Research Needs and Future Directions

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The recent produce-associated outbreaks demonstrate the critical need for increased research in multiple areas to ensure the safety of fresh produce. Unquestionably, the food safety challenges facing the growers, packers, processors, retailers, and consumers of fresh and fresh-cut produce are complex and multifaceted. Although established and ongoing research projects have provided insights on produce contamination at multiple steps in the supply chain, the goals of future research activities are to develop science-based intervention strategies that minimize the risks of potential contamination and strengthen the safety of fresh fruits and vegetables. Produce safety research grants funded by both the private (FEPSRI 2007) and public sectors (NRI 2008) have identified four key research areas to be pursued: internalization of pathogens into produce, interventions, vectors, and environmental risk factors. There is particular interest in the microbial ecology of pathogens, including their interactions with non-pathogenic microflora and identifying their routes of contamination (Gourabathini and others 2008; Cooley and others 2006).

In the context of produce safety, risk reduction can take one of three forms: prevention (to include microbial ecology), containment, and eradication. The most common postharvest intervention for produce, washing in chlorinated water, does not completely eliminate pathogens from the surface of produce. The general lack of a commercially acceptable kill step has limited the response options for growers, packers, and processors. Irradiation was recently approved by the FDA for use on lettuce and spinach to inactivate pathogens and extend shelf life (FDA 2008). Irradiation, alternative sanitizers including ozone, electrolyzed water, chlorine dioxide, peroxyacetic acid, and other nonthermal food-processing technologies, such as High Pressure Processing (HPP), biocontrol, etc., may provide additional tools to ensure the safety of fresh produce and protect public health.

The fresh produce industry is very interested in practical and useful interventions that can be readily applied in the field, packinghouse, or processing plant (Gombas 2008). It is important to provide research answers to the most pressing questions, to develop solutions that are relevant to the industry needs, and for scientists in academia and government to collaborate with industry partners on these mitigation strategies. Intervention technologies or treatments developed in the laboratory often do not result in effects of the same magnitude when applied in commercial operations. Conducting studies in actual commercial settings may involve the introduction of surrogates to fresh produce in the field, packinghouse, or processing plant. Alternatively, controlled growing chambers, such as greenhouses or pilot-scale processing facilities may be developed to allow closer study of human pathogens in realistic settings.
In recent years, the produce industry has held several high-level meetings to prioritize produce safety research. At these meetings, producers, processors, retailers, regulatory agency officials, and academics identified and assessed the key research gaps in our current state of knowledge and addressed barriers to improving the safety of fresh and fresh-cut produce. Two notable commodity-specific meetings held in 2007 included one focused on tomato safety research needs and hosted by the Joint Institute of Food Safety and Applied Nutrition (JIFSAN), with the University of Florida, Institute of Food and Agricultural Sciences (IFAS) in College Park, MD, (JIFSAN 2007), and a second focused on leafy greens safety research needs, and hosted by the United Fresh Produce Association in Herndon, VA, (UFPA 2007). By drawing on the collective expertise, knowledge, and experiences of the attendees, a prioritized list of recommendations that emphasized research efforts with high value and broad applicability was developed. So, with the conclusions and recommendations of these meetings in mind, a brief summary of the information presented in the preceding chapters provides the foundation for fresh fruit and vegetable safety research needs.

Prevention and Microbial Ecology

The epidemiology of several produce outbreaks suggests that focusing exclusively on prevention strategies is insufficient in dealing with the full range of problems associated with produce contamination. Before contamination can be prevented, the avenues of contamination must be more fully understood. A clearer understanding of the ecology of human pathogens in the field (Ch. 1, 2), on the surfaces of fruits and vegetables (Ch. 3), and on food contact surfaces (Ch. 18) is required. This understanding also provides a basis for improved practices and infrastructure in fields (Ch. 4–8), in packinghouses, in processing plants (Ch. 16–18), and at the point of sale (Ch. 15). The following are some of the critical questions pertaining to prevention:

- What are the physical, cultural, and economic barriers that have prevented adoption of available risk control measures such as good agricultural practices (GAPs) on farms?
- What soil, water, climatic, or environmental factors allow human pathogens to persist in and near fruit and vegetable production fields?
- What are the reservoirs for pathogens in the production environment?
- Are current recommendations for setbacks and buffer zones scientifically determined and verifiably adequate?
- Are some strains of pathogens more likely to be associated with certain fruits and vegetables? If so, can this association/relationship be used to develop new control strategies?
- How long can pathogens survive and grow in agricultural soils and on crop plants? Does survival on associated weed plants increase risk for fruits and vegetables?
- What aspects of crop production (tillage, chemical inputs, soil amendments, crop rotations, etc.) most directly influence this residence time?
- What are the most significant animal vectors for introducing pathogens to fruits and vegetables in the production environment?
- Do insect vectors contribute to pathogen transmission in the field?
• What are effective exclusion measures for feral animals?
• What new animal husbandry practices can be used in livestock operations to reduce microbial hazards and risks associated with raw manure?
• Under normal growing conditions, is internalization via the roots a significant risk factor in the field? If so, how does this compare to surface contamination and also to known internalization risks via wounds, stomata, etc., that can occur during harvesting, sorting, washing, processing, and packaging?
• Are current irrigation water quality standards adequate to prevent pathogen contamination of fruits and vegetables? What microbial water quality standards should be recommended for irrigation water delivered to plants by surface or overhead methods? Can water treatment procedures be implemented in-field?
• What are the transfer coefficients of microorganisms in water, soil, crops, equipment, and food contact surfaces?
• What is the best way to balance the needs for meeting new food safety rules with environmentally sustainable, best land management practices?
• How can compost verification programs be improved?
• What improvements in sanitary design and sanitation can be made to produce handling equipment in fields, packinghouses, processing operations, and in the cold chain?
• How do the various risk factors compare in significance and level of reduction?
• What are the components of a comprehensive risk reduction model for any given produce commodity?
• Can cold-chain monitoring and compliance be improved with new wireless sensor technologies?
• What are the risk factors in retail food stores that can be addressed?

