Microbial Food Safety IS Your Responsibility !

Farming practices that emphasize the use of animal manure, manure slurries or “teas”, and animal manure-based compost play an important role in the recycling of organic nutrients and developing a rich soil structure. Due to the increasing frequency of outbreaks of food-borne pathogens, we are very concerned with a different type of recycling through our agricultural production systems. The recycling of bacterial pathogens and protozoan parasites from animals to humans through water, soil and crops has created a serious challenge for producers, processors, and consumers of fresh produce. Researchers at the University of California, Davis and other academic, government, and private institutions are beginning to address the key information needs in understanding the environmental persistence and control points for these pathogens of global concern.

During a single 1996 *Escherichia coli* (*E. coli*) outbreak in Japan, nine people died, 30 people were reported in critical condition, and a total of 8,500 cases were recorded. The suspected cause of the outbreak was salad, with sprouted radish seeds being the primary suspected source of the foodborne contamination (Hara-Kudo et.al. 1997).

Closer to home in Montana that same year, another *E. coli* outbreak occurred**.** Leaf lettuces were the identified culprits**.** Affecting more than 70 people, this outbreak was associated with consumption of leafy red, green, and Romaine lettuce. Though not proved conclusively as the source, concern was raised for the potential risk of contaminated irrigation water or manure-amended soil.

Irrigation water or water used for foliar applications are the suspected sources of a recent outbreak of the parasite Cyclospora on imported raspberries and domestically produced mesclun (“spring mix” baby greens and leafy lettuces). From May to June 1997 over 200 laboratory confirmed cases and more than 600 clinically suspected cases of Cyclosporiasis have occurred.

To keep things in perspective, it is important to strongly emphasize that the number of cases of foodborne illness known or suspected to involve fresh produce are extremely few, relative to meat and poultry sources. The majority of confirmed cases that involve produce are the result of poor handling practices at the foodservice or home consumer level (FSIS-40, 1990; CDC, 1997; Harris, 1997) . The frequency is increasing, however, and the increased consumption of uncooked fruits and vegetables elevated the risk of exposure because there are limited process controls available to protect the consumer.

Without question, foodborne illness has emerged as a major worldwide issue impacting production, processing, domestic and export marketing, and consumer confidence in the food supply (Beuchat, 1996; CDC, 1997). Regulators view documentation, from field to fork, as a key element of a systemic approach to limiting the impact of an outbreak to the smallest component of the industry possible. The ability to rapidly and accurately traceback the presumptive or clinically proven ,produce-related outbreak to its source would prevent consumers from avoiding all sources of the same produce category. Regulatory access to such documentation may also prevent a nonspecific broadcast to the media to activate a consumer alert during an outbreak investigation. To begin to construct such a system, prevention and control programs for food safety must be implemented down to the farm level. Agricultural producers of all sizes will in the immediate future be increasingly charged with establishing and documenting methods of microbial risk reduction and prevention.

Prepared by Trevor V. Suslow, Ph.D.
Department of Vegetable Crops
University of California, Davis

Which are the key microbes of concern for fruits and vegetables?

Microbial pathogen	Type of organism	Major carriers	Primary source
Salmonella	Bacterium	Production animals Domestic pets Wild animals Cross-contamination from meat, poultry, egg	feces carcasses soil (persistent)
Campylobacter	Bacterium	Cross-contamination from meat, poultry	carcasses
Escherichia coli O157:H7	Bacterium	Production animals Domestic pets Wild animals Humans Cross-contamination from meat, poultry	feces water-borne soil (persistent unclear)
Cryptosporidium	Protozoan	Production animals Domestic pets Wild animals Humans	feces water-borne
Toxoplasma	Protozoan	Production animals Cats	feces
Cyclospora	Coccoid parasite	Humans	feces water-borne

There are several other food pathogens of concern, primarily associated with meat, dairy, or shellfish consumption. Examples are ***Bacillus cereus***, ***Clostridium***, ***Shigella***, ***Staphylococcus***, *Listeria, Yersinia, Aeromonas, Norwalk Virus* and other viruses. Collectively with *Salmonella* and Campylobacter the pathogens in boldface account for over 90% of foodborne diseases in the USA. *Salmonella* alone accounts for more than 40 % of the characterized outbreaks. Surprisingly high frequencies and populations of *Salmonella* have been documented from domestic produce (Wells, J M and Butterfield, J E.1997).

