

Detection and surveillance of Biothreats and Emerging Infectious Diseases

Frank Busta

Director Emeritus & Senior Science Advisor

University of Minnesota, Saint Paul

Third Annual DHS University Network Summit

18 March 2009

<http://www.ncfpd.umn.edu>

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Food Security/Safety/Defense

- Food **Security**: Supply *sufficiency* – access to nutritionally adequate and safe food
- Food **Safety**: System *reliability* – reducing exposure to natural hazards/errors/failures
- Food **Defense**: System *resiliency* – reducing the impact of system attacks
- Food **Protection**: Global food supply system Safety/Defense “umbrella”

Situation

- Food is an effective vehicle for efficient delivery of threat agents
- Food supply chain complexity, efficiency & speed present the ability to cause catastrophic harm well before an intervention is feasible
- Globalization of the food system provides the opportunity for attacks at a distance
- Food protection solutions are achievable, but not absolute

Situation

- Food systems can weaponize otherwise non-WMD agents
- Food systems are a challenge to sample
- Food matrices are varied and complex
- Food materials complicate standard analyses
- Analyses of food systems require special considerations of quenching and false positives

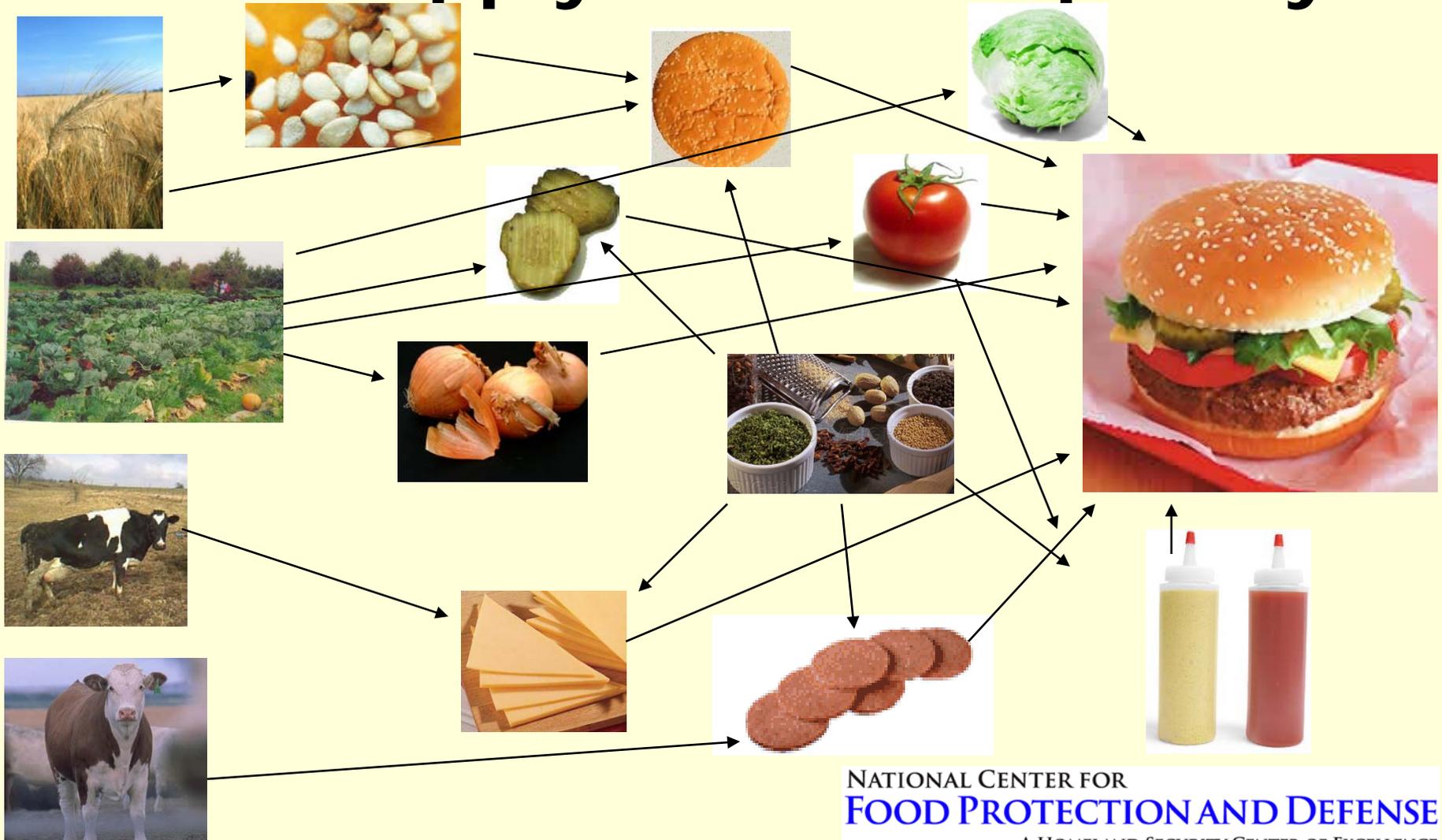
Some Characteristics of an Ideal Food/Beverage Vehicle for an Attack

