Overview of NABC 23
Food Security: The intersection of Sustainability, Safety and Defense

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The National Agricultural Biotechnology Council's twenty-third annual conference took place in St. Paul, Minnesota, and was organized and hosted by the College of Food, Agricultural and Natural Resource Sciences (CFANS) at the University of Minnesota.

The world will have to double food production in a sustainable manner in the next 40 years if it is to support the nine billion people expected by 2050. The amount of food to be produced in this short lapse of time is almost equivalent to the total produced in the world up to this point in time. This challenging task has to be accomplished in the context of a global warming trend due to the accumulation of greenhouse gasses (GHGs) generated by human activity and resulting in climate change. To make matters more complicated, world energy demand has grown significantly, and agriculture is envisioned as one of the sustainable sources of renewable energy. In the context of this conference, food security does not only mean food availability, but also its protection from contamination, bioterrorism and fraud.

Daniel Gustafson (Food and Agriculture Organization) opened the conference with his keynote presentation, *The Importance of the Convergence of Sustainability, Safety and Defense for World Food Security.* He reminded us that the challenge at hand is no longer local, regional or continental, it is global. He further pointed out that

> *natural resource degradation, water scarcity, and climate change are raising concerns that we are nearing a tipping point where disaster may be imminent if we continue on the same unsustainable path…It is clear that decades of progress may be wiped out very quickly. The issues are now elevated, and rightly so, to be seen as threats to national security.*

These interconnected threads demand the convergence of disciplines, generation of integrated solutions, in sum to develop the

> *…concept of "climate smart" agriculture that has the objective of looking for solutions that simultaneously increase productivity, reduce vulnerability and increase resilience to change, reduce or remove GHG emissions, and contribute to food security and national-development goals.*

However, Gustafson acknowledged the

> *inherent difficulty in creating a shared understanding of the problems and shared commitment to solutions… It is very difficult to integrate science and society where values are in conflict, where experts from science or industry expect to dictate policy objectives or command conformity. There is, for better or worse, reduced faith in the ability of science to manage risks, coupled with increasing communication within communities of like-minded individuals who share strong beliefs and opinions regardless of the evidence.*

Even though the latter is a difficult task, the urgency to find win-win solutions requires that we pursue the convergence that Gustafson proposed, a tall order for all involved in moving forward global solutions.

Plenary Session 1. Sustainability and Needs of 2050 Agriculture

Jonathan Foley (University of Minnesota, *Solutions for a Cultivated Planet: Simultaneously Addressing the Food Security and Global Sustainability Challenges Facing the World*) stated that the magnitude of the challenge in doubling food production equals all of the six previous efforts in doubling food production in human history. He proposed six contributory approaches from a global-scale perspective:

- Slow the rate of agricultural land expansion into sensitive ecosystems because production and productivity returns do not justify the increase in detrimental environmental effects.
- Close agricultural yield gaps. For example, corn yields vary by a factor of 100 between high- and low-efficiency farmers.
- Raise crop-yield ceilings: A phase-in approach is needed in some of the poorly performing regions of the world with nutrients and water limitations addressed first and genetic improvements made later.
- Improve the efficiency of environmental resource use. This is explained as the need to improve crop productivity with less nitrogen, less phosphorus and less irrigation water.
- Diet modification. About 60% of global crop production is for food, 35% is for feed and 5% is for biofuels production. Changing to 100% of production for food would increase availability of food by 40% over the current level.

- Food-waste reduction. It is estimated that about a third of the food produced worldwide is wasted. In high-income countries, waste occurs at the consumer end, and in low-income countries at the production end due to crop failures and lack of infrastructure.

Taking all of these recommendations together, great strides towards a comprehensive solution can be made. Foley stated:

> *The task is to feed the world while sustaining the planet. Failure is not an option. Civilization depends on solving this problem literally. We have to get it right and we get only one try at it.*

Water is an issue that needs to be addressed at various geographical scales; however, it is widely recognized that changes/actions in water management and conservation need to start at the local level, with the understanding that it affects, in comparable measure, the regional and continental scales. Water is perhaps the most important natural resource and agriculture uses most of the available fresh water. It is becoming scarce in some regions of the world and it must be managed and preserved if food production is to be doubled sustainably.

