Tomato Safety Research Needs Workshop
February 21-22, 2007
Wiley Building, College Park, Maryland
Workshop Report

INTRODUCTION

Recent outbreaks of salmonellosis associated with the consumption of fresh tomatoes have created an urgent need for an improved understanding of how tomatoes become contaminated with *Salmonella* and other pathogenic bacteria and how these bacteria survive (and grow?) in or on tomatoes. This understanding is critical for developing appropriate and effective prevention, testing, and mitigation strategies.

.A stakeholder forum on tomato safety, organized by Dr. Martha Roberts (Special Assistant to the Director, Florida Agricultural Experiment Station), was held November 30, 2006. Almost 90 individuals representing state and federal regulatory agencies, academia, industry (representing over 85% of the U.S. fresh tomato industry) and associations participated in this UF/IFAS and Florida Tomato Committee-sponsored effort. Information about that forum is available at http://www.research.ifas.ufl.edu. One of the action items identified by the forum for immediate follow-up was to hold a workshop to "identify research needs and priorities" to meet the goal of ensuring tomato safety. This Tomato Safety Research Needs Workshop, sponsored by the University of Maryland Joint Institute for Food Safety and Applied Nutrition (JIFSAN) and the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), was held February 21-22 in the FDA Wiley Building in College Park, Maryland. The two major goals of the workshop were to prioritize research needed to solve the problem of *Salmonella* and other human pathogens in tomatoes and to begin the process of developing a platform for on-going communication and coordination. Forty scientists representing academia, government, producers and trade groups participated (Attachment 1). This report describes the outcomes of the workshop.

BACKGROUND

Dr. Robert Buchanan (FDA/CFSAN) presented background information on the history of outbreaks associated with tomatoes (Table 1), an overview of current knowledge related to the microbiological safety of tomatoes (Attachment 2 is a bibliography of relevant references), and suggested research needs (which were incorporated into the Charge to the Working Groups, Attachment 5). Dr. Buchanan's presentation is Attachment 3.

Dr. David Gombas (United Fresh Produce Association) presented information on research needs for produce safety. He emphasized the difficulty inherent in using preventative controls for ready to eat products because of the need to ensure that they are followed throughout the supply chain. He also discussed the difficulty in moving from general Good Agricultural Practice (GAP) guidance to commodity-specific safety practices. He then described current on-going efforts to identify and prioritize research needs for leafy green vegetables. Dr. Gombas' presentation is Attachment 4.

Table 1 - Tomato Outbreaks 1998-2006

Month	Year	Tomato Type	Agent	Source	Fresh-Cut	Illnesses	Hospitalizations	Deaths
Dec -Mar	1998-99	Tomato	*S.* Baildon	FL		86	15	3
Nov-Dec	2000	Tomato	*S.* Thompson	FL or GA		29	14	0
Jul-Oct	2002	Red round	*S.* Newport[1]	VA		512	31	0
Feb-Mar	2002	Grape	*S.* Newport	FL or MX		12	2	0
Jun-Jul	2002	Roma	*S.* Javiana	FL or MX	Yes	90	3	0
Jun-Jul	2004	Roma	*S.* Javiana	FL, GA or SC	Yes	471	129	0
Jun-Jul	2004	Roma	*S.* Braenderup	FL		123	29	0
Jul-Sep	2005	Red round	*S.* Newport[1]	VA		71	8	0
Jun-Jul	2005	Tomato	*S.* Enteritidis	CA		77	1	0
Nov-Dec	2005	Roma	*S.* Braenderup	FL	Yes	76	18	0
Sep-Oct	2006	Red round	*S.* Typhimurium	OH		186	22	0
Jun-Oct	2006	Red round	*S.* Newport[1]	No traceback		107	8	0
Canadian Outbreak								
Jul	2004	Roma	*S.* Javiana	SC		12	2	0

[1] Identical matching PFGE patterns

CHARGE TO THE WORK GROUPS

To facilitate brainstorming and discussion of the research needs, the workshop participants formed two work groups. These groups were asked to each develop a prioritized list of research needed to address the issue of *Salmonella* and other human pathogens in and on tomatoes. The goal was to produce a manageable list of research needs in priority order for issues along the entire production, distribution, storage, processing, food service and retail chain, along with a brief explanation of the expected impact or value of the research. Factors to be considered in establishing the priorities included:

- The public health impact of the research,
- Whether a specific problem or issue can be addressed quickly using existing technology,
- Whether the information, techniques, or results of one research project are needed before other research can be started,
- Whether the research directly addresses identified data gaps,
- Whether the research addresses a regional or national problem,
- The difficulty and cost of implementing any solutions or changes in practice that might result from the work.

A list of previously identified research needs was compiled based on the results of the previous forum and was provided to the working groups serve as the starting point for discussion (Table 2).