- Opportunities for perpetrator access
- Lack of subsequent adequate heat-treatment
- Large volume and/or maximum mixing
- Product environment for agent growth or toxin chemical preservation
- Rapid distribution to consumers
- Rapid consumption by consumers
- Possible disproportionate consumption by “high risk populations”

Product Speed To Consumer

- Leading yogurt manufacturer goes from plant to retail in all 48 states in <48 hours
- Quick serve restaurants go from supplier to consumption in 24-96 hours for primary products (burgers, chicken, salad)
- Bottled water has an effective consumption pattern of 10 days for 80% of production
- Only seasonally harvested and canned/frozen or specialty products have effective shelf lives of significance

Global Supply Chain Complexity



NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Global Supply Chain Complexity



bleached wheat flour
malted barley flour
thiamine
riboflavin
Niacin
folic acid
reduced iron
Water
corn syrup
sesame seeds
soybean oil
Yeast
Salt
calcium sulfate
calcium carbonate
calcium silicate
soy flour

baking soda
wheat gluten
calcium propionate
enzymes
mono- and diglycerides
diacetyl tartaric acid esters
ethanol
sorbitol
polysorbate 20
potassium propionate
sodium stearoyl lactylate
corn starch
ammonium chloride
ammonium sulfate
calcium peroxide
ascorbic acid
azodicarbonamide



Grill Seasoning
Salt
Pepper
cottonseed oil
soybean oil



Milk
Water
sodium citrate
sodium phosphate
artificial color
acetic acid
Enzymes



Special Sauce
Soybean oil
distilled vinegar
egg yolks
sugar
corn syrup
spice extractives
xanthan gum
prop. glycol alginate
potassium sorbate
garlic powder
caramel color
Turmeric
EDTA

milkfat
cream
salt
sorbic acid
cheese culture
soy lecithin
starch

pickles
water
HF corn syrup
onion powder
spice
salt
mustard flour
sodium benzoate
mustard bran
hydrolyzed proteins
paprika
calcium disodium



USDA inspected beef



Cucumbers
water
Vinegar
Salt
calcium chloride
Alum
natural flavorings
polysorbate 80
turmeric



lettuce



dehydrated onions

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Food Protection Strategies: Detection & Diagnostics

Goal is real time, accurate detection of contaminants

- *Detect to Prevent*

- Positive control at site level

- *Detect to Protect*

- Positive control at system level

- *Detect to Recover*

- Rapid response for public health protection

Emerging Food Safety Threats

- Unanticipated food/agent combinations
 - *Salmonella* Saintpaul and produce
- Minimally processed and extended shelf life products
 - Botulinum neurotoxin and carrot juice
- Sourcing consolidation and broad use of common ingredients
 - *Salmonella* in peanut products

