report (http://www.hkc22.com/nanofood.html) also states that "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 2.6 bn. US dollars today 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."

[3] For example, Canola Active, a cooking oil that contains nano-sized self assembled structured liquids (NSSL) of approximately 30 nm to disperse phytosterols is on the market in Israel. See http://www.shemen.co.il/english/nutrition-health.html.

[4] Gardener, E. "Brainy Food: Academe, Industry Sink Their Teeth into Edible Nano." *Small Times*, June 21, 2002 http://www.smalltimes.com/document_display.cfm?document_id=3989&keyword=brainy%20and%20food&summary=1&startsum=1.

[5] Jane Macoubrie. *Informed Public Perceptions and Trust in Government*. Washington, DC: Woodrow Wilson International Center for Scholars, 2005, p. 9 and 11.

on risk and benefit issues surrounding it.[6] It is also important to explore oversight systems for agrifood nanotechnology before numerous applications enter the marketplace, especially given past and present controversies over technology in agriculture and food, such as the use of genetically engineered organisms.

Agricultural and food applications of new technologies pose a unique set of challenges. Individual benefits are often not as clear as those related to the use of technology in human medicine, and risks are often posed to sectors of society that do not directly benefit from the technology. Yet, societal benefits, for example through safer and more sustainable food production, could be great. This inventory takes a first step towards assessing the landscape of agrifood nanotechnology and the potential health and environmental risks and benefits of its products.

Projects in the database largely represent government-funded research, with the additional category of projects for which patents have been obtained. In the database, projects were categorized with respect to types of research (basic, applied, or development); projected time to commercialization; techniques, topics, and research areas, as specified in a USDA report on agrifood nanotechnology[7]; sectors in the food supply chain; and their fit to well-accepted definitions of nanotechnology. Four databases (USDA-CRIS, PTO, EPA-Science Inventory, NSF Awards) and five government websites (NIH, DOD, DOE, DHS, FDA) were searched for projects active during the years 2000 through 2005.

We welcome feedback on the database-- please send comments, changes, or additional entries to us.[8] We do not view this version of the database as complete or the end of this project. Rather, it is a start to evaluating activities in agrifood nanotechnology in the public domain, and it will continue to benefit from outside input and contributions.

This paper outlines the results of the database, definitions for categorization, and the methodology for searches, and criteria for preliminary safety evaluations.[9] It does not include our preliminary analysis of potential exposure endpoints and health and environmental risks and benefits, although the database does contain this information for each individual project. The results of a qualitative risk-benefit ranking will be submitted for publication elsewhere in the near future.[10]

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[6] This work is supported in part by the Consortium on Law and Values in Health, Environment, and the Life Sciences at the University of Minnesota. It is described in a subsequent section of the paper.

[7] *Nanoscale Science and Engineering for Agriculture and Food Systems,* USDA 2003. In this report, there is a matrix that includes thematic research and development topics such as environmental processing, pathogen detection, plant/animal transgenics/cloning, bioprocessing foods/industrial products, and sustainable agriculture on one axis, and nano-techniques such as transport processes, bio-selective surfaces, bioseparation, micro-fluidics, nano-bioprocessing, nucleic acid engineering, drug delivery, and modeling on the other. There are also eight broad categories of research: detection, identity preservation and tracking, smart treatment delivery systems, smart systems integration for agriculture and food processing, nanodevices for molecular and cellular biology, nanoscale materials science and engineering, environmental issues and agricultural waste, and education of the public.

[8] Please send edits, suggestions, or additional information to Prof. Jennifer Kuzma, jkuzma@hhh.umn.edu.

[9] Methodology, criteria, and definitions are listed in the final, “Methods”, section of the report.

[10] The PIs plan to refine the analysis and submit it to a peer-reviewed journal.

Results and Conclusions

As of March 30, 2006, One hundred and sixty projects were included in the database. Fourteen of these projects have questionable connections to agriculture, food, and/or nanotechnology (as noted in the database entries). We erred on the side of inclusiveness and decided to keep them in this first version of the inventory. Figures 1-3 display the number of projects that fell into each technique, topic, or USDA research category. Bioselective surfaces and nano-bio processing contained the most projects for techniques; biosensors and food bioprocessing contained the most projects for topics; and pathogen and contaminant detection and nanoscale materials science and engineering contained the most projects for USDA research categories. These results are consistent with the high number of nanotechnology projects focused on food packaging and sensing for foodborne pathogens during processing. Very few projects were found which addressed USDA research categories of identity preservation/tracking and education/workforce. The USDA research category of environmental issues/agriculture waste is well-represented given the number of products that focus on harvesting industrial nanomaterials from biomass.

