PROGRESS AND PLANS OF NATIONAL NANOTECHNOLOGY INITIATIVE (NNI) AGENCIES

February 2018

U.S. Department of Agriculture (USDA)

National Institute of Food and Agriculture (NIFA)

Summary

The National Institute of Food and Agriculture is the primary extramural science agency of USDA. NIFA invests in and advances agricultural research, education, and extension to solve grand societal issues. NIFA's vision is to catalyze transformative discovery, education, and engagement to address agriculture challenges. Nanoscale science, engineering, and technology has been recognized in the agency and by its broad stakeholders as an integral part of NIFA's comprehensive science and technology portfolio. NIFA will continue to advance the frontiers of interdisciplinary nanoscience and nanotechnology for addressing significant issues facing agriculture and food systems, including sustainable agricultural production systems, food and nutrition security, food safety and biosecurity, the bio-based economy, environmental systems, natural resources, water quality, and climate variability. The program also encourages studies of risk assessment and management, public deliberation, social acceptance, and communication about nanotechnology and nanotechnology-enabled products by agricultural stakeholders (including consumers).

Key Technical Accomplishments

The following are some examples of USDA/NIFA's recent accomplishments:

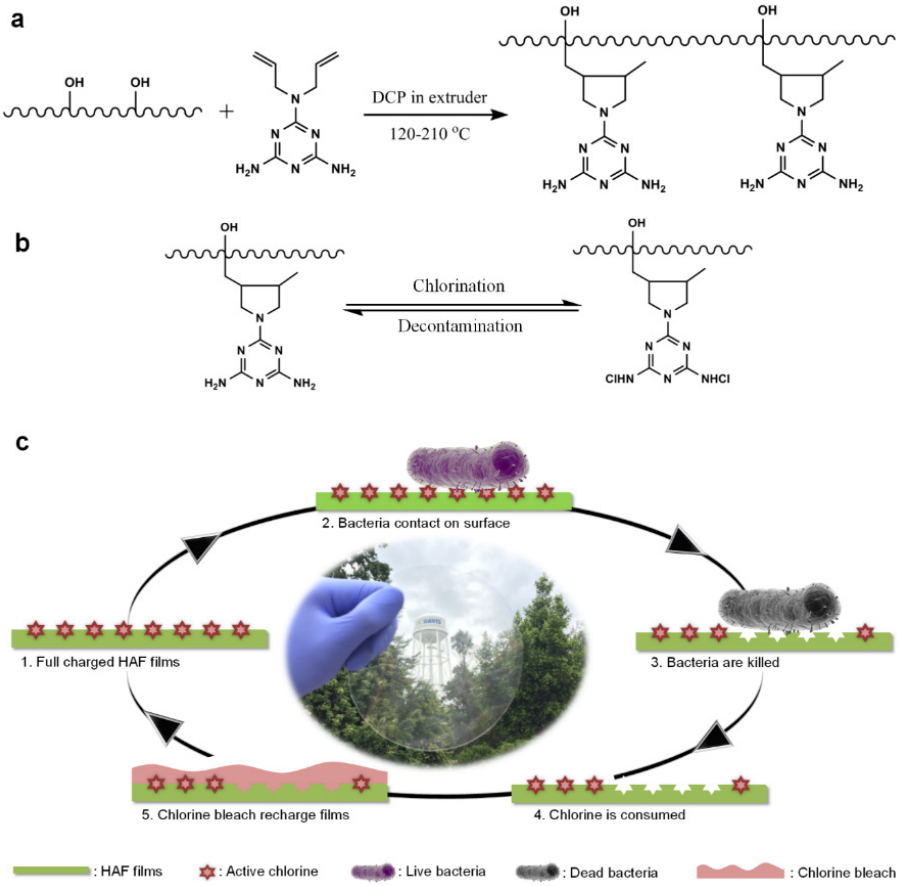
- Scholars have suggested that as much as 42 percent of the global annual production of six major food crops is lost due to plant diseases. NIFA's Agriculture and Food Research Initiative (AFRI) nanotechnology program has supported a research project at the Connecticut Agricultural Experiment Station that experimented with nanoscale nutrients to stimulate the plants' own immune systems against fungal infection and transform agriculture "on the cheap."[1] The results broadly showed that eggplant treated with nanoparticle copper fared better in a variety of ways than eggplant treated with bulk versions of the same nutrient (see photographs below). In one field trial, the treatment cost an estimated at $44 per acre, and raised the per-acre value of the yield from $17,000 to $28,000. (*Project: Connecticut Agricultural Experiment Station, Nanoscale Elements Suppress Plant Disease, Enhance Macronutrient Use Efficiency, and Increase Crop Yield.*)