Emerging Food Safety Challenges

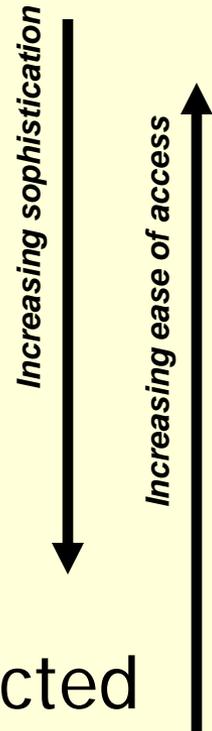
- Improved foodborne illness outbreak identification
 - Identifying outbreaks from illnesses that would not have been linked before
 - Systemic vs. episodic outbreaks
- Detection system expectations
 - Differentiating possibility, probability and plausibility
- Globalization

Salmonella Saintpaul – What If It Had Been Intentional?

- Actual contamination low level, inconsistent/ sporadic (systemic)
- Product receives little effective pathogen removal post processing
- Actual reported illnesses suggest >80,000 actually ill
- Average individual shipments from the producer implicated contain 195,000 servings

Threats Come in Various Forms

- Natural – *Unintentional*
- Negligence - *Accidental*
- Disgruntled employees - *Intentional*
- Criminals/subversives - *Deliberate*
[including economic adulteration]
- Violent activist groups - *Intentional*
- International/government supported or directed groups or individuals [terrorists] - *Deliberate*



Contamination Events Since 1998

Agents

- Arsenic
- Cyanide
- Feces
- Herbicide
- Household cleaner
- Insecticide
- Nicotine sulfate
- Pesticide
- Rat poison
- Tetramine
- Thallium

Countries

- Australia
- Canada
- China
- Hong Kong
- Iraq
- Italy
- Japan
- Korea
- Philippines
- Taiwan
- Thailand
- U.S.A.

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Vision

Defending the **safety** of the **food system** through **research** and **education**

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Agent Behavior

- Fundamental understanding of food/agent interactions to enable
 - Rapid detection
 - Process based inactivation/exclusion
 - Post event, facility compatible decontamination
 - Safe contaminated product disposal

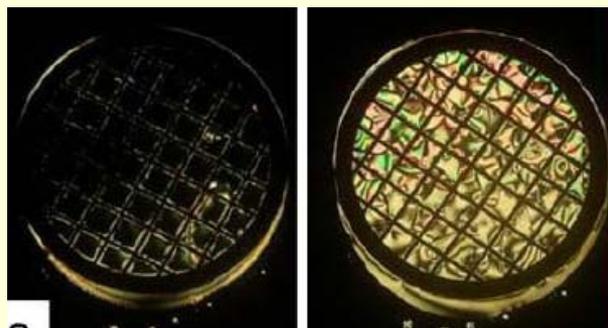
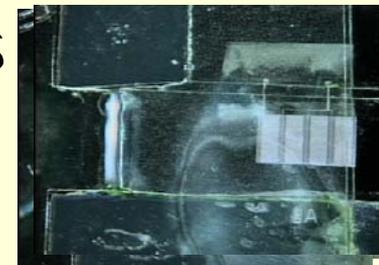
Agents of Concerns: Food-related Terrorism

- Biological
 - *Clostridium botulinum* toxin
 - *Bacillus anthracis*
 - Enteric bacteria
 - Animal/plant specific agents
- Chemicals
 - “Fast acting”
 - “Slow acting”

Promising New Detection Strategies

- Non-specific, highly sensitive detection using bioluminescent marine bacteria
- Micro-fluidic in-line detectors using threat agent specific membrane barriers
- Reactive films for rapid, specific threat agent detection