Minnesota is at the headwaters of three of the largest North American river basins, which are replenished largely from rain and snow. Minnesotans are conscious of their water heritage and of their responsibility to care for their state's water resources and for effects on users downstream. Three years ago (2008) Minnesotans added the Clean Water, Land and Legacy Amendment to the state constitution and part of a small increase in the state's sales tax goes to the Clean Water Fund to protect and enhance water resources. In her presentation, *Looking Far into the Future: The Minnesota Water Sustainability Framework*, Deborah Swackhamer (University of Minnesota) described the Framework as providing

> *…a long-range plan that frames major water sustainability issues and provides strategies and recommendations for addressing them. It is not a specific spending plan for the Minnesota Clean Water Fund, nor should it be limited by the availability of Clean Water Funds; rather, it includes recommendations for investments that may come from sources beyond the Clean Water Fund (other state funds, private funds,* etc.*), as well as recommendations that require little or no investment by the state.*

The Framework is not a set of strategies and recommendations that are applicable across the globe because there are factors that affect different regions in different ways. However, it can serve as a model for other states in the Union and beyond.

Terry Stone (Syngenta, *Developed and Developing World Sustainability Perspectives*) presented several examples of progress achieved in developing countries by application of new technologies and also of continued stagnation and poor efficiencies caused by lack of infrastructure, poor resources and restrictions to adoption of modern technologies due to lack of information and low literacy. If the goal to double food production is to be achieved, then increases in agricultural productivity in both developing and developed nations are essential.

In the developed world, it will require sustaining gains in agricultural productivity through continued investment and implementation of advanced technologies, measuring agricultural productivity holistically and harnessing the market power of major players to create farm-to-fork incentives for sustainability. The most problematic barriers in the developed world will likely continue to be over-zealous, under-informed and unsynchronized regulatory strictures. Many of the catalysts that can help accelerate the evolution of smallholder, subsistence farmers into viable commercial farmers are likely to come in the form of new hybrids, new traits, new seed treatments and new crop-protection chemistries.

Development of extension services to educate the approximately 1.5 billion smallholders and subsistence farmers in the use of these technological advances is a must if sustainable increases in productivity are to be realized.

Plenary Session 2. Systems-Based Approaches to Food Protection and Security.

This session was opened by June Medford (Colorado State University) with a keynote presentation, *Detector Plants for Agriculture, Food and Environmental Monitoring*. Plants are being developed as sentinels to monitor human and natural environments for the presence of pollutants, chemical contaminants and explosives that are intentionally or unintentionally introduced. To achieve this,

…sentinel plants need to have a reporting system which is easily detectable, allows remote monitoring and is re-settable.

Medford's laboratory has engineered a synthetic de-greening system that causes rapid chlorophyll loss when sensing a specific input. The chlorophyll loss can be detected within hours by remote sensing by induction of a white plant phenotype that is easily recognizable.

The de-greening circuit functions via light-dependent damage to photosystem cores and the production of reactive oxygen species.

These de-greened plants are also able to re-green after removal of the inducer agent. Hence, it provides the first easily re-settable reporter system for plants and the capacity to make re-settable biosensors.

The second component of this system is based on the conserved histidine kinase (HK) signal-transduction system. The Medford laboratory demonstrated that

HK sequence conservation and cross talk can extend across kingdoms and can be exploited to produce a synthetic plant signal-transduction system.

Hence, in response to exogenous cytokinin, the HK-engineered system is activated and a bacterial response regulator is translocated to the nucleus and activates gene transcription. The last piece of this integrated system uses computationally designed periplasmic binding proteins that allow specific small-molecule ligand-sensing capabilities on plant-leaf receptors. When the HK signal-transduction system is activated by these proteins, it prompts the expression of a gene that in turn produces a protein that activates the de-greening circuit, previously described, and generates a visual white phenotype (chlorophyll loss) that can be remotely monitored. This is a very clever system that will, in due time, be applied to monitor the presence of environmental contaminants.