Figure 1. Techniques Used in Agrifood Nanotechnology Projects

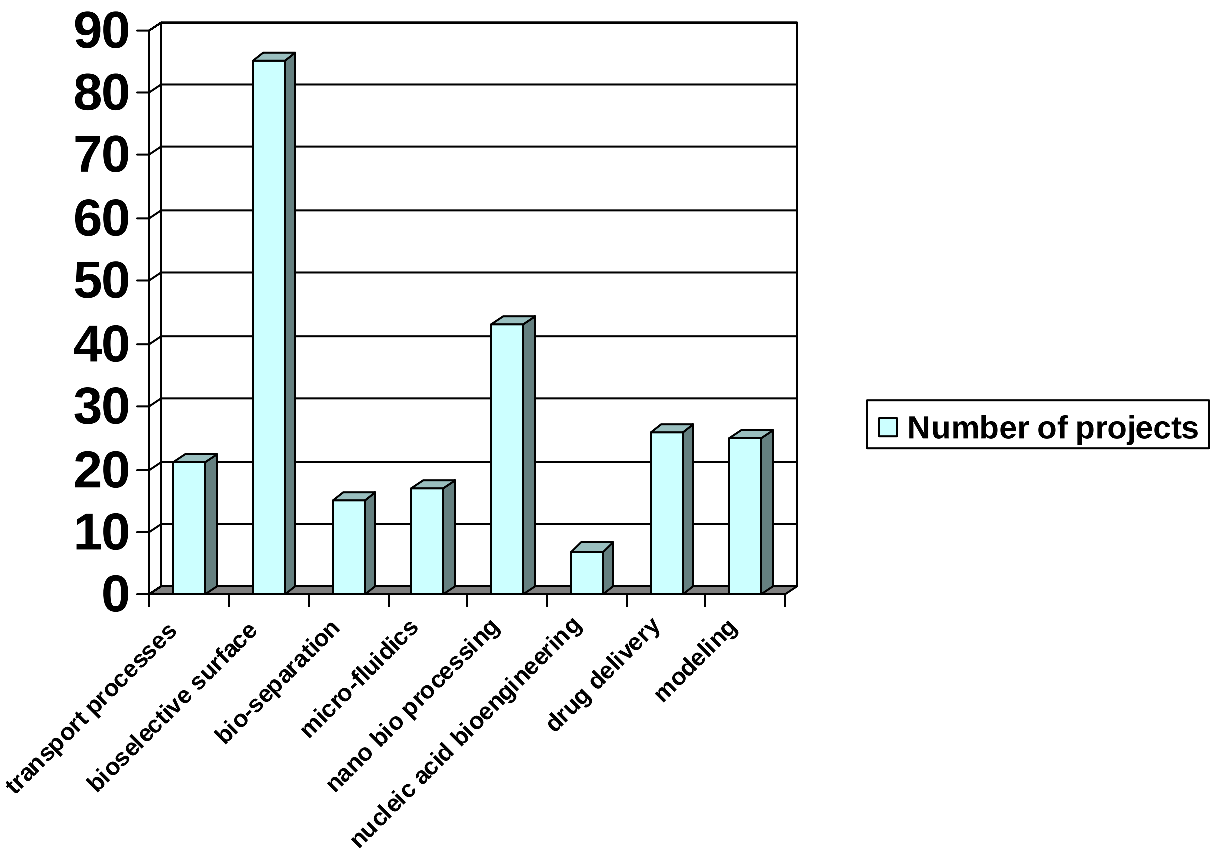


Figure 2. Topics Addressed in Agrifood Nanotechnology Projects

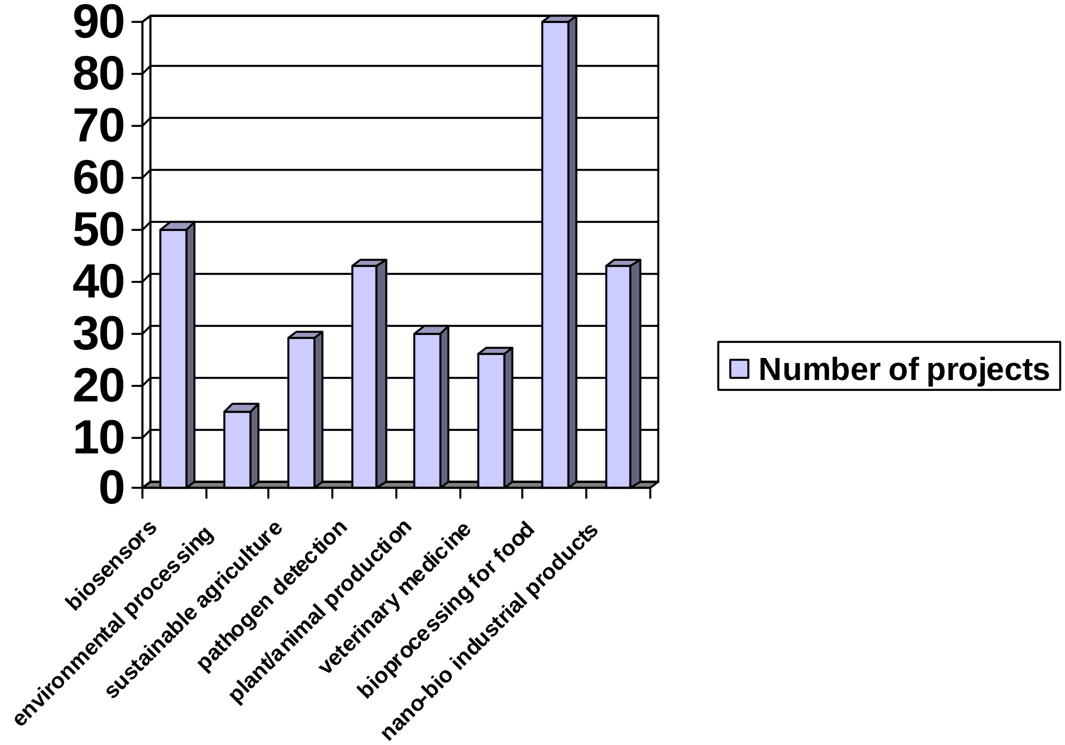
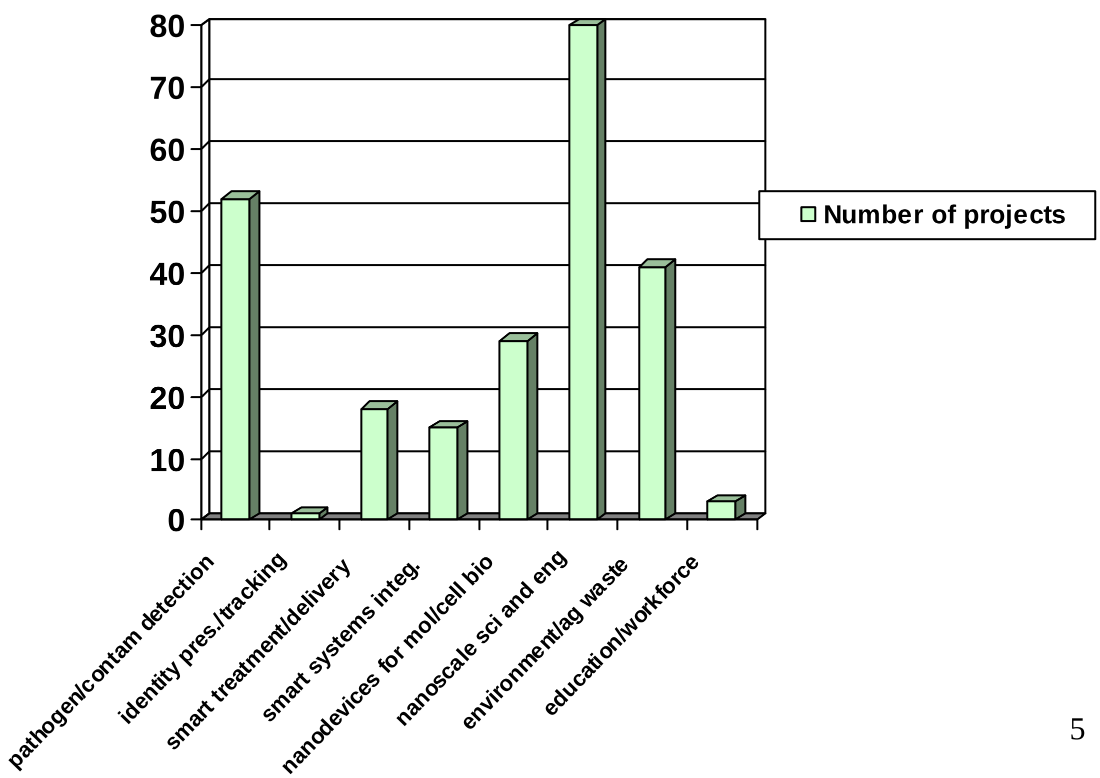


Figure 3. USDA Research Areas for Agrifood Nanotechnology Projects



Figures 4-5 give an indication of the commercialization timeframe for the projects. Most projects fell into the "applied research" category (55%) and were estimated to be commercialized in 5-15 years. The vast majority of the "development" and "0-5 years" entries came from the PTO database. Likewise, the majority of projects fell into post-harvest (47%), retail (27%) or consumer applications (39%) (Figure 6). This again reflects an emphasis on projects related to food packaging and pathogen/contaminant detection during food processing.