Currently, much of the focus of developing on-farm prevention programs is on *E. coli* O157:H7 and related toxigenic *E. coli*. Growers and others directly involved in crop management must increase their awareness of the elevated risk and potentially severe (or lethal) consequences of infection of these bacteria from noncooked produce. Current information supports a very low probability of contamination, at the farm level, across the majority of domestic produce but the potential consequences of a single, rare outbreak are severe.

Escherichia coli O157:H7 : A Key Focus for Prevention

E. coli O157:H7 is the predominant strain of a group of toxin-producing *E. coli*. Common *E. coli* is an ubiquitous intestinal inhabitant. The toxigenic forms, such as *E. coli* O157:H7 have been an increasing problem since first identified in 1982 (Buchanan and Doyle, 1997; Feng,1997). Although far fewer cases have been recorded than of *Salmonella* cases, *E. coli* O157:H7 is more hazardous causing the lifethreatening condition Hemolytic Uremic Syndrome (HUS) which results in acute kidney failure. An additional risk feature associated with *E. coli* O157:H7 results from the very low number of contaminating cells required for infection. Estimates, based on epidemiological evidence from recent outbreaks, vary but it is generally agreed that less than 10 bacteria per gram of food may be sufficient to cause infection in sensitive individuals. The population sector most at risk are the very young, the elderly, women during pregnancy, and immuno-compromised individuals. With so few bacterial cells necessary, growth on infested produce is not a requirement for human infection, as with most other pathogens. Therefore refrigeration of harvested produce during transportation and distribution is not a sufficient control for this group of pathogens. In addition, due to the very low infective dose, absence of detection is not a foolproof assurance of safety. Screening of harvested produce is not a practical approach to control. Awareness of the characteristics and potential sources of this pathogen in agricultural production systems and produce distribution are important first elements towards developing appropriate and reasonable strategies for microbial risk reduction.

Known Sources of *E. coli* O157:H7

E. coli O157:H7 has been found in reservoir and recreational water (Ackman et.al., 1997) and in water sources used for overhead irrigation of vegetables. It has been detected in the feces of many animals including dairy and feedlot cows, poultry (especially chicks), lamb, piglets, children, pets, deer, rabbits and waterfowl. Dairy herds have been targeted as presumptive sources of *E. coli* O157:H7 that may find their way on to produce through aerosols, surface water, and incompletely composted manures (Cliver, 1997; Hancock et.al.,1997 ; Zhao et.al. 1995). *E. coli* O157:H7 has been shown to persist in drying manure and to be present in incompletely composted dairy and feedlot waste. Persistence in manure amended soils is not well characterized and is the subject of current research efforts at UC Davis. The duration of soil survival, transfer to, and potential colonization of above ground plant tissue, such as leafy lettuce, are largely unknown for this and related toxigenic strains.

The transference of *E.coli* O157:H7 from these sources to the harvested portion of fruits and vegetables may seem logical and predictable but little documented evidence for their environmental behaviors is available. This information will be critical in the development of guidelines for the safe handling and application of animal manure’s to farm land, particularly for vegetable production systems. Outbreaks of both *Salmonella* and *E. coli* O157:H7 are often the result of cross-contamination from animal (meat, eggs) sources during food preparation in foodservice establishments or in the home. However, documented cases and research reports of these pathogens on fruit or vegetables directly from the farm source extend the need for prevention and control programs from “field to fork”.

Unique Characteristics of E.coli O157:H7

What makes *E. coli* O157:H7 and other related strains of *E. coli* a threat to humans is their acquired ability to produce toxins and other virulence factors (Buchanan and Doyle, 1997). In addition, recent research has shown that this strain is more resistant than standard *E. coli* to dry conditions, freezing, and acid conditions. Environmental stresses that inactivate conventional *E. coli* are much better tolerated by *E.coli* O157:H7.

Broader survival capacity in animal manure-based composts are a unique characteristic that has only recently begun to be evaluated. Farming practices which utilize these organic amendments require new information for their continued safe use in light of these discoveries. Organic amendments have the potential to provide many benefits to soil structural integrity, fertility and microbial activities in disease control and natural plant pest resistance. There is also a benefit of animal waste management. However, animal manure-based compost is a potential source of several microbial pathogens including *E. coli*. In some agricultural systems raw manure may be surface applied or incorporated into soil at various time intervals prior to planting or harvest. We are in the initial stages of determining what preplant processes and time intervals are required to minimize the risk of crop contamination.

