Food Safety in the Twenty-First Century

Elsa A. Murano

The past decade has taught us that pathogenic microorganisms are adapting themselves to processing treatments and environmental conditions once thought to be effective in controlling their proliferation. Genetic exchange is sprouting new varieties of bacterial strains with increased abilities to cause disease. The scientific community must adopt a proactive approach, including an aggressive research agenda that seeks to determine the ecology of the food production and processing environments, as well as the basic biology of pathogenic organisms. In addition, it is crucial that we develop a well-integrated educational strategy that seeks to educate industry and consumers.

Historical Perspective

In the past decade, food safety has become a very important issue to consumers. They have taken an organized stand, demanding that the foods they eat—whether produced domestically or imported—be safe and wholesome. Our society has come to realize that, if we do not examine our history and learn from it, we are doomed to repeat it. Thus, the following is a brief summary of landmark events in the history of food safety that have catapulted this issue into the national spotlight. It is in looking at this history that we will discover what we must do in order to improve the safety of our food supply for the twenty-first century.

1980s: Food Safety Receives National Attention

Prior to the 1980s, outbreaks of food-borne illness had been sporadic in nature, involving only a few cases at a time (Cliver, 1987). This changed in 1985 when two major outbreaks took place. One was due to salmonellosis in Chicago, where more than 19,000 people became ill after consuming contaminated pastry products (Lecos, 1986). The other involved several cases of listeriosis due to consumption of contaminated cheese in California (Fleming et al., 1985). In this instance, several miscarriages and stillbirths resulted, prompting action from policymakers. The result was that ready-to-eat products are now required by law to be devoid of any Listeria, setting up a "zero tolerance" policy for this pathogen (FSIS, 1990). This requirement has affected the way that many food processors do business as it has led to an increase in the number of analytical tests that processors must run to determine whether the pathogen is present. It has also forced many food processors to redesign their operations to accommodate new sanitation and production practices.

1990s: The Decade of E. coli

Late in 1991, a major outbreak of food-borne illness took place in the Pacific Northwest and California (CDC, 1993). Ground beef was contaminated with a pathogen of which not much was known at the time, the bacterium Escherichia coli O157:H7. Several children died after eating undercooked hamburgers served at chain stores of a fast-food restaurant; more than 600 became ill. This outbreak received tremendous media attention, with television programs aired, newspaper articles published, and congressional hearings held to discuss the now all-important issue of food safety. In 1994, more than 20 people became ill after consuming dry-cured salami contaminated with the same pathogen, pointing to ready-to-eat foods as an important vehicle for food-borne illness (CDC, 1995).

Two years later, large outbreaks of food poisoning due to E. coli O157:H7 in Japan claimed the lives of 11 people, with more than 10,000 cases reported (IDSC, 1997). The vehicle of infection was traced to alfalfa sprouts, with the Japanese government placing some of the blame on the U.S. company that supplied the sprouts. That same year, contaminated unpasteurized apple juice caused one death and 49 cases of poisoning by this organism in the United States (CDC, 1997a). The company had to answer to 16 counts of negligence. In 1997, a meat processing company was forced to recall 25 million pounds of ground beef, the largest food recall in U.S. history, after an outbreak of E. coli O157:H7 food

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Elsa A. Murano is associate professor, Department of Animal Science, and director, Center for Food Safety, Texas A&M University, College Station, TX.

poisoning in Colorado that affected 20 people (CDC, 1997b).

Also in that year, an outbreak of food-borne illness by the same organism occurred in Michigan and Virginia due to consumption of contaminated alfalfa sprouts (CDC, 1997c), and several thousand people became ill with the parasite Cyclospora due to consumption of raspberries imported from Guatemala (CDC, 1997d). In addition, several people became ill that year from eating strawberries contaminated with Hepatitis A virus (CDC, 1997e). As if food safety was not enough of a concern, in 1999, several hundred cases were reported in what is now considered to be the largest outbreak of E. coli O157:H7 poisoning due to consumption of contaminated drinking water in New York state (CDC, 1999a).

Recently, several outbreaks caused by a new strain of Salmonella typhimurium, designated DT104, have caught the attention of European and U.S. health officials (Threlfall, Ward, and Rowe, 1997; CDC, 1997f). This organism has developed a resistance to several antibiotic agents commonly used in animal production and for the treatment of infectious diseases in humans. Concern regarding the over-use of antimicrobials by both veterinarians and physicians has now prompted a move toward the ban of some of these products in Europe. Outbreaks due to Salmonella muenchen in unpasteurized orange juice have also taken place, pointing to a concern that some pathogens may be developing resistance to acid conditions as well as antibiotics (CDC, 1999b).

Issues Facing Food Safety

When we examine the historical overview presented above, we conclude that there are three basic issues, which must be addressed in the coming century if we are to make an impact in the improvement of food safety: our limited knowledge about food safety risks; the limited application and availability of effective intervention strategies; and limited educational efforts.

