2011-2015 Action Plan for NP108

Strategic Action Plan: National Program 108 - Food Safety

Goal: National Program (NP) 108, *Food Safety* provides through research, the means to ensure that the food supply is safe for consumers; and that food and feed meet foreign and domestic regulatory requirements. Food safety research seeks ways to assess, control or eliminate potentially harmful food contaminants, including both introduced and naturally occurring pathogenic bacteria, viruses and parasites, toxins and non-biological-based chemical contaminants, mycotoxins and plant toxins. Food safety is a global issue; thus, the research program involves both national and international collaborations through formal and informal partnerships. Accomplishments and outcomes are utilized in national and international strategies delivering research results and advances to regulatory agencies, commodity organizations, industry and consumers.

The safety of the food supply became an increasingly visible public health issue and a national priority for the Federal government. Outbreaks of foodborne illness are seen as a major cause of morbidity and mortality, and economic devastation both nationally and internationally. The full extent, specifically the cost/burden resulting from these outbreaks, remains unknown. The cause of the increased outbreaks also remains unresolved, but issues such as intensive food production, rapidly increasing international trade in foods, changes in consumption habits, and travel and immigration of peoples are regarded as areas of concern.

Persistent outbreaks of major commodity-specific foods that may directly affect public health, regulations, industry, and trade, require our immediate attention. Research towards improving public health requires reverse our thinking on the food chain, and the food chain to be treated as a single entity, not separated into pre-/post-harvest. Food safety research has also changed during the past decade, having moved past simple, surveillance/prevalence studies to asking more complex questions. Consequently, researchers are required to think creatively to solve problems, which means considering alternate perspectives, exploiting new opportunities and technologies, and crossing conventional boundaries. Multidisciplinary collaborations, especially between Centers/Institutes, in and internationally are an absolute necessity. Therefore the Program will draw upon relevant expertise and coordinate and effectively integrate resources to develop focused strategies for solving specific problems. In this way the Program as a whole is expected to substantially enhance the impact of its research accomplishments.

Relationship of this National Program to the ARS Strategic Plan: Outputs of NP108 research support the "Actionable Strategies" associated with the performance measures outlined below from the ARS Strategic Plan for 2006-2011, Strategic Goal 4, Enhance Protection and Safety of the Nation's Agriculture and Food Supply. Objective 4.1: Provide the Scientific Knowledge to Reduce the Incidence of Foodborne Illnesses in the U.S.

> **Performance Measure 4.1.1:** <u>Develop new technologies that assist ARS customers to detect, identify, and control foodborne diseases affecting human health.</u> **Target:** Cumulatively, 40 new technologies developed and used by ARS customers.

<u>Component 1: Foodborne Contaminants</u>

The production, processing and distribution system for food in the United States is a diverse, extensive, and easily accessible system. This open system is vulnerable to introduction of contaminants through natural processes and global commerce, and by intentional means. Thus the food supply must be protected from pathogens, toxins, and chemical contamination that cause disease in humans. The Food Safety Research Program seeks ways to assess and control potentially harmful food contaminants. ARS will conduct research and provide scientific information and technology to producers, manufacturers, regulatory agencies, and consumers to support their efforts to provide a secure, affordable, and safe supply of food, fiber, and industrial products.

Problem Statement 1.A Population Systems

The populations themselves may be multi-layered, for example, microbial, animal, plant, human, or environmental, or any combination of these. This approach unifies pre-and post-harvest food safety into a single entity, as it identifies and characterizes the movement, structure, and dynamics of populations throughout food production and processing; hence, the entire continuum. At a microbial level, the diversity and complexity within environments and food matrices may change with spatial and temporal influences, or with the competitive or synergistic relationships among pathogens and commensals. Microbial populations influence the safety of food, that is, the environment may determine the conditions under which a microorganism exists, and the microorganism may in turn influence the conditions prevailing in the environment. An identifiable area of study would include, for example, biofilms. Biofilms combined with quorum sensing studies could be extended to investigate polymicrobial communities found within the food chain continuum. Since interrelated they fall under both Problems Statements 1 and 2.

<u>Research Needs</u>

- Develop approaches that will evaluate the impact of intervention or management strategies on microbial contamination in the food continuum. These may include epidemiologic methods that will facilitate the understanding of quantitative data on pathogen load within the safety continuum, and facilitate the linking of food safety outcomes to public health outcomes.