Figure 4. Type of Research in Agrifood Nanotechnology

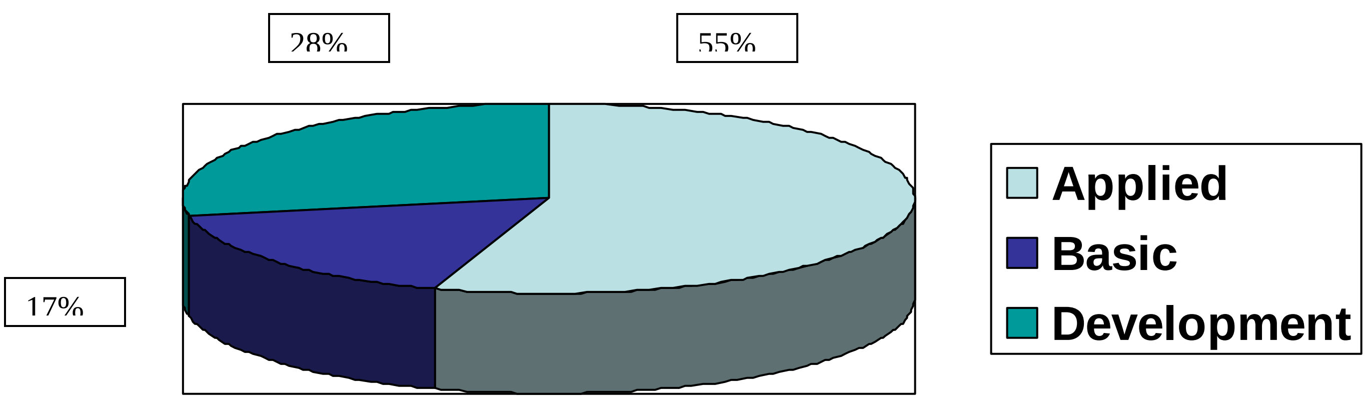


Figure 5. Estimated Time to Commercialization