The second presentation in this session was by David Andow (University of Minnesota) who focused on *Risk and Vulnerability*. Andow's talk provided a series of examples of environmental risk assessment (ERA), their uses and acceptability to validate environmental policy. In general when ERA is carried out, the public is more likely to accept policy decisions. However, he pointed out that risk assessment is imperfect and highlighted some of the underlying reasons of why this is so. For instance, different risk-assessment frameworks exist in different countries. In Australia, agriculture has a separate ERA, whereas Europe considers agriculture as part of the environment and farming practices are part of risk assessment. Conversely, in the United States, only some aspects of agriculture are considered to be part of the environment. Therefore, many indirect effects may or may not be considered as part of the risk assessment of specific technologies, depending on the regulatory process of the country. Andow argued in favor of including cultural significance as part of ERA. His example for the latter was based on the public uproar due to possible negative effects of *Bt* corn on the monarch butterfly; the public reaction was linked to the cultural significance of monarch butterflies in the United states and Mexico. Other countries may also have "preferred" species that need special consideration for ERA analyses. In general, Andow pointed out that

> *...polarization of opinions results from the fact that some people see mostly benefits and some people see mostly risks and everyone balances risks and benefits differently. It's a social phenomenon with no agreement about how we weigh the factors involved and, therefore, it is impossible to reach consensus.*

Martin Duplessis (Health Canada, *Detection and Prevention*) explained the organization of the Canadian food-safety system and the several responsibilities of the institutions involved. He elaborated on the methodological approach used to identify foodborne pathogens, and emphasized the importance of sampling, sample preparation, pathogen enrichment, and methods for pathogen detection, isolation, identification and typing. Each of these steps has its own criteria and complications that need to be managed and overcome to deliver quick and accurate results. Microfluidic modules are being developed and are proving to be effective. Future technologies are focusing on more-rapid detection methods and miniaturization.

Detloff von Winterfeldt (International Institute for Applied Systems Analysis, *Systems and Risk Analysis for Food Protection and Security*) provided definitions for system analysis and risk analysis.

> *Systems analysis is a group of model-simulation analysis tools—applied mathematics if you will—specifically applicable to very complex systems that undergo dynamic changes and are fraught with uncertainty...[T]he analysis is problem-focused and solution-oriented....The model is usually developed by a multidisciplinary team taking a holistic view of the problem.*

On the other hand, his definition of risk analysis

> *... is a combination of risk assessment and management that involves identifying the risks, quantifying them*—i.e. *quantifying the possibilities of events that could occur as well as quantifying their consequences—and then looking at decision-opportunities, intervention and risk reduction, and evaluating them.*

von Winterfeldt gave examples of systems and risk analysis for bioterrorism and food protection. His recommendation for food protection was

> *... to find risk-management options with large co-benefits that pay for themselves. For food defense, you might think in terms of strategies to prevent a terrorist tainting something that may be beneficial for other food-safety reasons. Equally, solutions that address regular safety issues by introducing new testing and inspection procedures may help prevent terrorism.*

In sum, he concluded:

> *The main challenge is how secure is secure enough? Clearly, we will never be completely safe from terrorism. Nor will we ever have a completely safe food supply.*