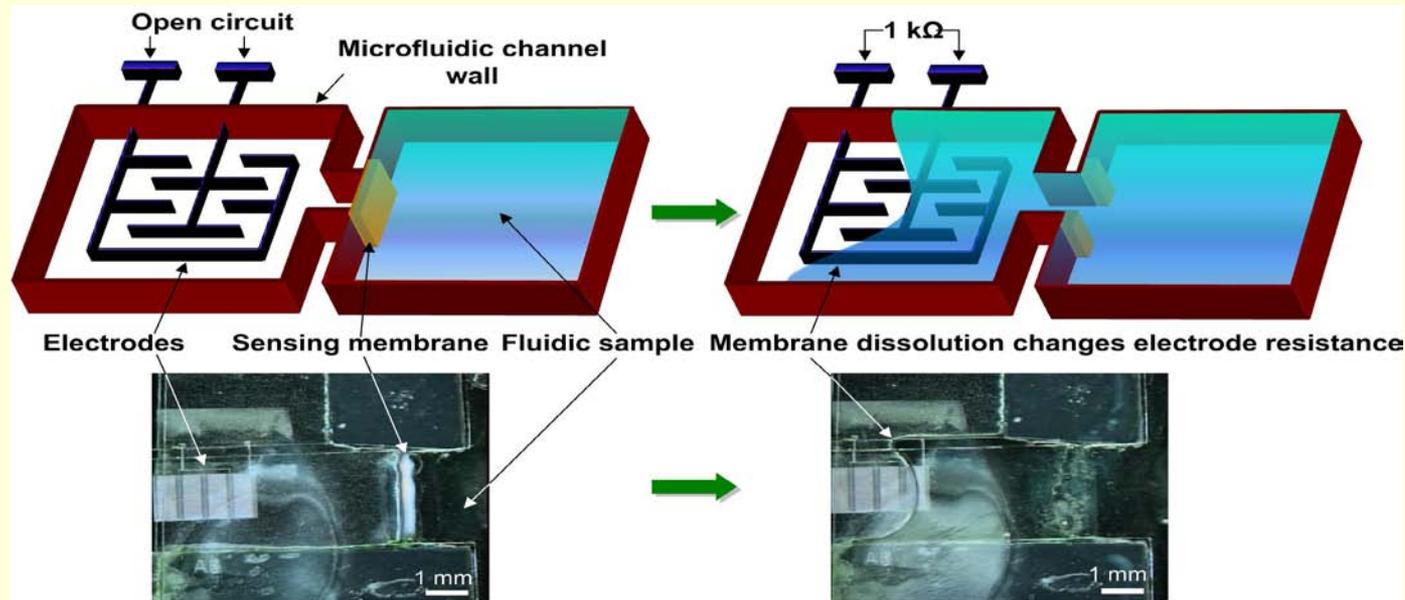
Eric Johnson



Eric Johnson/David Beebe

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Example: In-Line Botulinum Neurotoxin Detection