Preliminary reports are beginning to address the issue of survival of *Salmonella* and *E. coli* through the composting process (Droffner and Brinton, 1995; Pfaller et.al. 1994). Peak temperatures reached during the composting process, 140^{o}F sustained for three weeks, are sufficient to kill these microbes, but the uniformity of application of this process has not been adequately addressed or observed in practical applications.

Preliminary research has shown that regrowth on incompletely composted manure's, from undetectable populations is a possibility.

Growth of *E. coli* O157:H7 on Vegetables

To date, published research on the fate of *E. coli* O157:H7, introduced to vegetables as a model for inadvertent contamination from water, soil, or nonhygienic human activities, has dealt primarily with risk assessment analysis on crops where outbreaks have been documented (Abdul-Raouf et.al., 1993; Diaz and Hotchkiss, 1996). Once introduced to lettuce, or other test vegetables including cucumber, cantaloupe, watermelon, alfalfa sprouts, and radish sprouts survival and growth under permissive temperature conditions is highly likely to occur.

These permissive temperature conditions are not uncommon in the mainstream distribution and foodservice handling chain and may be more likely in small-scale operations and consumer-direct outlets. The best approach, at this time, is a comprehensive prevention and on-farm risk management program. Sanitation and proper worker hygiene during harvest and postharvest processing are important additional components of a comprehensive program.

What Controls Are Needed?

Until more specific information is available about the environmental dissemination and persistence of *E. coli* O157:H7 and other key pathogens, common sense approaches to on-farm microbial safety will go a long way to minimizing the risk of foodborne illness. Some farming practices that were considered safe in "the good-old-days" are a current liability. Some new practices developed as a source of supplemental organic nutrients and pest control (foliar applied manure slurries) seem ill-advised without greater process control information and documentation. Awareness of the known traits of these microbes that make them a threat will help each individual grower and handler of fresh produce design prevention and control measures specific to their cropping situation or postharvest system.

All current evidence supports the fact that established manure management and compost process controls are sufficient to kill *E. coli* O157:H7 and other key pathogens. Time:Temperature relationships for thermal inactivation of these bacteria are known and should be used as indices of proper static pile or windrow composting of animal manure or manure blends (Soldier and Strauch, 1991; Juneja et.al. 1997). If the temperature of the environment immediately around the bacterial cell reaches 60^{o}C (140^{o}F), the predicted kill-time for an initial population of one million *E. coil* or *Salmonella* cells per gram of manure would be far less than one hour. Adequate inversion of the composting material is necessary to allow all material to reach peak temperatures without compromising the fertilizer nutrient and microbial biomass quality of the compost for soil fertility management due to overheating.

Moving from Farm to Shipment

Like most *E. coli*, type O157:H7 is sensitive to chlorine, ozone, and other disinfectants provided there is physically contact with the bacterial cell. Preharvest contamination-prevention programs and postharvest sanitation are key tools to preventing outbreaks. On-farm prevention programs should include basic sanitation practices for all harvest containers, contact surfaces, and postharvest washing. Washing fruit and vegetables with clean, potable water removes many undesirable surface contaminants. Although not an assurance of complete safety, disinfection is an essential process to include, any time produce intended for commercial sale is washed, to remove soil, debris or reduce decay on surfaces wounded or cut during harvest. Some pathogens such as *Cryptosporidium* are very resistant to chlorine and new approaches must be taken.

What Are Researchers Doing?

Our immediate objective as researchers is to identify where data gaps exist and could be addressed in future near-term research. Immediate-term information is needed to guide growers, Cooperative Extension, the diagnostic service industry, shippers, and processors in the development of on-the -farm management practices to prevent these microbial pathogens from being introduced during production and at harvest. Areas we are beginning to address include;

- Information on sources and persistence
- Manure management and compost process control
- Timing of incorporation of animal manures relative to crop seeding and harvest
- Depth of incorporation into soil to minimize persistence or transfer
- Potential for establishment of key pathogens on plant parts during production
- Postharvest prevention programs

A Team Effort

California growers and crop management consultants need to take the threat of microbial pathogens seriously. The produce industry is being compelled to move towards a systems approach to prevention. Fortunately many industry leaders have taken a proactive role in ensuring that common sense and manageable guidelines are in place before the more difficult and lengthy task of specific commodity and grower-based prevention plans are initiated. Research in a number of UC Davis departments is providing the information database to assist in the development of these good farming practices.

Growers must make microbial food safety a top priority and take an active role in creating practical guidelines that will allow the continued flow of quality produce to the world.