Plenary Session 3. Preparing for Emerging and Unknown Threats

In his presentation, *Preparing for Emerging and Unknown Threats: Public Health,* Robert Buchanan (University of Maryland) discussed factors affecting the emergence and re-emergence of foodborne diseases, research needs, and the role of biotechnology innovation in assessing and preventing foodborne diseases. The drivers that cause disease emergence are global demographics, global food chains, processing technologies, and gene transfer that causes pathogen variation. He identified research needs in the areas of anticipation and prevention of emergence of food pathogens, containing diseases before they become established, and disease eradication. Buchanan acknowledged the inherent difficulties of these research needs and their relative importance based on their effectiveness. Biotechnology may be helpful in determining the mechanisms of gene transfer and what selective pressures, if any, can prevent it. Many foodborne microorganisms show considerable diversity, *e.g.* 2,400 serotypes of *Salmonella enterica* have been identified; is it possible to identify a common factor that biotechnology can take advantage of to prevent foodborne outbreaks? Is it possible to reduce genetic variation in microorganisms? Biotechnology may also provide tools to assist in assessing sentinel populations like the very young, the elderly and immune-compromised individuals. Likewise, Buchanan identified long-standing research needs that have not been resolved: sample size and assessment of the immune status of individuals. In the former, as food-sample size becomes smaller, assay sensitivity is significantly reduced, and it is important to have rapid methods to determine the immune status of affected individuals to help in risk assessment and in determining what factors should be emphasized. In essence, he placed emphasis on the need for "just in time" research when responding to an emerging foodborne disease.

With *Recent Animal Disease Outbreaks and their Impact on Human Populations*, Jeff Bender (University of Minnesota) reminded the audience that there are very positive and strong connections between animals and humans, but that there are, as well, reasons for concern because about 61% of all human pathogens are zoonotic (acquired from animals); of 175 newly emerging pathogens in humans, 132 are zoonotic. The increase in new diseases, aside from the fact that humans are encroaching more and more on wild-animal habitats, is due to increases in world trade, animal translocation, ecological disruptions, climate change, adaptation of pathogens, and changes in the way we raise animals. Animal health and human health are intertwined, and we should be cognizant of the global consequences of international trade in animals and animal products and the impacts of human population growth on the environment. Early and rapid detection coupled with prompt intervention are the goals that will allow quick identification of exposed individuals for early treatment, isolation and containment of emerging diseases.

Jacqueline Fletcher (Oklahoma State University) presented a talk on *Preparing for Emerging and Unknown Threats in Crops*. Plant diseases have significant impact on food security. Our vulnerability resides principally on the fact that we grow, for the most part, monocultures that could be wiped out in a single season by a new pathogen. Fletcher provided the example of the potato famine in Ireland in 1880. A relatively new race, TTKS, of the wheat stem-rust pathogen, *Puccinia graminis* f. sp. *tritici*—commonly known as "Ug99" because it emerged in Uganda in 1999—has spread beyond its area of origin. Most currently grown wheat varieties lack resistance to Ug99. Accordingly, the task is to identify resistant varieties and incorporate that resistance into cultivated genotypes.

Plant-disease impacts on food security and social stability can be significant, and in the last few years plants have been the sources of foodborne diseases by consumption of contaminated fresh produce. Fletcher described for the audience the National Plant Disease Recovery System (NPDRS) that is the responsibility of the USDA Office of Pest Management Policy.

> *This initiative consists of the preparation of response plans for each of the APHIS plant pathogen select agents as well as a number of other threatening plant pathogens. The NPDRS's purpose is to ensure that the tools, infrastructure, communication networks, and capacity required to mitigate the impacts of high-consequence plant-disease outbreaks are such that a reasonable level of crop production is maintained in the United States.*

A second initiative established the National Plant Diagnostic Network (NPDN) after the September 11, 2001, attacks. This is a nationwide system of plant diagnostic laboratories that include USDA, land-grant universities, state Departments of Agriculture and private laboratories. Furthermore, in 2007, the National Institute for Microbial Forensics & Food and Agricultural Biosecurity (NIMFFAB) was established at Oklahoma State University. NIMFFAB's role is "to serve as a link between the plant-pathology community and law enforcement and security communities, policymakers, and funding agencies," *i.e.* a system to assess, characterize and respond to emerging plant diseases and reduce our crops' vulnerability to harmful intent.