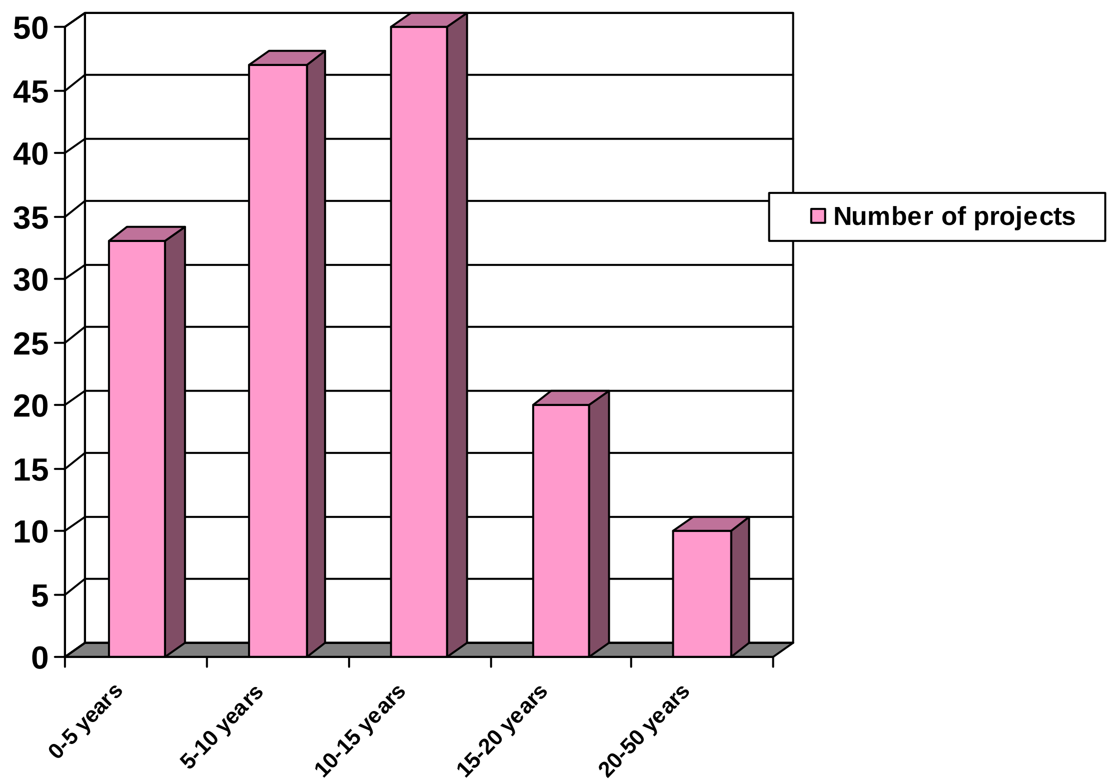
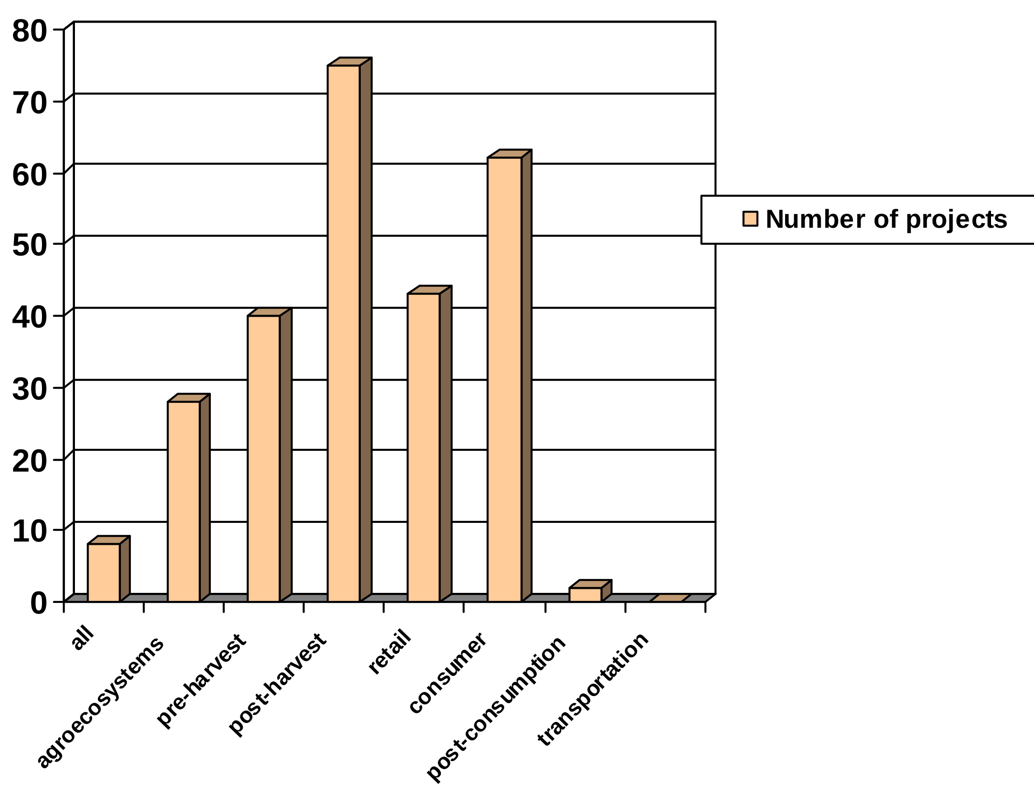
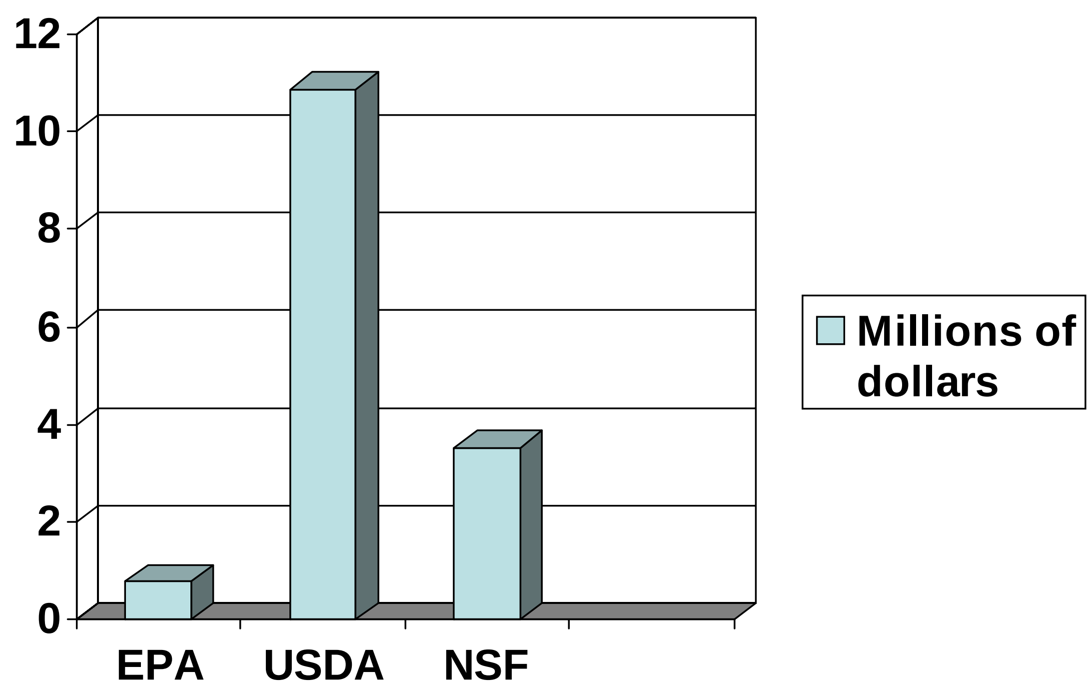