- Develop new approaches to analyze and interpret more complex and emerging microbial methods; for example, molecular serotyping and phylogenetic analysis.
- Develop and use different approaches/designs for both microbial and population-based studies, monitoring of emerging pathogens, and supplying data for identified data gaps.
- Develop multidisciplinary approaches to understand the development, persistence, and transmission of resistant genes, and antimicrobial resistant microorganisms.
- Develop and validate best sampling collection protocols to maximize the probability of describing the exceedingly large number of diverse organisms that inhabit ecological communities.
- Determine any particular ecological niche or reservoir for a specific pathogen, and elucidate any factors, for example: environmental, nutritional, and/or biological, which enhance or reduce fitness characteristics related to persistent colonization, survival and growth.
- Determine the complex interactions among fungal/crop/environmental factors/production practices. Specifically, research will be focused on factors that elevate mycotoxins and their effects on the availability of a safe food supply.
- Determine/evaluate the role of food safety on public health outcomes, including acute and chronic sequelae.

<u>Anticipated Products</u>

- Epidemiologic studies will provide a scientific approach for population-based studies on new detection methods and interventions, to design and evaluate risk factors for potential control or intervention strategies, and a framework to integrate genomic data with disease in populations.
- Ecologic studies will determine the attributes and changes in the ecological communities in order to understand the transmission and dissemination of pathogens and toxins in and among food producing animals and crops, and the interactions and relationships within the population community.
- Host-pathogen relationship studies will provide an understanding of the acquisition of genetic traits, such as the development and movement of resistance genes; traits connected with colonization and evolution of virulence; the role of protozoa in harboring or transmitting bacterial foodborne pathogens (Trojan horse concept); and the role of commensals.

<u>Potential Benefits</u>

- Epidemiologic studies conducted in various populations (microbial, animal, plant, or human) will help bridge the gap between agriculture and public health.
- The knowledge gained will help understand the transmission and dissemination of pathogens and toxins in and among food producing animals and crops; develop effective production practices and intervention strategies; develop and validate predictive microbial models; and provide data for risk assessments.

Problem Statement 1.B Systems Biology
The 2006-2010 Action Plan included the implementation of an "omics" research effort to sequence and annotate the genomes, develop microarrays, and construct data-bases of several critically important pathogens. Although some sequencing efforts will continue in the next research cycle, it is clearly recognized that "omic" technologies are in reality a series of methods used to examine more complex challenges that involve a systems approach to the study of pathogens. The concept of "systems biology" involves an integrated, systematic approach combining genomics, proteomics, transcriptomics, and metabolomics, as well as bioinformatics. Included within this Problem Statement is the study of pathogenicity and virulence. The pathogenicity of a specific organism is an issue at all stages of the food safety continuum. It is important to differentiate between microorganisms that are relevant to agriculture versus food safety and public health. Understanding pathogenicity is critical for pathogen intervention and control, modeling, and providing data for the development of risk assessments by regulatory agencies. Pathogens have the capacity to readily and rapidly adapt and evolve. Implemented control strategies may lose their effectiveness forcing the development of new production processes and products to maintain and improve the safety of foods. This in turn may restart the cycle of pathogen adaptation resultant from the altered environmental stresses. Risk assessment(s) conducted by our regulatory stakeholders are also predicated on understanding the pathogen, the dose response, the behavior in foods, and any positive or negative influences that may affect virulence. Assessing the virulence of foodborne organisms and differences among serotypes is critical in implementing new surveillance and intervention strategies.

Research Needs

- Assist in the development of specialized detection technologies, for example to differentiate pathogenic from non-pathogenic strains, and elucidate the differences between pathogens and non-pathogens.
- Conduct genome sequencing of specific pathogen strains to provide data for developing high resolution genotyping and molecular serotyping methods, and for identifying virulent strains.
- Expand knowledge on virulence factors: Why are some species/serotypes are highly virulent while others less virulent; identify and characterize virulence factors and determine their interactions; determine if and/or how virulence is directly related to the infective dose.
- Understand the adaptive responses to intrinsic and extrinsic stressors, and determine any role in pathogenicity and virulence. Determine if resistance genes affect virulence or pathogenicity.
- Identify and characterize virulence attributes and responses of specific pathogens to their environment relative to changes in immunogenicity in the host.
- Determine why evolutionary shifts occur when populations system studies fail to identify the selection pressure.
- Determine whether quorum sensing is involved in regulating virulence factors or persistence. This area is appropriate for metagenomic studies to understand the fundamental composition of microbial communities and their contribution to pathogen