Limited Knowledge of Food Safety Risks

In considering the risks to food safety, we must think in terms of the food continuum, from farm to table. Although much is known regarding how some organisms cause disease and how they are introduced into our food supply, we do not have a complete picture of how the practices that we employ from production to distribution impact the contamination of foods. For example, how do animal husbandry practices affect colonization with food-borne pathogens, as well as contamination of the farm environment? How do agents of disease interact with the animal host, and how do these interactions affect the ability of the animal to carry and/or spread these organisms?

In addition, our knowledge of some of the basic science behind microbial behavior is limited. For instance, how do microorganisms develop resistance to treatments designed to eliminate them? What environmental factors affect the emergence of new pathogens in nature? These and other unanswered questions are what stand in the way of our ability to proactively prevent future outbreaks since they are at the core of our ability to assess the risk that food production, processing, and preparation pose to food safety.

Limited Application of Effective Intervention Strategies

In the past few years, several strategies have been developed and tested for the decontamination of animal carcasses at the slaughterhouse as well as strategies for the sanitation of fresh fruits and vegetables. These strategies include organic acid rinses, hot water treatments, and steam pasteurization (Corry et al., 1995). However, the use of several of these strategies in combination has not been sufficiently elucidated. Moreover, the opportunity for recontamination of foods after treatment can occur, yet our strategies for minimizing such events are limited. If we are to impact the safety of our food supply, we need to use several strategies throughout the food continuum. For example, at the farm level, feeding regimens, type of feed used, competitive exclusion, vaccine development, and genetic manipulation could be employed to prevent colonization and shedding of pathogens from the intestinal tract of animals.

In the case of fruits and vegetables, practices used on the farm can impact the level and type of contaminant present on the crop (Beuchat, 1996). The type and method of application of fertilizer, the source and frequency of irrigation, and genetic manipulation of surface properties could have an impact on the reduction of contaminants attaching to plant tissue. In addition, the handling and storage of produce often leads to the spread and growth of microbial contaminants. Washing regimens—as well as the application of novel technologies such as irradiation—must also be studied with an eye on the costs and benefits of using such treatments.

Limited Educational Efforts

Several educational programs aimed at processors have been implemented, all based on the Hazard Analysis Critical Control Points system. However, these programs are limited in scope and have been provided primarily to the meat, poultry, and seafood industries. There is a need to develop training programs on HACCP to farmers, both in animal and plant production. For maximum impact, such programs should be designed for both English- and Spanish-speaking audiences and for all levels of learning ability. Delivery of these programs is of utmost importance, requiring a vast network of educators working together. The primary problem is the lack of coordination between educational institutions.

In addition, a concerted effort needs to be mounted to educate all sectors (farmers, industry, food service, and consumers) for any educational program to be successful. Such an effort could be in the form of assembling dedicated teams to deliver information to specific audiences and to specific regions. Farmers must be surveyed to determine their knowledge of food safety and of the impact that their practices have on food-borne illness. Programs should be developed to prepare farmers and ranchers to meet future challenges associated with the introduction of the HACCP system on the farm. Finally, food service and consumers need to be included, with adequate resources being allocated to ensure the success and prompt application of existing and new efforts.

Strategies and Solutions

Several government agencies have gone through strategic planning exercises that have helped them to identify the strategies to be pursued in addressing the above issues. In simple terms, we can think of it as a two-pronged approach in which research and education are linked together to develop the best solutions.

Research

First, the microbial ecology of food-borne pathogens needs to be fully characterized throughout the production and processing of muscle and plant foods. In order to do so, the prevalence of specific pathogens in specific foods needs to be determined, including the sources of contamination from production through processing, retail sale, and food preparation. Through epidemiological studies, we must characterize the risk to food safety related to specific practices on the initial level and type of contaminants. We must also characterize the biological mechanisms of survival, adaptation to stress and antimicrobials, and growth of these organisms. Advanced technologies for the rapid and sensitive isolation and identification of food-borne pathogens need to be developed so as to provide real-time detection.

Second, scientists must develop, test, and implement new technologies for the decontamination of a variety of foods in order to reduce the risks posed by food-borne pathogens. Along these lines, the effectiveness of existing strategies must be clearly determined and the appropriate application elucidated. Third, a thorough study and documentation of the economic benefits of these strategies needs to be included in order to obtain a realistic picture of what strategies should and should not be used in particular operations and by particular-sized companies.

Education

An educational strategy, which is coordinated throughout all segments of the food continuum and involves all institutions, needs to be developed. Partnerships with appropriate agencies, trade organizations, food industry organizations, consumer organizations, and educational organizations need to be established and/or strengthened. This will facilitate the dissemination of food safety information to those members of the continuum responsible for a particular segment. Educational materials—related to the characteristics, prevalence, symptoms of illness, risk of certain practices, and preventive measures gained through research efforts at each step of the food continuum—need to be developed. Producers and processors should be educated through partnerships with commodity associations. Food service should be trained through existing vehicles and coordinated through partnerships with foodservice associations. Consumers should be made aware of safe food handling, preparation, and storage through television, radio, public service announcements, print publications, interactive display/exhibit learning devices, as well as the World Wide Web.