[1] https://undark.org/article/nanoscale-connecticut-agricultural-station/

- With support from AFRI, a research team from the University of California, Davis, is developing new disinfection methods to reduce cross-contamination during food processing.[2] While many traditional methods for disinfection exist, they do not completely remove or inactivate bacteria in protected structures called "biofilms." Antibacterial membranes consisting of nanostructured halamine coatings are a new approach to reduce the formation of bacterial biofilms that cause outbreaks. These membranes can inactivate pathogens like *Listeria monocytogenes* and pathogenic *E. coli* on contact, and prevent outbreaks in the food processing industry. The researchers found that these membranes afford continuous sanitation and disinfection of surfaces and can be used as a lining material for many devices, including conveyor belts (see figure below). These membranes may also affect the biomedical sciences and could be used in hospitals to prevent bacterial biofilm from forming. (*Project: University of California, Davis, An Integrated Approach to Eliminate Cross-Contamination during Washing, Conveying, Handling and Packaging of Fresh Produce.*)
- With the support of USDA/NIFA, the National Science Foundation, and the Roy J. Carver Charitable Trust, Iowa State University researchers have developed flexible, water-repellent circuits for washable electronics using inkjet-printed graphene treated with a rapid–pulse laser.[3] "We're micro-patterning the surface of the inkjet-printed graphene," one researcher said. "The laser aligns the graphene flakes vertically—like little pyramids stacking up. And that's what induces the hydrophobicity." The technology could have many applications in flexible electronics, washable sensors in textiles, microfluidic technologies, drag reduction, de-icing, electrochemical sensors, and technology that uses graphene structures and electrical simulation to produce stem cells for nerve regeneration.

[2] http://aem.asm.org/content/early/2017/07/24/AEM.00975-17.full.pdf

[3] https://www.mbtmag.com/news/2018/01/researchers-develop-flexible-water-repellent-circuits-washable-electronics



- NIFA-supported research has demonstrated that there is a hierarchy of acceptance regarding the application of nanotechnology to food and agriculture. Understanding the parameters of consumer acceptance of nanotechnology is particularly important in better directing the future development of nanotechnologies intended to be applied to food and agricultural products. The research has also underscored the importance of understanding how people come to comprehend the meaning of nanotechnology. The role of images in particular appear to be key to perceptions about nanotechnology. Nanotechnology is dependent on visual representation to communicate to the public. NIFA has disseminated the findings through a webinar entitled "Parameters of public acceptance of nanotechnology."[4] More than 80% of audience members were more aware of recent scientific discoveries as a result of attending the seminar, and felt it very useful.
- In a project funded by NIFA, Iowa State University researchers have made "wearable" sensors for plants, enabling measurements of water use in crops. Using these sensors, the researchers have been able to measure the time it takes for two kinds of corn plants to move water from their roots to their lower leaves and then to their upper leaves (see photograph below). This is a new, low-cost, easily produced, graphene-based, sensors-on-tape technology that can be attached to plants, and can provide new kinds of data to researchers and farmers.[5]

[4] https://nifa.usda.gov/resource/december-2017-ifsn-seminar

[5] https://scienmag.com/engineers-make-wearable-sensors-for-plants-enabling-measurements-of-water-use-in-crops/

Plans and Priorities by Program Component Area (PCA)

PCA 1. Nanotechnology Signature Initiatives (NSIs) and Grand Challenges

1a. Sustainable Nanomanufacturing: Creating the Industries of the Future

NIFA's sustainable nanomanufacturing effort will continue its focus on nanobiomaterials derived from crops, woods, and other biomass-based agricultural by-products. The Nanotechnology for Agricultural and Food Systems program in the AFRI Foundational and Applied Science Program area supports novel uses and high-value-added products of nano-biomaterials from agricultural and forest origins for food and non-food applications. There are ongoing research efforts in synthesis of carbon-based nanomaterials, development of cost-effective production methods, functionalization and characterization of nanobiomaterials, and exploration of applications of nanocellulose such as piezoelectrics, renewable nanocomposite polymers, food packaging, barrier films, and energy and fuels.