Prioritization of research needs is, in itself, not useful if there is no ongoing mechanism for communication and coordination among the research community, or for communication between researchers and funding agencies, regulatory authorities, and producers. A focused coordinated effort is important to ensure that the results of the workshop and the ongoing research remain effective and efficient. Therefore, secondarily, each working group was asked to consider ways to ensure that such communication and coordination takes place in the future.

Table 2 – Research Needs Suggestions: What We Need to Know

ON THE FARM

Sources/Reservoirs of *Salmonella*

- Are there environmental reservoirs for *Salmonella*?
- Are there domestic or wild animal reservoirs for *Salmonella*?
- Are there human reservoirs for *Salmonella*?
- Are there specific seasons associated with contamination of tomatoes in the field?
- What is the prevalence of *Salmonella* in tomato seeds?
- How long can Salmonella persist in tomato fields? In plant waste?
- Why are specific serotypes associated with tomatoes?
- Is it because this reflects their presence in the environment or that they are host-adapted to infect or grow on/in tomatoes?

Vectors and Vehicles

What vectors or vehicles are important in transmitting *Salmonella* from source to tomato plant or fruit?

- Wild animals
- Insects
- Nematodes
- Water
- Airborne
- Humans
- Pesticide applications
- Soil amendments

Internalization

What is the potential role of internalization of *Salmonella* in the tomato fruit?

- Can *Salmonella* in seeds be taken up by seedling?
- Are certain varieties more resistant to internalization?
- Are there specific times when *Salmonella* can be taken up by the root system?
- Can "biting" insects inoculate the tomato plant or fruit with *Salmonella*?
- What is the practical significance of *Salmonella* inoculation via the flower?
- What is the increased risk due to cracking and splits?
- At what stage is tomato plant most susceptible to internalization?

Impact of Farm Practices

- Does the method of cultivation (e.g., stake, bush, black plastic) influence the potential for contamination?

- Does the method of irrigation influence the potential for contamination?
- Does the method of pesticide application influence the potential for contamination?
- Does the method of harvest influence the level of contamination?
- Are the *Salmonella* strains associated with tomatoes match the *Salmonella* strains associated with farm workers?
- What food handling practices during harvesting contribute to risk of contamination?
- How amenable are current equipment to disinfection as a means of preventing the spread of contamination from one part of a farm to another?
- Can competitive exclusion concepts be applied to tomatoes?
- Does the rate of crop rotations influence the potential for contamination?
- Are current requirements for composting and/or pasteurization of animal manures sufficient to eliminate *Salmonella*?
- Does the plowing under of plant waste increase the survival of *Salmonella* in the environment?
- What adjacent land uses contribute to the potential for contamination?

POST HARVEST

- What is the prevalence of *Salmonella* in tomatoes not subjected to factors that increase infiltration?
- What would be the prevalence with a "dry" processing system?
- Are there better approaches for inactivating internalized *Salmonella*?
- Are there specific post-market diseases that foster *Salmonella* post-harvest contamination or growth?
- What is the practical increase in risk of *Salmonella* contamination in chill injured tomatoes?
- What are the cooling and cold chain requirements that are needed to prevent the growth of *Salmonella* on tomatoes?
- Is the temperature in the ripening room high enough to encourage growth of *Salmonella*?
- Are there marketing practices that contribute to the growth of *Salmonella* on tomatoes?
- Are there practical secondary barriers to prevent the growth *Salmonella* after slicing or dicing tomatoes?

RESEARCH PRIORITIZATION RESULTS

Each working group discussed the research needs identified in Table 2, and in some cases combined or reorganized related areas that were listed separately in the table. They also identified additional research needs that were not listed. Each group then produced a list of research priorities using a five step rating system. Most of the highest priority items were the same for both groups. The results from the two groups were combined to produce an overall list of research priorities in three categories (high, medium and low).

High Priority Research Needs

Are there alternate processing technologies (particularly 'dry' processing systems that can be used to reduce either the presence or spread of microbiological contamination?

- Use of dump tanks, flume systems and "wet" packing of tomatoes represent unique challenges in terms of potential cross contamination of both product and the packing environment, potential infiltration of the tomatoes, and the need to maintain careful control of water temperature and antimicrobial levels. Lessons learned from other foods, including other fruits and vegetable, show that reducing the exposure of foods to excess amounts of water can be an effective means of reducing contamination. Additionally, reduced use of water provides a means for reducing concerns associated with water supply and disposal issues. The research is needed to determine if moving to less water-intensive packing procedures for tomatoes is feasible and could lead to reduced risk of contamination.

Are specific seasons, microclimates, or weather events associated with contamination of tomatoes in the field?