persistence and/or toxin production, and metabolism.
- Understand the effect of environmental (extrinsic and intrinsic) conditions under which microorganisms exist, and determine how the microorganism may in turn influence the conditions prevailing in the environment.
- Develop a comprehensive database that can used to supply information on the ecological context of molecular, physiological and genetic data. For example; develop an integrated information system for risk management prevention and surveillance of foodborne diseases and/or genomic and proteomic databases specific to unique Program generated data. This should be directly coordinated and conducted within Problem Statement 5.
- Develop new or modified effective biocontrol organisms and delivery systems that do not introduce toxic factors; for example, in the control of mycotoxins.
- Delineate the role of endophytic fungi in regulating plant metabolism and in providing effective defense against predators and stresses.
- Identify unique fungal genes for specific biological and physiological functions.
- Determine how plant and environmental factors affect the mycotoxin synthesis, as it relates to food safety and public health.
- Utilize "omic" technologies in order to develop the multidisciplinary approach to address this Problem Statement.

Anticipated Products

- This approach provides a unique opportunity to understand the basic genetic components of pathogens, their expression, and directly relate this information to the microorganism's biology.
- While the tools for gene expression studies are available, there needs to be an increased focus on understanding how the studies will be performed and interpreted, and how they can be used to promote food safety.
- Establish a metagenomics approach to selected research areas which will for example, allow determination of metabolic contributions to risk.

Potential Benefits

- Implementing a "systems biologic" approach will impact various areas. For example: the generation of data for the specific development of molecular phylogenetics.
- The approach will identify genes which code for resistance to antimicrobials and disinfectants, for toxin production, or for the ability to grow in specific ecological niches.
- Regions of the genome that may have variations in the rate of nucleotide substitution or in the rate of intergenic recombination will be identified. These data can be utilized for the design and optimization of detection technologies, and to facilitate comparative genomic analyses for determining critical areas for targeting strategies for controls, and improve molecular tracking.
- This approach provides an understanding and comprehension of organisms and how they may induce disease, such as data on genes that contribute to pathogenicity; gene expression involved in virulence and/or viability in foods; and understanding population genetics and epidemiology.

- Implementation will provide better scientific data for more complete risk-based decisions.

Problem Statement 1.C Technologies for the Detection and Characterization of Microbial Contaminants

Challenges arise from either uncontrolled microbes entering through raw materials, or contamination during processing. To answer these challenges, detection and characterization is required at the earliest possible stage in the food chain, providing the necessary data for targeted interventions and reducing the need for recall of food products from purchase endpoints. Where possible, technologies must be developed for the entire food chain which allows the most effective and rapid detection and characterization capabilities. It is critical that research be focused to address the specific needs of the stakeholder, while balancing the inherent capabilities of the Program. That is, the need to focus on the most promising technologies (depending on the matrix) or point of use, and whether the technology is used for baseline studies, traceability and/or forensics. This requires that decisions be made relative to what should be detected, and the required level of detection and characterization. Further, this dictates that technologies which have the highest level of detection/characterization capability might not necessarily be the most practical, useful, economically viable, or be readily implemented. High-through-put analysis is important, but it may be impractical. Coordination among various agencies with similar initiatives and priorities will be critical.

Research Needs

- Develop and validate best sampling collection protocols to maximize the probability of detecting contaminants; combined with innovative approaches to sample processing [universal separation/concentration steps].
- Develop culture methods that do not bias the types of strains isolated, for example: virulence factors, resistance attributes, and serotype) food, animal/plant, and environmental samples.
- Develop and validate sample recovery methods. More attention must be paid to the initial sample preparation as various matrices present particular problems.
- Develop and validate culture methods that detect viable-but-non-culturable (VNC) cells.
- Developing data to assess the risk that VNC pose. This requires integration and coordination with Problem Statement 5.
- Development and validation of technologies for multiple agents in light of limited time for trace-back and attribution, and where fiscal and personnel resources are also limited.
- Develop and validate technologies that have improved speed, are cost effective, and provide most, if not all required informational detail for the determination and implementation of subsequent actions.
- Develop and validate technologies utilizing “omics” and nanotechnology where appropriate.
- Develop and validate technologies that allow uniformity of implementation both nationally and internationally [may require Codex involvement].
- Develop and validate technologies that have a critical use in food defense.