Containment

The containment of pathogens has two aspects: 1) rapid and accurate testing and detection (Ch. 16–18) and 2) developing appropriate response plans when contamination is detected. Well-developed action plans are required to deal with pathogen-contaminated produce in the short (Ch. 6, 19), medium (Ch. 20), and long term (Ch. 21, 22). The following are some of the critical questions pertaining to containment:

• How can fields be tested and certified prior to planting, particularly after potential contamination events occur?
• Is detection of aerial contamination from windblown manure or dust a practical or meaningful risk reduction approach?
• How can microbial sampling of equipment be improved?
• How can the transmission of pathogens from farm, packinghouse, retail food store, and food-service workers be reduced?
• What seasonal or environmental factors would trigger enhanced monitoring in the field?
• What are the parameters of a testing program (methodology, sampling plan, frequency of testing, sample size, etc.) that would adequately detect pathogen
contamination on produce in the field? During sorting, packing, processing, and in the finished, packaged product?

* What role can in-field mobile testing labs play in improving speed, efficiency, and accuracy of microbial testing?
* How can detection and testing tools developed for food safety be adapted for use in agroterrorism or food defense scenarios?
* What monitoring and testing program would detect amplification of pathogens between harvesting, sorting, and processing or packaging?
* Can accurate and rapid testing methods be developed for products with a short shelf life?
* Can communication and information sharing among growers, processors, retailers, and regulators be improved? Are current communication and information-sharing procedures adequate for produce recalls, traceback, and source identification?
* Are current labeling practices sufficient to facilitate traceback and recall of produce commodities? Can Radio Frequency Identification (RFID) or other enhanced technology labeling be used as an effective risk reduction tool?

**Eradication**

Changing industry standard practices to eradicate pathogen contamination will include improved cleaning and sanitizing procedures as well as other chemical treatments (Ch. 9), improved thermal and nonthermal physical treatments (Ch. 10, 12, 13, 14), and advanced research on biological control measures (Ch. 11). The following are some of the critical questions pertaining to eradication:

* Can current processing systems be modified to reduce risks of cross-contamination? Can water flumes be replaced by belts, air beds, or other systems?
* Can aqueous chemical treatments be improved by modification to gas-phase treatments?
* Can a combination of treatments, similar to hurdle technologies used in other food-processing applications, be used to reduce pathogen contamination of fruits and vegetables?
* Can the tools of molecular biology from the study of microbial ecology and biofilm formation also be used to develop new interventions that inhibit or prevent pathogen attachment to fruits and vegetables?
* Can plant pathology and plant breeding tools be used to develop fruits and vegetables that are “resistant” to human pathogens?
* How can new nonthermal processes (pulsed light, pulsed UV, high pressure processing, cold plasma, radio frequency treatment, etc.) be adapted for use with produce?
* Are biological controls suitable for use in controlling or eliminating human pathogens? Can phage technology be used as a pre- or postharvest intervention strategy?
* What are the barriers to the adoption of irradiation to produce other than leafy greens? How can these be addressed?
* Aside from irradiation, are there additional antimicrobial processes that are effective against protected pathogens, such as those that are internalized or that are associated with biofilms?
• How are various intervention methods compared? What standards or metrics can be used to verify the levels of risk reduction achieved through the interventions that are used?
• What nonpathogenic organism(s), i.e., surrogate(s), would be a verifiable indicator for *E. coli* O157:H7? For *Salmonella*?
• Can food contact surfaces be modified to provide antimicrobial characteristics or barriers to microbial attachment?
• What aspects of modified atmosphere packaging (MAP) can be used to enhance active packaging technology?

This summary of information presented in previous chapters provides a framework for identifying key research needs and a starting point for future research approaches that will improve the safety of fresh produce. This list of recommendations is neither exhaustive nor immutable. It must be adaptable and responsive to changing conditions and newly emerging information on produce contamination and safety. The significance and complexity of the problem facing researchers in industry, government and academia may seem daunting, but focused research efforts by recognized experts will provide a better scientific understanding of the issues. This will guide advances in the most important areas of research and will ultimately provide the development of tools to improve the safety of fresh and fresh-cut produce for consumers.

References


