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THE FUTURE OF FOOD SAFETY

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## Novel analytical methods and models for enhanced food safety

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Food can be adulterated by a wide variety of chemical and microbiological contaminants, which may occur at any point in the distribution chain. To address food contamination issues, regulators, public health officials, and the food industry must continually invest in new technologies that lead to innovative approaches to rapidly and accurately identify and characterize the hazard.

The key to maintaining food quality and safety standards are consistent, adaptable monitoring and surveillance systems. The globalization of food supply networks-- largely made possible by fast, reliable transport systems-- has led to dramatic increases in food imports from a much greater geographic distribution. As consumers demand a wider variety of foods, these changes have led to new, innovative farming and food production systems, often resulting in foods being manufactured/grown in places they have never previously been produced.

These changes in global food production have impacted food quality and safety systems. The availability and quality of water for food processing and irrigation is one major example of complicated change. New practices will likely identify other new and potentially unsuspected sources of food contamination. Existing national and global food safety surveillance systems must deal with such issues by investing in, developing, validating, and implementing innovative, new analytical solutions. These solutions, in turn, require data access, creating a never-before-seen need to share surveillance and analytical data in globally open databases.

1.0 Rapid Screening Technologies

1.1. Compact, portable devices

Portable devices have the potential for cost effective techniques that allow for rapid screening of regulated commodities for authenticity and detection of economic adulterants. Advances in this area include: (1) infrared and Raman spectroscopies, using both scientific and consumer-marketed instruments, for evaluation of commodities that may be prone to mislabeling (*e.g.,* dietary supplements, olive oil) or detection of analytes/constituents that may represent potential economic adulterants (*e.g.,* adulteration of milk powder); (2) X-ray flourescence analyses for evaluating cosmetics, spices, and baking ware for heavy metals; (3) lateral flow assays with portable readers for toxin quantitation (*e.g.,* shellfish toxins) and drug residues (*e.g.,* antibiotics in milk); (4) electronic nose and bioelectrical impedance devices for seafood decomposition analysis and; (5) a modified Arsenator for field portable detection of inorganic arsenic in rice.

1.2. Non-targeted mass spectrometry assays

Researchers are developing new workflows for the analysis and data processing of LC/MS data that is applicable to different types of foods. The largest impact will be from the creation of workflow specific databases (*e.g.,* pesticides) that can be shared globally and searched against. These new databases use a metabolomics-like workflow to identify trends, seasonal and geographic differences, as well as similarities between foods. In future we will be able to use predictive algorithms to minimize contamination and to reduce the sample burden using these data.

1.3 Global access to whole genome sequencing data

Whole genome sequencing (WGS) technologies and the resulting data have revolutionized surveillance of infectious disease, tracking of contaminated foods/ingredients, and identification of harborage sites in food production facilities. Understanding the global nature of the food supply chain and the importance of including data from all sources, the U.S. FDA's GenomeTraker network in collaboration with the NIH/NCBI established the Pathogen Detection database (https://www.ncbi.nlm.nih.gov/pathogens/), with the goal of more accurately capturing the global diversity of food and environmental isolates. Currently, the database includes regular WGS data submissions from laboratories in 12 countries, and contains searchable/downloadable information and analysis on more than 300,000 genomes for 22 different human bacterial pathogens. The open access nature of the database provides scientists, government officials, and food producers with tools to examine the extent, potential origin, and distribution of pathogens in their food systems.

1.4 Nanotechnology based applications

Scientists are looking to create inexpensive, highly selective, and robust assay for food safety. Researchers have used molecularly imprinted polymers (MIPs), apatamers, and quantum dots to attach and detect foodborne pathogens and other toxins. Scientists have developed nanomaterial-based colorimetric test for cholera toxin using a cholera antibody, as well as other assays for microcystins and gluten. The ability to create very specific assays for very specific problems could be beneficial to countries to reduce infrastructure costs to test foods; however, multiplexing may be difficult and performance may not work as well for all food matrices.