Figure 6. Sector of Food Supply Chain



In Figure 7, the amount of USDA ($10.9M), EPA ($0.78M), and NSF ($3.5M) extramural funding in agrifood nanotechnology from 2000 to fall 2005 is depicted. The total amount of extramural funding for projects in this database across all three agencies is $15.2M. Funding levels were not available for several projects, including some from the USDA-CRIS database. Furthermore, projects at these agencies may have been entirely missed. So, the numbers likely are underestimates of investments in nanotechnology at USDA, NSF, and EPA. Other agency and departmental funding is not shown, as this information was not available from the searches.

Figure 7. Funding from 2000 to 2005 at EPA, USDA, and NSF



Current and Future Work

Using this database, we have selected a draft set of case studies for subsequent risk-benefit and governance analyses. Case studies span a range of topics, research areas and techniques, timeframes, sectors, and endpoints. They also span a range of safety issues. Other selection criteria include:

- Likelihood of entering the marketplace in the near future;
- Availability of data and information on the case;
- Reflection of larger social or economic issues; and
- Magnitude of possible benefits.

We are currently gathering information on the draft set of case studies in order to better identify and categorize the potential human health and environmental risks and benefits. We will largely focus on the scientific and technical risk/benefit issues (e.g. human and environmental health), although socioeconomic issues that overlap with these will not be excluded. Case studies will eventually be used to consider the following questions:

- Are there current regulatory or non-regulatory governance systems that cover the proposed applications or products? If so, what are they?
- Do these systems address the risk and benefit issues? If so, how? If not, what are the gaps?
- What are other strengths and weaknesses of existing systems?
- If there are no current systems in place for the products or the issues, what are the possibilities under existing legal or organizational frameworks?

This analysis is similar to one done on the products of biotechnology (genetically engineered organisms) by OSTP/CEQ in 2000.[11] The OSTP/CEQ analysis will be used as a guide. Our analysis will strive to be specific as to how governance systems cover the health and environmental safety issues of emerging agrifood nanotechnology products.