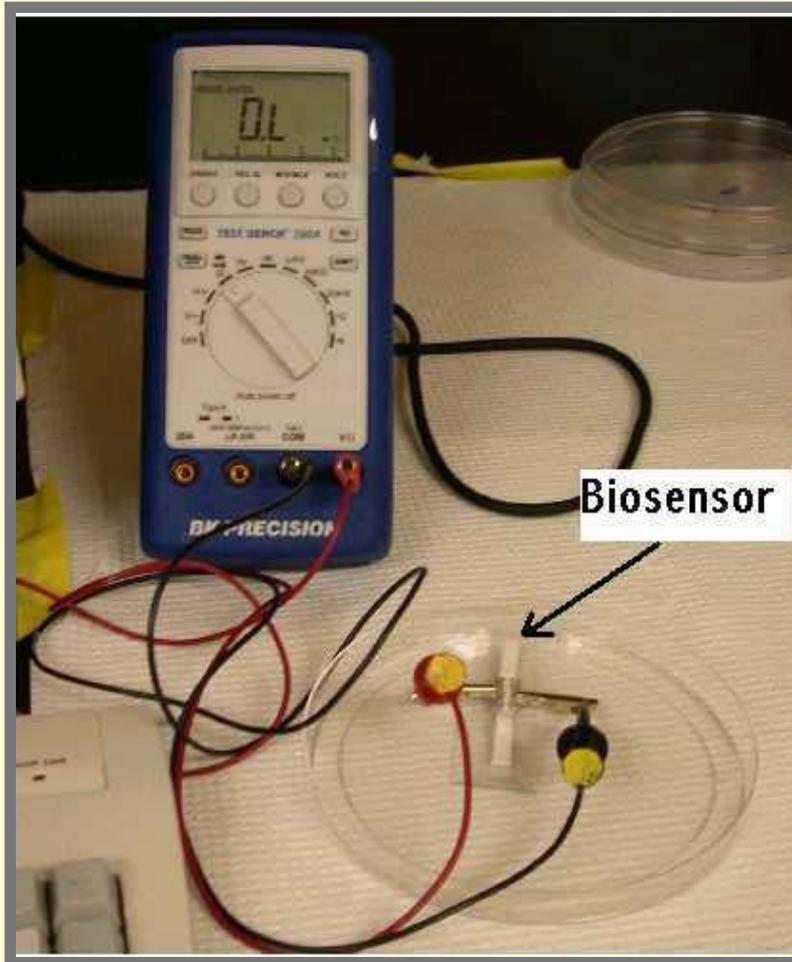


- Bio-recognition membrane cleaved by specific target
- Sample flows into electrodes and changes resistance drastically
- Ideally ∞ transduction/amplification (enzyme activity)
- Zero power consumption until target detection
- Applicable widely to bio-sensing

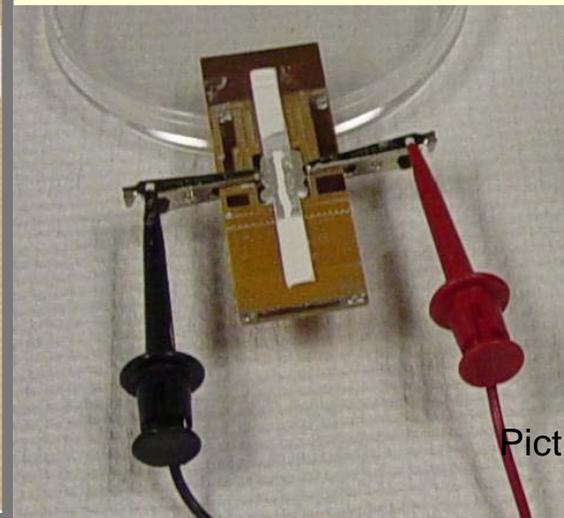
S. S. Sridharamurthy, et al. *Lab on a Chip* 2006, vol. 7, pp. 840-842

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Example: Nanowire-based Biosensor



Dimension: 60mm x 5mm



Picture of biosensor strip

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Agent/Matrix Research Areas

- Rapid specific detection
- Stability of agents in foods and in processing
- Surrogates for specific agents or classes of agents
- Non-specific, rapid methods to identify adulteration
- Sample acquisition and pre-analytical processing
- Supply chain informed detection and diagnostic strategies
- Evaluation and validation of elegant detection methods in food system situations

Broad Academic Collaboration



Diverse Industry and Association Collaboration



Collaborating Across Agencies



U.S. Food and Drug Administration

CENTER FOR FOOD SAFETY AND APPLIED NUTRITION
OFFICE OF REGULATORY AFFAIRS



United States Department of Agriculture



Department of Health and Human Services
Centers for Disease Control and Prevention



Agricultural Research Service

the in-house research arm of the U.S. Department of Agriculture

aphis.usda.gov



Cooperative State
Research, Education, and Extension Service



United States Department of Agriculture
Food Safety and Inspection Service



ERS

ECONOMIC RESEARCH SERVICE
United States Department of Agriculture

The Economics of Food, Farming, Natural Resources, and Rural America



Sandia
National
Laboratories



State/Local Agencies

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE



Defending the **safety** of the **food**
system through **research** and
education

<http://www.ncfpd.umn.edu>

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Projects by theme – Agent behavior

Ongoing Projects

Thermal and Chemical Inactivation of Select Agent Toxins in Liquid Foods

Ted Labuza, University of Minnesota

Francisco Diez-Gonzalez, University of Minnesota

Validation of Methods for Decontamination of Food Processing Equipment and Facilities Deliberately Contaminated with Bacillus Spores

Peter Slade, National Center for Food Safety and Technology (NCFST), Illinois Institute of Technology