2.0. Consumer and Process Technologies

2.1. Consumer devices

Recent advances, largely in smartphone technologies (*e.g.,* wireless communication, touchscreen displays, virtual keyboards, GPS capability, rapid processors, fingerprint scanners, and advanced cameras), have allowed several compact instruments to appear in commerce in the form of both portable analytical devices and consumer-focused tools. Such devices could potentially be harnessed by global food safety and industry partners to allow for improved screening of foods, dietary supplements, and drugs. However, challenges to implementation abound, including the need to validate and understand the detection capabilities and limitations of each of the myriad of devices available. Further, consumer devices have additional evaluation needed based on their reduced analytical capability due to simplified architecture and cloud-based data acquisition and analysis that is driven by nonscientific users. Researchers have tested a few of these types of devices (SMART, Nima, and ScIO) as well as the gluten strips. They all "work" to some degree; however, the complexity of food is a problem for some of these tests. Another issue is that to do the tests properly, some of these devices currently are cost prohibitive.

2.2 Processing facilities devices

Providing tools to the food industry includes advanced mechanics of vision inspection equipment allow processing facilities to rapidly detect multiple types of anomalies such as checking that the right label is on at the right site, assuring that the bottle is not broken or chipped and is filled to the right correct level. These vision inspection technologies have greater precision and speed than manual techniques and invites opportunities for cost savings and early warning that processing has gone awry. This model includes reflexive testing on an ongoing basis, which will improve food safety through increased surveillance, a strategy that would benefit any of the above technologies.

## 2.3 Portable laboratory infrastructure

Despite the footprint of the molecular hardware becoming remarkably small, the *operational* footprint of the work is not equally small. Ancillary equipment, including power supply, cold-chain storage, computational capacity, a stable workbench, biohazard waste disposal strategies, and other logistics are all necessary for the effective use of modern, hand-held hardware. The analytical instrument industry has developed complete laboratories as small as a suitcase to address this problem by providing all the necessary operational equipment in a laboratory-workbench design such that rapid, reproducible deployment of advanced genomic technologies to field-forward locations is supported.

## 3.0 New innovations – Large scale

## 3.1 Metagenomics

Metagenomics has the potential to serve as a transformative tool for rapid pathogen detection in food and environmental samples. These methods are pathogen agnostic and can be simultaneously screened for multiple adulterants. Important strain attributes such as virulence factors, antimicrobial resistance, and serotypes, can also be identified in enriched samples, allowing for pathogen identification concurrent with culture-based pathogen recovery. This culture independent sequencing technology allows for the identification of multiple subtypes of a pathogen in one workflow, which was demonstrated in a recent papaya outbreak that was attributed to multiple serotypes of *Salmonella*. These methods can inform industry of hazards before they enter the food supply by identifying foodborne pathogens, and indicator microorganisms that may pose issues with food quality (spoilage) and food safety (contamination). These methods can also be used to inform trace-back analysis and post outbreak surveillance activities. The study of food microbiomes, which likely influence the quality and nutrition of our diet have the potential to interact and alter with our gut microbiomes.

## 3.2 Bioinformatics and Data Analysis

The accumulation and direct comparison of data from any of the aforementioned technologies can constitute “BIG DATA” if enough of the information (technical data and meta data) is globally shared . Long-term harmonization, standardization, and validation processes that require careful planning and coordination are prerequisite to successful global data sharing. Global organizations can provide mechanisms that are put in place to coordinate collaborative work. Databases can be as simple as single lab validation of new technology and the direct sharing of results, including false positive and false negative results, and measures of sensitivity and specificity that would enable fitness-for-purpose decision making. However, the current trend in “BIG DATA” analysis is to integrate and analyze the combined data from multiple databases. This approach necessitates data sharing of the resulting digital information, along with harmonization of the methods for collecting the data, for these analyses to work efficiently and effectively. If laboratories chose to share the data along with the methods, then “BIG DATA” can be used to look globally at larger patterns that may be obscured at the local level. “BIG DATA” sharing can identify shared patterns due to global travel or trade and may identify emerging food safety issues. “BIG DATA” can support risk assessment and risk management models so that the greatest risks can be prioritized by their respective governmental organizations.