- Develop and validate integrated food safety/public health databases [national and global]. This will require significant collaborative efforts.
- Develop detection technologies that consider the needs for surveillance systems, not just technologies for monitoring the food supply.

<u>Anticipated Products</u>

- Promising technologies will be advanced. Technology transfer has to be done quickly, and where possible, and appropriate, will undergo validation through national or international bodies (FERN, Codex).
- Research that offers minimal outcome or impact will be terminated, and alternate approaches formulated. For example, detection methods related to serotyping and subtyping pathogens are useful; however, stronger emphasis <u>must</u> be placed on methods for more effective identification.
- Development of technologies must yield method(s) that are faster and yield improved resolution.
- In developing technologies decisions cannot be made in isolation. There needs to be an integration of biology, epidemiology and the physical sciences systems.

<u>Potential Benefits</u>

- ARS will lead in developing and specifically validating technologies that have public health, regulatory, trade, industry and research use; that is, a commonality of interests between government and stakeholders.
- Effective and efficient technologies that can be readily implemented will allow improved response times to events, and subsequently allow for the development of mechanisms for treating foods taken out of commerce.
- The technologies will provide data to identify areas where interventions are most critically needed, thus assisting the implementation of HACCP programs by FSIS, FDA, and their regulated industries.
- The data will also assist to develop and validate predictive microbial models and to help fill identified data gaps.

Problem Statement 1.D Intervention and Control Strategies
Intervention and control strategies will help to significantly decrease or eliminate pathogens in food animals and their derived products (eggs/milk), seafood and plant crops (produce/grains/ tree nuts) during critical periods of production and processing. Reduced shedding of zoonotic pathogens by food producing animals, and contamination of seafood and plant material will subsequently help reduce the pathogen load during slaughter/harvesting, and subsequent processing and storage. Recent foodborne outbreaks have shifted attention from solely animal origins to a balance of animals (meats) and plants (produce). This provides an opportunity to strengthen and increase research specifically addressing produce needs.

Many food processing/storage technologies have the ability to inactivate microorganisms to varying degrees; however, the intensities required can result in adverse functional and/or sensory properties, combined with a significant reduction in quality. Consequently, there is a continued need to develop and subsequently combine new/innovative processing technologies using the intelligent hurdle concept. In the concept, incremental changes in interventions are additive or synergistic, leading to greater control over pathogen growth without potential changes in food quality or reduction in nutrition. Unintended or unanticipated consequences of alternate technologies and processing intervention strategies such as changes in virulence, production of toxins, pathogen resistance or selection of resistant strains, and shifts in microbial ecology should certainly be considered for further investigation.

Research Needs

4.1: Animals and their Derived Products

- Develop interventions that prevent colonization or modulate pathogens from the gut; target specific metabolic endpoints; and decrease shedding of zoonotic pathogens at the time of slaughter.
- Determine the role of transportation and lairage; slaughter/processing methods and equipment on pathogen survival, transfer, post-harvest processing and storage.
- Identify and describe the critical points in production and processing that can be mitigated through the development and implementation of intervention and control strategies.
- Determine the effect of intrinsic and extrinsic parameters in production, processing and storage of eggs and milk.

4.2: Seafood

- Elucidate the mechanism(s) of pathogen introduction, persistence and survival in shellfish.
- Identify and describe the critical points in production and processing that can be mitigated through the development and implementation of intervention and control strategies for shellfish and USDA regulated finfish (Catfish).

4.3: Plant Crops/Produce

- Elucidate the mechanism(s) of pathogen introduction, persistence and survival. Determine the role of: environmental factors; seasonality, production cycles; adjacent land use, buffer zones, water sources (irrigation); epiphytic and soft rot microorganisms on pathogen internalization and/or attachment; and pathogen occurrence and movement.
- Develop practices and tools to control and predict the transport and fate of pathogens.
- Determine differences associated with the production and processing of conventional and organic grown crops.
- Determine the role of harvesting methods and equipment on pathogen transfer, post-harvest processing and storage.
- Identify and describe the critical control points in both production and processing of fresh produce, plant crops (grains/tree nuts) that can be mitigated through the development and implementation of intervention and control strategies.

- Develop methods to prevent the growth of pathogenic and spoilage microorganisms in minimally preserved, brined, and fresh-cut foods.
- Develop predictive models that describe the growth, survival and inactivation of critical pathogens, conducted in collaboration with Problems Statement 5.