Extraction of Bacillus anthracis Spores and Ricin from Liquid Foods and its Potential Utilization for Inline Detection

Ted Labuza & Francisco Diez-Gonzalez, University of Minnesota

Extraction and Concentration of Chemical (Tetramethylenedisulfotetramine) and biological (ricin) toxins using Molecular Imprinted Electrospun Fibers Coupled with Detection at Aptamer Modified Polymer Electrodes

Keith Warriner, University of Guelph

Detection and Removal of Select Agents from Complex Food Matrices: Phase II

Lee Ann Jaykus, North Carolina State University

Development of biologically modified electrically-active magnetic nanoparticles (nano-BEAMs) for direct capture and concentration of Bacillus anthracis spores and cells in various food matrices

Vangie Alocilja, Michigan State University

NATIONAL CENTER FOR
FOOD PROTECTION AND DEFENSE
A HOMELAND SECURITY CENTER OF EXCELLENCE

Projects by theme – Agent behavior

Ongoing Projects

A Microfluidic Approach for Separation and Concentration of Bacterial Spores from Milk and Juices

Suresh Pillai, Texas A&M University & Ali Beskok, Old Dominion University

A Simple and Rapid Method for the Simultaneous Purification and Concentration of Nucleic Acids and Proteins from Food Matrices

Charles Young, The Johns Hopkins University Applied Physics Laboratory

Optimized Detection of Intentional Contamination Using Simulation Modeling

Don Schaffner, Rutgers University & Craig Hedberg, University of Minnesota

Development of a Multiplex Bio-barcode DNA Biosensor for Bacillus anthracis Detection Without PCR Amplification

Vangie Alocilja, Michigan State University

Capture and Detection of Botulinum Neurotoxin (BoNT) in Complex Food Matrices using Novel Biosensor Platforms

Eric A. Johnson, University of Wisconsin-Madison

Stability of BoNT in Food Matrices

Eric A. Johnson, University of Wisconsin-Madison

Identification and Characterization of Temperature-Dependent Virulent Genes in Y. pestis, Y. pseudotuberculosis and Y. enterocolitica

Teshome Yehualaeshet, Tuskegee University

Projects by theme – Agent behavior

Completed Projects

Determination of Y. pseudotuberculosis Survival in Milk under Temperature Stress

Teshome Yehualaeshet, Tuskegee University

Hydrophobic Extraction of B. anthracis Spores from Liquid Foods

Francisco Diez-Gonzalez, University of Minnesota

Ted Labuza, University of Minnesota

Electrochemical Biosensors for B. anthracis

Vangie Alocilja, Michigan State University

Rapid Testing for Botulinum Toxin using Egg Yolk Antibodies

Mark Cook, University of Wisconsin–Madison

Botulinum Neurotoxin Sensing Technologies

Eric Johnson, University of Wisconsin–Madison

FASTMAN Integrated Device for Detection of Select Agents

Vivek Kapur, University of Minnesota/ANDX

Biosensors for Detection of Chemical Toxins

Paul Takhistov, Rutgers University

Projects by theme – Agent behavior

Completed Projects

Bioluminescent Bacteria as Biological Sensors for Toxic Agents in Food

Vangie Alocilja, Michigan State University

Bioluminescent Imaging for High Throughput Screening for Bacterial Pathogens and Toxins

Mansel Griffiths, University of Guelph

A Systematic Approach for the Detection of Bioterrorism Agents in Complex Sample Matrices

Lee-Ann Jaykus, North Carolina State University

Concentrating Bacterial Spores from Milk and Juices using Dielectrophoresis-Based Microfluidic Capture Systems

Suresh Pillai, Texas A&M University

Ali Beskok, Old Dominion University

Extraction, Concentration, and Detection of Toxins in Solid Food Systems using Molecular Imprinted Polymer Films

Keith Warriner, University of Guelph

Subrayal Reddy, University of Surrey (UK)

Heat Inactivation Kinetics of Spores in Liquid Milk

Ted Labuza, University of Minnesota

Francisco Diez-Gonzalez, University of Minnesota