[11] See CEQ/OSTP Assessment: Case Studies of Environmental Regulation for Biotechnology http://www.ostp.gov/html/012201.html.

Methodology

1) Categories for Entries

***Type of Research*:**

Development—specific product cited, largely experiments or studies to optimize product

Applied—specific application noted, but may also lead to better understanding

Basic—fundamental understanding is goal, specific application not stated (although there could be one in the future)

Time to Commercialization:

0-5 years –applied/development projects which directly address regulatory or product optimization issues. The applications of the work appear to be very near- term with minimal regulatory concerns, or they are already in the marketplace and properties are being studied or optimized.

5-10 years –applied/development research that is based upon proven technology and for which there are not serious safety concerns

10-15 years—applied research that is in the early stages of concept or development

15-20 years—applied/basic research for which applications are not specified, but they can be envisioned.

20-50 years—basic research for which few, if any, applications are envisioned, but for which fundamental knowledge will eventually lead to some.

Techniques:

More than one technique might be utilized in a given project (multiple boxes might be checked):

Transport processes—nanomaterials as agents for transporting chemicals, molecules, etc.

Bio-selective surfaces—nanomaterials with enhanced or reduced ability to bind or hold specific molecules and/or organisms.

Bio-separation—nano-materials or -processes with ability to separate molecules, biomolecules, or organisms.

Microfluidics/MEMs—liquid streams used to separate, control, or analyze at the nanoscale. They might have special flow properties at this scale.

Microelectromechanical systems (MEMs) are also included here. They are devices with channels and wells, electrodes for detection, connectors, and fluidic input/output ports.

Nano-bioprocessing—use of nanoscale technology and/or biological processes to create a desired compound or material from a defined stock. The product itself may be bulk or nanoscale.

Nucleic acid bioengineering—use of DNA as building blocks to form nano-particles or use of nano-particles for genetic engineering.

Drug delivery—use of nanoparticles or nanomethods to deliver drugs to animals.

Modeling—use of nanotechnology to build models of systems, or the modeling of nanoparticles in systems.

Topics:

The project might fit more than one topic (multiple boxes might be checked):

Biosensors—use of nanotechnology for sensors based upon biological processes or biological molecules, or for detection of biological molecules, processes, or organisms.

Environmental processing—use of nanotechnology for studying environmental phenomena, removing contaminants in the environment, or remediating/reducing waste. Study of nanomaterials in the environment too.

Sustainable agriculture—use of nanotechnology for reducing agricultural inputs or outputs that can harm the environment or human health (e.g. pesticides) or are in short supply (e.g. water); or for making products from agriculture in a sustainable way.

Pathogen detection—use of nanotechnology to detect pathogens in surroundings, organisms or food.

Plant/Animal Production—use of nanotechnology to improve the cultivation of plants or animals, including via transgenics or cloning.

Veterinary medicine[12]—use of nanotechnology to improve animal health and/or the safety of animal derived foods.

Bioprocessing for food—use of nanotechnology for better food processing or quality.

Nano-bioindustrial products—use of nanotechnology for developing industrial products from agriculture or its by-products.

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[12] This category was added by the investigators. Not in USDA Nanoscale Science and Engineering 2003 Report.

USDA Research Areas:

The project might fit more than one topic (multiple boxes might be checked), involving nanotechnology in the following ways:

Pathogen and Contaminant Detection—pathogen or contaminant detection in agriculture, food, or the environment.

Identity Preservation and Tracking—systems that provide producers, processors, and customers with information about the practices and activities used to produce a particular crop or agricultural product. Also, provide information on the origin and movement of crops, animals, or products.

Smart Treatment Delivery Systems—delivery of molecules in agricultural production or processing in time-controlled, spatially targeted, regulated, responsive, or other precise ways. Also, systems could have the ability to monitor effects of delivery.

Smart System Integration for Agriculture and Food Processing—integration of a working system with sensing, reporting, localization, and control. System could be used anywhere along farm to table continuum, or at multiple points.

Nanodevices for Molecular and Cell Biology—devices based on or applied to molecular and cellular biology that separate, identify, study, modify, or sense.

Nanoscale Materials Science and Engineering—development of novel materials through materials science and engineering. Work to better understand the behavior and properties of nanomaterials.

Environmental Issues and Agricultural Waste—study of nanoparticles in the environment, such as in the transport and bioavailability of nutrients and pollutants. Understand transport and toxicity of nanoparticles in agricultural pollutants. Nanotechnology applied to environmental or waste issues.

Educating the Public and Future Workforce—education about nanotechnology and nanoproducts; studies on ethical and social issues (cited in USDA report, although not reflected in USDA's short title of this research area); infrastructure support; technology transfer support; public understanding of risks and benefits.

Sectors:

The work or research could be applied to more than one sector (multiple areas might be listed in the database):

Agroecosystems—application for or research on agricultural systems, and/or on surrounding natural systems.

Pre-harvest—application or research on the farm or in the forest, during agricultural production.

Transportation—application or research dealing with transporting agricultural or forest raw commodities or products from the farm to the processor or retailer.

Post-harvest—research or application after harvest, at the stage of processing the commodity or product

Retail—research or application dealing with storage, display, etc. at the place where the product is sold.