Plenary Session 4. Emerging Biotechnologies to Promote Safety, Enable Defense, and Discourage Fraud

John Besser (Centers for Disease Control) began his presentation *Emerging Biotechnologies to Promote Safety* by indicating that "each year, one out of six American—48 million people—are thought to become sick with a foodborne illness, and 3,000 die." By this measure, foodborne illnesses are quite common, hence emphasis is being placed on prevention and surveillance. A national network of public-health and food-regulatory agency laboratories coordinated by the Centers for Disease Control and Prevention (CDC) has been developed. All collaborators perform standardized molecular fingerprinting of foodborne-disease-causing microorganisms by pulse field gel electrophoresis (PFGE). PFGE images are deposited in a centralized database at the CDC and are used to make comparisons and identify strains of microorganisms. The consortium and database are known as PulseNet USA. PulseNet collaborations and databases have been developed in Canada, Latin America and Caribbean countries and are integrated with PulseNet USA. PulseNet International includes 86 countries with the exception of Europe where it has been difficult to integrate the systems because some EU countries prefer to operate independently. Besser presented several examples of foodborne diseases for which the use of PulseNet information facilitated the identification of the origin and also reduced the time of detection and of recall of the contaminated food. Research in enhancing strain resolution for identification is necessary. At present, the system is limited to only the 30% of known foodborne-disease-causing pathogens. Use of metagenomics technology to assess unknown pathogen seems to have potential.

In his talk, *Emerging Food Systems Defense Risks and Technology Needs*, Shaun Kennedy (University of Minnesota) defined differences between food security, safety, defense and protection. Security may be defined as supply sufficiency, whereas safety implies system reliability. Defense, on the other hand, implies system resiliency and protection is defined as the continuum of safety and defense. Kennedy examined emerging intentional threats and technology needs in two areas:

- Food-system drivers—public-health surveillance systems; system complexity and globalization; and developing-world value-added agriculture—that generate concerns for intentional contamination, and
- Intentional-contamination drivers—economically motivated adulteration (EMA); disgruntled employees; criminals and deviants; and terrorists.

Essentially, surveillance systems require technologies for earlier detection of contamination. The complexity of food systems (the many components of any product delivered to consumers and the global origin of each component) make the task of identifying origin of contamination difficult and lengthy. It is obvious that new, fast and reliable technologies for traceability are needed. When developing countries move from commodity production to value-added production, although it contributes to the food supply, risks for food contamination and vulnerability increase, hence the need to develop better capability for assessment of systems-based risk and vulnerability.

Food Fraud: Public Health Threats and the Need for New Analytical Detection Approaches was the theme addressed by Jeffrey Moore (US Pharmacopeia), who focused largely on EMA of food products. A practical example is the adulteration of milk with water—when milk was sold by weight—to increase its value at sale. When milk was sold based on protein content, its adulteration with water was eliminated. However, in more recent times, it has been adulterated with melamine because protein content is often assayed with non-specific technologies like the Kjeldahl method, which measures total nitrogen. More-specific methods and/or method combinations can detect melamine adulteration and more precisely measure protein content. EMA examples are numerous: wheat can be extended with urea; turmeric powder can be extended with lead chromate; and olive oil can be diluted with hazelnut oil. Factors that motivate EMA are the rising prices of agricultural raw materials, the complexity of supply chains, and the complex compositions of food products. Many times, adulteration has had significant public-health consequences, *e.g.* fatalities from adulteration of baby formula with melamine. Moore provided examples of the significant advances achieved by the US Pharmacopeia[1] (USP) in collaboration with many institutions in establishing standards to detect EMA. However, he also pointed out that

> *...the nature of EMA and the paucity of analytical detection methods means that the safety of counterfeit foods is in the hands of fraudsters. A significant gap needs to be filled to develop analytical technologies to detect and deter EMA.*

[1]A global independent, not-for-profit, non-governmental, science-based, public-health, volunteer-based organization dedicated to the collection and establishment of standards for pharmaceuticals, medicines and dietary supplements. Since 1966 it has produced the Food Chemicals Codex, a compendium of internationally recognized standards for the purity and identity of food ingredients.