Conclusions

What will food safety look like in the twenty-first century? The past few years have shown us that microbial pathogens are very adaptable, with newly emerging organisms challenging our long-established concepts of safety. In addition, the centralized food distribution system and the changes in the demographic and cultural practices of consumers are contributing factors to the apparent increase in the number of outbreaks of food-borne illness in the United States. Increases in international food trade will only augment the challenges to food safety currently facing us. Thus, only with a proactive, aggressive, and science-based approach can we hope to have a measure of control over the future of food safety. In this manuscript, we have presented the types of programs that should be implemented in order to do this. It is up to scientists, policymakers, and health officials to work together now and not delay.

References

Beuchat, L.R. 1996. "Pathogenic Microorganisms Associated with Fresh Produce." *Journal of Food Protection*. 59: 204–216.

CDC. 1999a. "Public Health Dispatch: Outbreak of *Escherichia coli* O157:H7 and *Campylobacter* Among Attendees of the Washington County Fair—New York, 1999." *Morbidity and Mortality Weekly Report*. 48: 803–804.

CDC. 1999b. "Outbreak of *Salmonella* serotype Muenchen Infections Associated With Unpasteurized Orange Juice—United States and Canada, June 1999." *Morbidity and Mortality Weekly Report*. 48: 582–585.

CDC. 1997a. "Outbreaks of *Escherichia coli* O157:H7 Infection and Cryptosporiodiosis Associated With Drinking Unpasteurized Apple Cider—Connecticut and New York, 1996." *Morbidity and Mortality Weekly Report*. 46: 4–8.

CDC. 1997b. "*Escherichia coli* O157:H7 Infections Associated With Eating a Nationally Distributed Commercial Brand of Frozen Ground Beef Patties and Burgers—Colorado, 1997." *Morbidity and Mortality Weekly Report*. 46: 777–778.

CDC. 1997c. "Outbreaks of *Escherichia coli* O157:H7 Infection Associated With Eating Alfalfa Sprouts—Michigan and Virginia, June–July 1997." *Morbidity and Mortality Weekly Report*. 46: 741–743.

CDC. 1997d. "Update: Outbreaks of Cyclosporiasis—United States and Canada." *Morbidity and Mortality Weekly Report*. 46: 521–522.

CDC. 1997e. "Hepatitis A Associated With Consumption of Frozen Strawberries—Michigan." *Morbidity and Mortality Weekly Report*. 46: 288–295.

CDC. 1997f. "Multidrug-Resistant *Salmonella* serotype *Typhimurium*—United States, 1996." *Morbidity and Mortality Weekly Report*. 46: 308–310.

CDC. 1995. "*Escherichia coli* O157:H7 Outbreak Linked to Commercially Distributed Dry-Cured Salami—Washington and California, 1994." *Morbidity and Mortality Weekly Report*. 44: 157–159.

CDC. 1993. "Preliminary Report: Food-borne Outbreak of *Escherichia coli* O157:H7 Infections From Hamburgers—Western United States." *Morbidity and Mortality Weekly Report*. 42: 85–86.

Cliver, D.O. 1987. "Food-borne Diseases in the United States, 1946–86." *International Journal of Food Microbiology*. 4: 269–277.

Corry, J.E.L., C. James, S.J. James, and M. Hinton. 1995. "*Salmonella, Campylobacter*, and *Escherichia coli* O157:H7 Decontamination Techniques for the Future." *International Journal of Food Microbiology*. 28: 187–196.

Fleming, D.W., S.L. Cochi, K.L. MacDonald, J. Bronctum, P.S. Hayes, B.D. Plikaytis, M.B. Holmes, A. Audurier, C.V. Broome, and A.L. Reingold. 1985. "Pasteurized Milk as a Vehicle of Infection in an Outbreak of Listeriosis." *New England Journal of Medicine*. 312: 404–407.

FSIS. 1990. *FSIS Directive 10,240.1 Rev. 1, Microbiological Monitoring Program: Sampling, Testing Procedures, and Actions for Listeria monocytogenes and Salmonella*. FSIS, USDA, Washington DC.

IDSC (Infectious Disease Surveillance Center). 1997. "Verotoxin-Producing *Escherichia coli* (Enterohemorrhagic *E. coli*) Infections, Japan, 1996–June 1997." *Infectious Agents Surveillance Report* (Tokyo, Japan). 18: 153–154.

Lecos, C. 1986. "Of Microbes and Milk: Probing America's Worst *Salmonella* Outbreak." *FDA Consumer*. 20: 18–21.

Threlfall, E.J., L.R. Ward, and B. Rowe. 1997. "Increasing Incidence of Resistance to Trimethoprim and Ciprofloxacin in Epidemic *Salmonella typhimurium* DT104 in England and Wales." *Euro Surveillance*. 2: 81–84.