- Preliminary epidemiological and field investigations suggest that specific seasonal and microclimate environmental conditions, as well as weather events, can lead to increased risk of contamination of tomatoes with human pathogens. However, these observations have not been verified systematically, nor have the mechanisms by which these factors contribute to susceptibility to contamination been established. Potentially, the identification of such risk factors could lead to practical guidance in terms of harvest procedures, planting location, and post-harvest packing/processing. Such knowledge would be an important determinant in the development and implementation of different intervention strategies.

What vectors and vehicles are important in transmitting pathogens to tomato plants and fruits? What are the mechanisms of pathogen movement?

- A number of potential scenarios have been proposed by which tomatoes become contaminated either in the field or during subsequent harvesting and packing; however, to date the relative importance of these vectors and vehicles have not been established. Without such knowledge, the science-based selection of risk mitigation strategies and intervention sites and technologies is not possible and

the industry and FDA are forced to use much less focused and cost effective umbrella approaches to hazard control.

How long can pathogens persist in tomato fields, in plant waste, chemical sprays, etc.?

- Critical to making informed decisions regarding commodity specific good agricultural practices that will lead to improved microbiological safety of tomatoes is an improved understanding of the microbial ecology of the farm environment. In particular, an improved understanding of survival and persistence in the farm environment is critical to the assessment of a particular farm for risk, the persistence of *Salmonella* in adjacent environmental or animal reservoirs, and the development and timing of on-farm interventions.

Are bodies of water in close proximity to tomato fields significant reservoirs for pathogen contamination of tomatoes? How are the populations of pathogens in the soil and water related?

- A series of initial studies have suggested that water in the primary agricultural environment may be an important source of *Salmonella* for tomatoes. However, these studies have not established the relative importance of the water sources, the effective physical separation distances needed to prevent the transfer of Salmonella from the bodies of water in the environment, and potential means for preventing those transfers. This information is critical for developing potential intervention technologies and the implementation of improved tomato-specific GAPs.

What are the cooling and cold chain requirements (aka temperature management) that are needed to prevent growth of pathogens on tomatoes?

- Past research has clearly identified the potential of tomatoes to support the growth of *Salmonella* in the pulp if the fruit is held at temperatures that support growth. This is particularly true when tomatoes are sliced. However, there is little information available to assess what portion of the microbiological food safety risks associated with tomatoes is attributable to inappropriate temperature management (both too warm and too cold). This information is critical to developing reasonable product pathway risk assessments for tomato and tomato products, the articulation of enhanced GAPs and GMPs, and the development of "secondary barriers to growth" of *Salmonella* in tomato products at increased risk (due to the ability of tomatoes to support the growth of the pathogen).

What proportion of tomato producers have implemented GAPs, and to what extent? What are the barriers to GAPs implementation?

- Reduction in the risk of a food serving as a vehicle for *Salmonella* infections is dependent not only on the identification of effective mitigation strategies but also on the extent to which these strategies are consistently implemented. In the case of tomato production, this reflects the extent to which producers and packers are adhering to recommended GAPs and related GMPs. At this stage, it is difficult to determine whether ongoing tomato outbreaks are due to non-adherence to existing

GAPs or whether these GAPs are insufficient to control key risk factors. Determining the adequacy and adherence to GAPs and GMPs, and differentiating between them, is critical to making decisions on future food safety strategies, and the need for more research and more oversight. The ability to measure the adherence to GAPs and GMPs is critical to effective priority setting, risk assessments, education programs, and consumer outreach initiatives. This information can lead to development of more effective interventions.

What is the relative importance of internalization vs. surface contamination of tomatoes in the field?

- The selection of effective post-harvest interventions to reduce *Salmonella* associated with tomatoes and tomato products is dependent on understanding the location of the microorganisms on or in the fruit. Most antimicrobial treatments based on surface application are ineffective for internalized microorganisms. Thus, if contamination is largely limited to the surface of the fruit, surface treatment may be sufficient as an intervention technology. Conversely, extensive internalization will require the development of alternative technologies. This information is needed to determine which interventions are likely to be effective and is thus critical to the direction of future research efforts.

Are there specific microbial serotypes or genotypes associated with tomatoes? Are certain varieties of tomato more likely to carry pathogens?

- Initial studies have suggested that there may be substantial differences in the ability of different *Salmonella* strains to contaminate, survive and growth on tomatoes. The identification of the factors contributing to this differential response will provide information needed for assessing the risk of tomatoes serving as a vehicle for *Salmonella* and possibly lead to targeted interventions strategies.

Are there effective approaches that can be used to inactive internalized or attached pathogens? What interventions will reduce the risk of contamination?

- Current approaches for reducing the presence of *Salmonella* on tomatoes are largely restricted to those capable of reducing the pathogen on the surface of the fruit. Most of these treatments are not effective against internalized *Salmonella* and they are likely to be less effective against the pathogen if embedded in a biofilm.