1d. Nanotechnology for Sensors and Sensors for Nanotechnology: Improving and Protecting Health, Safety, and the Environment

NIFA will continue to support development of nano-biosensors for more sensitive, specific, reproducible, and robust detection of pathogens, toxins, allergens, and various contaminants in food to ensure food safety and biosecurity. The Nanotechnology for Agricultural and Food Systems program in the AFRI Foundational and Applied Science Program area supports research projects in nanoscale sensing mechanisms and smart sensors for reliable and cost-effective early detection of pathogens, allergens, insects, diseases, chemicals, and other contaminants in food, plant, and animal production systems, and in water, soil, and the agricultural production environment. The program also supports research in monitoring physiological biomarkers for optimal crop or animal productivity and health. The program seeks to develop cost-effective, distributed sensing networks for intelligent and precise applications of agricultural inputs (e.g., fertilizer, water, and agrochemicals).

USDA/NIFA and the National Science Foundation are planning for a partnership to advance nano-biosensing and analytical technology that addresses food safety, water quality, biosecurity, plant and animal diseases,

and similar topics for monitoring of food- or water-borne pathogens and allergens and accidental, natural, or intentional biological or chemical contaminants.

1e. Water Sustainability through Nanotechnology: Nanoscale Solutions for a Global-Scale Challenge

Water quantity and quality remain a great challenge facing U.S. agricultural and food production. Use of systems approaches and transformative technologies including nanotechnology, sensors, modeling, microbiome manipulation, and data-driven decision tools to develop drought- and flood-tolerant cultivars, intensify food production, improve crop and livestock health, or reduce overall water use across food production systems will be reflected in the agency programs.

PCA 2. Foundational Research

NIFA continues to advance the frontier of interdisciplinary nanoscale science, engineering, and technology research for solving significant societal challenges facing agriculture and food systems. The Nanotechnology for Agricultural and Food Systems program in the AFRI Foundational and Applied Science Program area supports discovery and characterization of nanoscale phenomena, processes, and structures relevant and important to agriculture and food. It also encourages new platforms of nanotechnology in the area of higher-order assembled systems, and more complex systems that include the exploitation of bio-nano interfaces, hybrid bioinorganic systems, systems biology, and additive manufacturing technology. The AFRI Social Implications of Emerging Technologies program supports research projects to assess the broad social, ethical, legal, and other potential impacts that major emerging technologies like nanotechnology may pose for society, agricultural markets, consumer preferences, and other domains.

PCA 3. Nanotechnology-Enabled Applications, Devices, and Systems

The NIFA nanotechnology efforts support various innovative and applied research to develop nanotechnology-enabled applications, devices, and systems for a wide range of national priorities. The application scope includes early detection and effective intervention technologies for ensuring food safety and biosecurity, more effective therapies to improve animal health and wellness, development of novel biology-based products, and protection of natural resources, the environment, and agricultural ecosystems. Applications, especially those with potential near-term commercial impact, are encouraged to include socioeconomic analyses of anticipated benefits to agriculture, food, and society and to identify the factors that may contribute to, or hinder, adoption and commercialization. Systems approaches are emphasized, to address the convergence of agricultural sciences with engineering, nutritional and food sciences, social sciences, and other disciplines (including nanotechnology, computational sciences, and advanced manufacturing) to generate new scientific discoveries, new products, new markets, and consequently new high-skilled jobs.

PCA 4. Research Infrastructure and Instrumentation

NIFA will continue supporting universities to develop new curricula and the future workforce. NIFA's higher education programs support competitive grants to universities for developing nanotechnology curricula for undergraduate and graduate students in agriculture and food science and technology. NIFA's Education and Literacy Initiative programs will continue to focus on building institutional capacity and enhancing the pipeline for producing more science, technology, engineering, and mathematics (STEM) graduates to meet the projected shortfall in agriculture-related fields.

NIFA also invests in new programs focused on maximizing the value of data-driven research in specific foundational domains of agricultural science, as a part of the Food and Agriculture Cyberinformatics and

Tools (FACT) initiative. The availability of big data provides unprecedented opportunities for synthesizing new knowledge, for making predictive decisions, and for fostering data-supported innovation in agriculture.

PCA 5. Environment, Health, and Safety

NIFA's nanotechnology programs support the environmental, health, and safety (EHS) research targets that are most relevant to agricultural production and food applications. Appropriate EHS assessments of engineered nanoparticles applied in food and agricultural systems include characterization of hazards, exposure levels, and transport and fate of engineered nanoparticles or nanomaterials in crops, soils (and soil biota), livestock, and production environments. These assessments may also include animal feed formulations and processes that utilize novel nanomaterials or the development of new nanostructured materials or nanoparticles that are bio-persistent in digestive pathways. The AFRI program also supports research on transport and fate of engineered nanoparticles or nanomaterials associated with food production, processing, and interactions in the human gastrointestinal tract (GIT).