Consumer—research or application dealing with the consumer end, such as storage and use of agricultural products in the home. Also, this category is used for research which primarily improves the quality of the end product (e.g. better taste).

Post-consumption—research or applications for after the product is consumed. For example, for food safety illness detection.

Exposure Endpoints:

Boxes are checked if there is exposure to the following (multiple boxes might be checked):

Lab workers—most nanomaterial or particles are made or studied in the lab at some point. In most cases, lab workers will be exposed. The study of naturally-occurring nanoparticles would be a case in which this box would not be checked.

Farmers—farmers are exposed if the nanomaterial, particle, or method is being used on the farm.

Ecosystems—ecosystems are exposed if the nanomaterial is used 1) on the farm (animals and plants on the farm, or the farm agroecosystem) or 2) for wide environmental applications, or 3) if it is not disposed of properly. We assume that material used in manufacturing or the lab is disposed of properly. So, if this box is checked, it is because the material is intended at some point for environmental release.

Industry Workers—industry workers will be exposed during production, manufacture, transport, processing, or at the retail/distribution stage.

Consumers—if consumers will likely come in contact with the material, this box is checked. The applications are either intended for consumer products or are left in the material as a result of production or processing.

Others—in some cases, there might be sub-populations that are specifically exposed as a result of the application or research.

Unknown—this box is checked when the description of the project is too vague, or the applications are too broad to determine who will be exposed.

Known Toxicity Records:

No—we could not easily (via quick web search for articles) find toxicology studies on the nanoparticles or nanomaterials cited in the project description. Or the particular particles or materials are not specified in the project description.

Yes, benign—we found studies which indicate low toxicity, or hypothesize that the particles are generally non-toxic (e.g. DNA). However, please note that toxicity is still dependent on the system tested in those studies (*in vivo, in vitro,* acellular endpoints), the form of the particle, and the amounts.

Yes, toxic—we found studies which indicate that the nanoparticles or materials are harmful to health and/or the environment, or the class of compounds is generally known to be toxic.

Environmental/Ecological Risks or Health Risks

This is just a first pass, qualitative ranking. More information is needed on virtually all of these projects for better qualitative or quantitative risk assessment.

Low
If exposure to humans, animals or the environment is minimal and the particles are generally non-toxic, we categorize the risk as low.

Medium
If exposure to humans, animals or the environment is minimal OR the particles are generally not-toxic we categorize risk as medium. In this category, there are relatively benign particles that are widely used in food and agriculture. Likewise, a toxic particle that is meant to stay in the lab or processing plant could also be in this category. In the cases of nanotechnology applied to biobased products, "medium" was used for environmental or ecological risks with the question of whether harvesting and processing are done in a sustainable way (i.e. life cycle issues).

High
Exposure to humans, animals or the environment is widespread and particles show toxicity or are expected to be toxic.

Environmental/Ecological or Health Benefits

This is just a first pass, qualitative ranking. More information is needed on virtually all of these projects for benefits assessment.

Low
Application or research not meant to improve human or animal health, or the environment.

Medium
Application or research might improve health, or the environment, but not explicitly developed for that purpose or for addressing a great societal problem.

High
Application or research specifically developed to address an important societal need for improving health or the environment.

Does this fit nanotech?[13]

After reading the project abstract, objectives, and additional information, we are using the three criteria of the NNI definition to determine whether the project fits the definition of nanotechnology. If so, the box is checked. In some cases, there is not enough information to determine, and we note this in the comment box.

Does this fit agrifood?

Nanotechnology should be applied to or used to study agriculture, food, forestry, or agroecosystems for this box to be checked. Sometimes the project description is vague, or the work is broad to determine whether it fits. This is noted in the comment box.

2) Search Process

USDA CRIS Database:
We searched the USDA CRIS database using the following keywords: nano + food, or nano + agriculture. Projects were limited to those active after 2000. The search was completed on August 15, 2005. The text of each project was then searched for the words nano and food or agriculture to exclude false leads as artifacts of the search terms. Initial results included many projects that did not fit agrifood nanotechnology, such as those containing the terms NaNO (sodium nitrite) or the use of measurements at the nanoscale (nanometers, nanoliters, etc.). To be included in the survey, the project must have utilized

[13] The National Nanotechnology Initiative lists the following three criteria for defining nanotechnology: 1) research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1 - 100 nanometer range, 2)creating and using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size, and 3) ability to control or manipulate on the atomic scale.

or created materials on the nano-scale. The project must also have pertained to either food or agriculture production, or agroecosystems. Once a project was deemed relevant, the project information was placed into the database. There were a total of 90 projects included from the CRIS database search. Although forestry projects arose, this was not used as a search term, so other projects funded by the USDA in this area may exist.

Patent and Trademark Office:

To search the PTO database of patent applications, we used the same keywords as in the case of the CRIS database search, as well as similar criteria for selecting appropriate projects. The key words used in the search were nano + (food or agriculture), and a cut-off date of December 1, 1999 for filed patents was used. Over 600 projects contained the search terms. About 40 of them fit our definition of nanotechnology and agrifood. When there was question as to whether a project fits, we erred on the side of including it. Due to differences in how the data is presented in each patent application and the length of the patent applications, the description given in the application was paraphrased and placed in the "objective" or "additional information" sections of the database. The search was concluded on October 14, 2005.