UC Resources You Should Know

Dean Cliver, Professor, School of Veterinary Medicine, Microbial Food Safety and Population Health. 916.754.9120
James Cullor, Director, Veterinary Medicine Teaching & Research Center; Dairy Food Safety Lab-Tulare. 209.688.1731
Linda Harris Extension Specialist, Microbial Food Safety; Department of Food Science, UCD 916.754.9485
Deanne Meyer, Extension Specialist, Waste Management Specialist. Department of Animal Sciences, UCD. 916.752.9391

Additional Background Reading and Information Resources

- Abdul-Raouf, U.M., L.R. Beuchat, and M.S. Amman. 1993. Survival and growth of *Escherichia coli* 0157:H7 on salad vegetables. Appl. Env. Microbiol. 59: 1999-2006
- Ackman, D; Marks, S; Mack, P; Caldwell, M; Root, T; Birkhead, G.1997. Swimming-associated haemorrhagic colitis due to Escherichia coli O157:H7 infection: Evidence of prolonged contamination of a fresh water lake.Epidemiology and Infection. 119: 1-8.
- Beucaht, L.R.. 1996. Pathogenic microoragnisms associated with fresh produce. Jour. of Food Protection. 59: 204-216
- Buchanan, R.L. and M.P. Doyle.1997. Foodborne Disease Significance of *Escherichia coli* O157:H7 and Other Enterohemmorhagic E. coli. FOODTechnology. 51: 69-76
- CDC (Center for Disease Control). 1997. Food Safety from Farm to Table: A new strategy for the 21st Century.
- Cliver, D.O.. 1997. Research and reason can minimize foodborne and waterborne illness. California Agriculture. 51: 8-14.
- Diaz, C. and J.H. Hotchkiss. 1996. Comparative growth of *Escherichia coli* 0157:H7, spoilage organisms and shelf-life of shredded iceberg lettuce stored under modified atmospheres. J.Sci. Food Agric. 70: 433-438.
- Droffner, M.L. and W.F. Brinton. 1995. Survival of *E. coli* and *Salmonella* populations in aerobic thermophilic compost as measured with DNA gene probes. Zentralblatt fuer Hygiene undUmweltmedizin 197: 387-397.
- Feng, P. . 1997. Escherichia coli Serotype O157:H7 : Novel vehicles of infection and emergence of phenotypic variants. EID Vol 1: No. 2
- FSIS-40. FSIS Facts ; Bacteria That Cause Foodborne Illness.1990. USDA Food Safety and Inspection Service. Washinton D.C.
- Hancock, D.D., Rice, D.H., Herroitt, D.E., Besser, T.E., Ebel, E.D., and Carpenter, L.. 1997. Effects of farm manure-handling practices on *Escherichia coli* O157:H7 prevalence in cattle. Journ. Food Protection 60: 363-366.
- Hara-Kudo, Y; Konuma, H; Iwaki, M; Kasuga, F; Sugita-Konishi, Y; Ito, Y; Kumagai, S.. 1997. Potential hazard of radish sprouts as a vehicle of Escherichia coli O157:H7. Journal of Food Protection. 60: 1125-1127.
- Harris, L.. 1997. Food Safety for Fresh Produce : Fact Sheet. Department of Food Science and Technology. University of California at Davis. 95616-8631.
- Juneja, V.K., Snyder, O.P., and Marmer, B.S.1997. Thermal destruction of Escherichia coli O157:H7 in beef and chicken: Determination of D- and z- values. Int. Journ.of Food Mocrobiol. 35: 231-237

- Pfaller, S.L., S.J. Vesper, and H. Moreno. 1994. The use of PCR to detect a pathogen in compost. Compost Science and Utilization 2: 48-54.
- Soldierer, W. and Strauch, D. 1991. Kinetics of death of Salmonellae during thermal liquid manure disinfection. Jour. Vet. Med. 38:561-574
- Wang, G., T. Zhao, and M. Doyle. 1996. Fate of Enterohemorrhagic *Escherichia coli* O157:H7 in bovine feces. Appl. Environ. Microbio. 62: 2567-2570
- Wells, J M; Butterfield, J E.1997. Salmonella contamination associated with bacterial soft rot of fresh
- fruits and vegetables in the marketplace.Plant Disease, v.81, n.8, (1997): 867-872.
- Zhao, T. Doyle, M.P., Shere, J. and Garber, L.. 1995. Prevalence of enterohemorrhagic Escherichia coli O157:H7 in a survey of dairy herds. Appl. Environ. Microbiol. 61: 1290-1293