4.4: General

- Develop, evaluate, and validate through laboratory, pilot-plant processing and commercial processing facilities the effect of single and combinations (parallel and serial) of intervention technologies (multi-target approach) on pathogen reduction.
- Determine whether combinations of non-thermal technologies can be incorporated in the hurdle concept; and determine whether single or combinations of non-thermal technologies are more effective if used in combination with traditional interventions.
- Increase fundamental understanding of the mechanisms, modes and sites of action at the cellular level of various intervention (inactivation) processes, and combination(s) thereof.
- Develop and evaluate the outcome/impact of post-harvest interventions options for small and very-small FSIS regulated plants.
- Use a "systems approach" to evaluate intervention and control strategies.
- Develop mechanisms and approaches to evaluate the effect of intervention and control strategies on food safety. That is, any technology transferred must have utility, have the capacity to be readily implemented, and be effective in reducing pathogen load, and/or biological/chemical contaminants.
- Use knowledge of host pathogen relationships/population systems to determine and evaluate interventions and control strategies.

Anticipated Products

- Intervention strategies will be developed to eliminate and/or control microorganisms in animals and their derived products, seafood and plant production, processing and storage systems. An underlying assumption is that production control interventions reduce downstream contamination which subsequently reduces disease risk.
- Efforts will focus on developing environmentally compatible technologies.
- Strategies will be developed for operations of all sizes (large to very small).
- Pathogens may develop resistance to some interventions; thus, efforts should focus on development of combinations of new or innovative intervention technologies for (minimal) processing.
- Interventions will be developed based on an understanding of their modes of action and effects on the microbial ecology of a food product, since inadequate suppression of spoilage could create an opportunity for human pathogen growth and toxin production.

Potential Benefits

- Development of intervention strategies can provide critical data to industry, commodity organizations and regulatory/action agencies that allows for the development, evaluation and implementation of Good Agricultural Practices (GAP's); Good Manufacturing Practices (GMP's) or regulations based on sound science.
- Studies will enable methods/strategies for the evaluation of any developed interventions and controls.

Problem Statement 1.E Predictive Microbiology and Data Acquisition
The basic principle of predictive microbiology is that the behavior of any microorganism is deterministic and able to be predicted from knowledge of the microorganism itself, and the microorganism's immediate environment. Behavioral predictions are [with limitations] accepted as an integral part of microbial risk assessment used to support food safety measures by both industry and regulatory bodies. It is widely accepted that predictive microbiology, in order to be effective, requires a multidisciplinary approach. This is a special challenge that necessitates coordinated efforts with other research institutes throughout the world.

Research Needs

- Develop predictive microbiology [models] that have validity and usefulness while addressing the limitations of the predictive ability. This includes the influence of challenge strain(s); assessment of a model's performance; predictive value on extrapolation; and efficacy especially in complex food matrices where the intrinsic and extrinsic parameters may change.
- Determine if growth/no-growth interface models predict the probability of growth occurring when a population faces more than one stressor/constraint.
- Develop models that have utility for risk assessment from both the producer and consumers perspective. There are distinctly different consequences of conservative (over) vs. non-conservative (under) prediction of growth (or risk).
- Determine if changes in the microorganism(s) themselves occur, due to up/down regulation of genes; quorum sensing; or transfer of genetic information between species.
- Utilize the inactivation data to model pathogen and non-pathogen behavior in complex food systems. These types of studies are fundamental to developing HACCP systems and regulations.
- Provide predictive models for external examination and review through such efforts as the ARS Pathogen Modeling Program (PMP).
- Provide through national/international efforts an accumulation of data into a shared informational database. This is being done in-part through the continued development and expansion of the international collaborative project Combase, and the National Antimicrobial Resistance Monitoring System (NARMS).
- Provide relevant data to regulatory agencies for use in HACCP programs, risk assessments, labeling, persistence, and issues relative to international trade.
- In order to address the "systems" approach, develop and maintain the inherent

potential underlying the data produced by the Programs sequencing efforts.

- Increase the focus on bioinformatics (computational biology) as more sequence data becomes available, and the complexity of both the data and questions being asked become more sophisticated.

Anticipated Products

- The ARS Food Safety Program does not develop or conduct risk assessments (RA), where RA is defined as the determination of a quantitative or qualitative value of risk related to a specific situation and a recognized hazard.
- The Program conduct research and provide data when requested by our regulatory stakeholders (FSIS, FDA) for their use in conducting risk assessments.
- Collaborations with regulatory and public health agencies will be strengthened regarding research for RA development efforts, so as to effectively utilize the inherent ARS expertise and modeling mechanisms.
- Methods used to identify data gaps will be described and integrated into the research project.
- Data acquisition will be an ambitious interdisciplinary research challenge that will eventually translate into improved public health.