NSF:

The NSF website "Awards" page was searched using the following terms: "nano food" (35 projects) or "nano agriculture" (15 projects). When "nano agricultural" was substituted for "nano agriculture" the same 15 projects appeared. The search was conducted on 11/11/05. Projects were then scrutinized for their fit to our definition of nanotechnology and agriculture and food.

EPA:

The National Center for Environmental Research's webpage was searched http://es.epa.gov/ncer/ru/index.html) using the keyword "nano." Thirteen projects were found and each abstract was read to see if the work is applicable to agriculture and food. None contained the keywords "agriculture" or "food". However, one had "soil" as a keyword, and this was included in the database. The Science Inventory (SI), a searchable database of EPA science activities and scientific/technical work products, was searched using the term "nanotechnology." (http://cfpub.epa.gov/si/). All "Record Type" boxes were selected for the search, so the projects resulted from Archived and full EIMS searches. The SI provides information about current or recently completed activities, providing a snapshot of EPA science being conducted in its research laboratories and centers, program and regional offices, and through grants and other assistance agreements to universities and other institutions. Four entries arose from the search. One contained the keyword "soil" and this was included in the database. When the search term "nano" was used, 21 entries arose. None were found to be directly related to agriculture or food. Drinking water projects that were found were not included in the database. Searches were conducted in December 2005.

NIH:

The NIH website was searched for "nanotechnology" and the page NIH Nanotechnology and Nanoscience Information (http://www.becon2.nih.gov/nano.htm) came up. Each of

the links on this page was scanned for NIH funded research in agrifood nanotechnology. The Nanomedicine funded research site, http://nihroadmap.nih.gov/nanomedicine/fundedresearch.asp, was searched and no projects mentioning food or agriculture were found (although the basic science might be applicable to food and agriculture in several projects).
The Summary of Funded NIH Bioengineering Nanotechnology Initiative (SBIR) Grants for FY 2000 to 2004 were searched for the keywords food or agriculture. Each FY was searched for "food" or "agriculture". Five projects were found to contain these keywords and they were added to the database. Searches were conducted in December 2005.

DOE:
The Department of Energy's Office site was searched for nanotechnology. The Department of Energy's Office of Science supports nanotechnology through its Materials Sciences subprogram. The Materials Sciences subprogram was searched under "Research Programs."
(http://www.science.doe.gov/bes/dms/Research_Programs/research_program.htm)
Summaries of research in the National DOE labs were listed on this page. Each summary was searched for "food" or "agriculture" or "agri." No projects with these search terms were found. The DOE Basic Energy Sciences site was searched, which led to the DOE Nanoscale Science Research Centers page http://www.science.doe.gov/Sub/Newsroom/News_Releases/DOE-SC/2006/nano/index.htm. When possible, center websites were searched for "food" or "agri." Most centers did not have searchable features on their sites. The document "Nanoscale Science, Engineering, and Technology in the DOE" http://www.sc.doe.gov/bes/brochures/files/NSRC_brochure.pdf was also searched. In this case, "agriculture" was found, but only in the general statement in the document that nanoscale applications could have benefits to agriculture. Searches were conducted in December 2005. No projects from DOE were added to the database.

DHS:
Department of Homeland Security website was searched for "nano." Two items were retrieved. Neither mentioned specific research projects in agriculture or food nanotechnology. The National Plan for R&D in Support of Critical Infrastructure Protection mentioned nanotechnology, and food/agricultural safety and security were mentioned separately in the document. Searches were conducted in December 2005. No projects from DHS were added to the database.

DOD:
Nanotechnology research awards at DOD were searched http://www.defenselink.mil/releases/2001/b02232001_bt079-01.html.
None contained the keywords "food" or "agri" in the title. The naval nanotechnology site http://www.nanosra.nrl.navy.mil/, was also searched for "food" and "agri". No specific research projects on agrifood nanotechnology were found. Searches were conducted in December 2005.

FDA:

FDA's website was searched using the term "nanotechnology," which led to the page http://www.fda.gov/nanotechnology/ When the site was searched for "nanotechnology research," several powerpoint presentations came up indicating that FDA does research in this area through its centers. The content of these presentations was reviewed. Research projects at FDA seem to focus on biological effects of nanomaterials and nanoparticles. No specific projects were found which focused on research and development in agrifood nanotechnology. Some of the general toxicity research will apply to agrifood nanotechnology products, however. Searches were conducted in December 2005.

3) PI Review and Validation of the Entries

The majority of primary investigators (n=121, those for whom we could find contact information) were sent entries for their projects and the definitions of the categories (Section 1 of this Methods Section). They were asked to review the classification of their research and make additions or corrections. We received seventeen responses (14% response rate), and of these, 11 completely agreed with the categorization. Others asked for minor adjustments to their entries. In one case, the time to commercialization was decreased from 10-15 years to 3-5 years. In 3 cases, additional categories of techniques, topics, or research areas were added (however, none were removed). In one case, the PI supplied additional information on the nature of the nanomaterials that allowed for a more appropriate classification of the risks and benefits. In another case, the PI indicated that the majority of her work is not in the area of nanotechnology, although the project in the database states that nanoparticles will be made in the laboratory. Changes suggested by PIs were incorporated into the database.