Additional Comments on High Priority Needs

There was additional discussion of the need to consider regional differences. For example, there may be a unique opportunity to carry out comparative studies in natural laboratories such as in the Eastern Shore of Virginia and in Florida. Two carefully designed studies with broad multidisciplinary review and input were discussed. The first would study the role of factors such as the proximity of wells to contaminated ponds, the

chemistry and conditions of the ponds, and the presence of migratory bird populations. The second would study the influence of microclimates and other field conditions.

To capture a complete and holistic view of the influence of these environmental factors, both studies should be developed with the assistance of a broad multidisciplinary group of advisors. This group would review research study designs from the perspective of multiple disciplines, as well as help analyze study results. This advisory group might include, for example, hydrologists, soil scientists, herpetologists, microbiologists, microbial ecologists, bird and wildlife ecologists, climatologists, plant pathologists, plant physiologists, extension specialists, nematologists, and other pertinent disciplines.

Medium Priority Research Needs

Does the method of irrigation influence the potential for contamination?

There is currently no information on how different irrigation practices influence the potential for transmitting *Salmonella* to tomatoes at different times.

Does the method of pesticide application influence the potential for contamination?

There is currently no information on how different pesticide application practices influence the potential for transmitting *Salmonella* to tomatoes.

Does the method of harvest influence the level of contamination?

There is very little information on the potential influence of the methods and practices used to harvest tomatoes on the probability of, or level of, contamination of tomatoes.

How do the conditions of post-harvest wash influence contamination?

Laboratory studies indicate that the conditions of post-harvest wash can influence the probability of contamination and internalization of pathogens. However, there is little corresponding information related to field practice.

What post-harvest food handling and marketing practices (other than temperature management) contribute to the risk of contamination?

As tomatoes move through the food handling chain to the consumer, practices at each step have the potential to either increase of decrease the probability and level of potential contamination.

Can a formal risk ranking approach be used to identify the most effective control and prevention strategies?

A formal risk ranking analysis would help to integrate the existing knowledge base and research needs.

Additional Research Needs Discussed But Not Considered of High Priority at the Current Time

- Are there relevant human reservoirs for *Salmonella*?
- What is the prevalence of *Salmonella* in tomato seeds?
- What vectors or vehicles (other than animals and water) are important in transmitting *Salmonella* to tomatoes?
  - Insects
  - Nematodes
  - Airborne
  - Soil amendments
- Do soil organisms serve as means of maintaining or selecting for *Salmonella* in soil or water?
- Does the method of cultivation (e.g., stake, bush, black plastic) influence the potential for contamination?
- Do the *Salmonella* strains associated with tomatoes match the *Salmonella* strains associated with farm workers?
- How amenable are current equipment to disinfection as a means of preventing the spread of contamination from one part of a farm to another?
- Can competitive exclusion concepts be applied to tomatoes?
- Does the plowing under of plant waste increase the survival of *Salmonella* in the environment?
- What adjacent land uses contribute to the potential for contamination?
- What measures can be taken to reduce or eliminate *Salmonella* colonization in agricultural soils or water?
- Are there methods to screen tomato fields for *Salmonella*?
- Are there specific post-harvest diseases that foster *Salmonella* contamination or growth?
- What is the practical effect of chill injury on the risk of *Salmonella* contamination in tomatoes?

In addition, two questions were deemed be not be relevant because they relate to practices that are not used in growing tomatoes (Does the rate of crop rotation influence the potential for contamination, Are current requirements for composting and/or pasteurization of animal manures sufficient to eliminate *Salmonella*).

COMMUNICATION AND COORDINATION PLATFORM

A number of different mechanisms for ensuring ongoing communication and coordination were identified. The ability to build on existing platforms was considered vital in determining which mechanisms to implement. In addition, it will be important to ensure that communication occurs within the research community, between researchers and producers, and between both groups and regulatory agencies. Regular communication was considered a key component of the follow up from this workshop.

Among the suggested communication mechanisms were:

- A Listserv email list
- An annual symposium
- A GAPS conference
- A special edition of a relevant journal
- A Website (at Univ. of Florida and/or JIFSAN)
- Short programs or workshops at meetings such as IFT and IAFP
- Web conferences
- Meetings to bring together microbiologists, plant biologists, growers, packing houses and chemical suppliers

The major communication barrier that was identified was the need to exchange information among multiple scientific disciplines and between scientists and multiple participants in the production chain. The potential role of agricultural extension in bridging some of these communication gaps was acknowledged.

To facilitate continuation of the communication and coordination effort that was started at this workshop, an *ad hoc* committee was formed that will work to ensure that the there is an on-going process to inform decision makers and funding agencies of these research priorities, to promote involvement by others who were not present, and to facilitate interactions among researchers.