Potential Benefits

- To generate data on the responses of microorganisms to both defined and changing environmental conditions, and to translate these data into mathematical models and user friendly software tools such as the PMP. These will be readily usable by national and international regulatory and public health agencies, and industry, to assist in ensuring the safety of the food supply.
- Internet-based database construction and development through Combase will ensure that data-mining and acquisition will continue to be coordinated. Database and bioinformatics efforts become increasingly important so that biologists have the ability to gain information that will foster technological innovation, and an understanding of the genetic basis of foodborne microorganisms.

Problem Statement 1.F Chemical and Biological Contaminants: Detection Methodology, Toxicology and Toxinology

The regulation and control of veterinary drugs, chemical residues, heavy metals, persistent organic pollutants, and biological toxins derived from bacteria, fungi and plants are an integral component of any food safety program. To protect public health and the environment, regulations [through Laws] have been passed and implemented that set limits on contaminants in edible agricultural products. Compliance and enforcement of these regulations is a critical role of the Program's stakeholders that requires the availability of practical detection and characterization methods for chemical residues (dioxins, pesticides), veterinary drugs (antibiotics, beta-agonists), heavy metals (As, Cd), and organic pollutants (polybrominated diphenyl ethers). In addition to regulatory monitoring there is a need to understand the biological effects of any inadvertent human or animal contamination. ***Toxicology*** examines the relationship between dose and its effects on the exposed organism; whereas ***Toxinology*** deals specifically with animal, plant and microbial toxins produced by or accumulated in living organisms, their properties and their biological significance for the organisms involved. This Problem Statement also includes food safety research directed towards methods for detection and identification of mycotoxins, their toxicity evaluation and mechanism of action. Research on the development of biocontrol technologies, and crop/fungal/toxin relationships is found under Problem Statement 2. Research on production practices and expert systems, and breeding resistant crops, will either be limited or where appropriate transferred to other National Programs within the 300 series.

<u>Research Needs</u>

- Develop and validate accurate, rapid, and easy to use analytical detection methods: single/multiclass, single/multi-contaminant analytical methods; lab and field-based (real world) methods and instruments for analytical screening.
- Develop and validate mechanism/action-based bioassays for laboratory and field use.
- Develop and validate multi-task on/in-line [field] inspection technologies [for all size processors] that detect contaminants and quality attributes simultaneously at required line speeds [functioning in real or near real-time].
- Develop and validate assays for assessing the efficacy of various processing methods to reduce or eliminate the toxicity in contaminated foods for human/animal consumption.
- Develop and validate assays that can be used for and in toxico/toxinological studies.
- Identify major sources of contaminants. Develop and validate intervention methods [for example, in bioremediation] to reduce bioavailability.
- Determine the fate and transport of contaminants and their derivatives in food systems and the environment. Provide parameters on residue depletion and withdrawal rates. Determine factors that affect fate and transport.
- Develop and validate when requested, technologies that have a critical use in food defense.
- Determine the dose-response relationships and tissue specificity of biological toxins.
- Determine the relevance of biotoxins with undetermined toxicity through the use of animal models. Determine/improve exposure assessment data.
- Determine the use of biomarkers as a measure of exposure and disease susceptibility.

<u>Anticipated Products</u>

- The successful implementation of technologies developed and validated through research is the major goal.
- These technologies provide tangible benefits through a more effective and efficient means of monitoring the food supply, and environment where food is grown. Better methods assist researchers conducting toxico/toxinological studies.
- Toxico/toxinological studies provide basic and applied knowledge on the effect of exposure to biological toxins.

Potential Benefits

- This research also provides data for better scientific and regulatory decision-making, reducing the likelihood of tolerance limit-errors, protection of consumers, and prevention of economic losses resulting from inappropriate regulatory actions.

Component 1 Resources

The following ARS locations have research projects addressing the Problem Statements identified under Component 1

Beltsville, MD
Wyndmoor, PA
West Lafayette, IN
Peoria, IL
Ames, IA
Albany, CA
Maricopa, AZ
Clay Center, NE
Fargo, ND
College Station, TX
Fayetteville, AR
Stoneville, MS
New Orleans, LA
Dawson, GA
Athens, GA
Raleigh, NC