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# *E. coli* Prevention and Control in Fresh Produce from Farm-to-Fork

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Escherichia coli (E. coli) is a common bacterium found naturally in the digestive systems of warm blooded animals and soil and is not normally harmful. However, certain types of *E. coli* produce toxins, called Shiga Toxins, that are harmful. These Shiga toxin-producing E. coli, also called STEC, are significant foodborne pathogens that cause illness in approximately 265,000 people in the United States each year (Scallan, 2011). There are numerous steps along the farm-to fork continuum where growers, harvesters, shippers, and processors implement prevention and control methods to minimize risk from foodborne pathogens, with the goal of ensuring that only the safest fresh produce reaches consumers' tables. Some of these measures are taken to comply with recent federal guidelines under the Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA), which began to be implemented by the fresh produce industry in January 2018 (FDA 2017) Table 1., but for Arizona growers, the FSMA regulations are not burdensome. Since 2007, growers of fresh produce in our state have been voluntarily following equally strict, and even more specific, guidelines developed by the Arizona Leafy Greens Marketing Agreement (LGMA) as enforced by the Arizona Department of Agriculture (https://www.arizonaleafygreens. org). You may ask, "If guidelines are so strict and if growers are so cautious, why do people still get sick from outbreaks of *E. coli* and other foodborne pathogens?" This paper will provide a roadmap of how fresh produce travels from farm-to-fork, identifying potential routes of contamination. We also describe the preventative controls that are implemented by the fresh produce industry at each stop to reduce the potential for microbial contamination, and how consumers can take simple steps to maintain safe foods eaten in their homes or in restaurants.

# **On-Farm Prevention and Control**

The produce growing season in southern Arizona, including for leafy greens, runs from September through April. Every large grower of leafy greens employs a Food Safety Director who is responsible for managing a Food Safety Plan and

Table 1. Food Safe	y Modernization Act	Regulations	(FDA 2017)
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The seven major FSMA regulations include:		
1. Produce Safety Rule - Standards for the Growing, Harvesting, Packing, & Holding of Produce for Human Consumption		
2. Preventive Controls for Human Foods		
3. Preventive Controls for Animals		
4. Foreign Supplier Verification Programs		
5. Third Party Accreditation		
6. Mitigation of Intentional Adulteration		
7. Sanitary Transportation		



Figure 1. Flagged Area in Field to Aid identification of Animal Intrusion, Debris, Etc. Photo courtesy of Dr. Paula Rivadeneira.

maintaining meticulous records related to contaminant surveillance, worker training, animal intrusions into fields, produce field buffer zones (Figure 1), and every other aspect of the farm's Food Safety Program.

## Pre-season Internal Farm Audits

Before planting, growers conduct pre-season assessments of the farm where they intend to plant their crops and the surrounding areas. The assessment includes testing of irrigation water for generic *E. coli* and inspecting the farm and water distribution system for any type of potential contamination, including biological (animal scat, leaky septic, etc.), chemical (leaks or spills of pesticides, fertilizers, etc.), and physical (trash, foreign objects, leaves, etc.) contamination. They also examine activities on land adjacent to their fields to identify the presence of loose pets, nearby hobby farms and livestock, or other activities that could potentially impact their fields. LGMA guidelines mandate that a field can only be used to grow fresh produce for human consumption if it is located more than 400 feet from a concentrated animal feeding operation (CAFO) such as a dairy, or 30 feet from a hobby farm.

In addition to pre-season assessments, every August, the farm's Food Safety Director conducts an annual training for all farm staff to reinforce messages about worker health and hygiene, animal intrusion, and internal food safety policies.

#### **Field Preparation**

Once the internal farm audit is complete, the field is prepared for planting. Biological soil amendments are purposefully added to the soil to make it healthier and more productive, and include things such as compost made from the fecal material of animals. Since the feces of mammals, including humans and animals, can be contaminated with *E. coli*, some growers of conventional crops opt to use synthetic fertilizers instead. Suppliers of synthetic fertilizers must provide a letter of guarantee that their products do not contain biosolids or raw manure. Organic growers use biological soil amendments commonly made from cattle manure, but these amendments may also be made from chicken or fish waste. According the LGMA metrics, manure utilized on fresh produce fields must undergo composting, which raises the temperature of the manure to at least 131°F for 3 days, high enough to destroy most pathogens. Compost suppliers must provide pathogen testing results for their product that confirm that there are less than 1 organism per 30 grams of compost for *E. coli* O157:H7 (the most common type of STEC found in the United States) and *Salmonella*.

In addition to intentional impacts on fields like biological soil amendments, growers must also be prepared for unintentional field impacts. Growers maintain a great deal of historical data about wildlife near their fields. Because wildlife species are known to carry *E. coli* (Somarelli et al., 2007; Crook et al., 2017), many growers have erected fences to keep out large mammals, such as deer, javelina, coyotes, and wild burros. Other animals, such as birds, are harder to keep out of fields, so growers use a multitude of bird deterrents, including scarecrows, pyrotechnics, and sound cannons. In some cases, animal deterrents are implemented before the field is planted, but in other cases, when animal intrusion is not expected, deterrents are put in place during the growing season after the presence of animals is suspected or confirmed.

#### Growing Season

Prior to irrigating the crops, irrigation canals are inspected for the presence of trash and animal fecal contamination. Under LGMA guidelines, water sampling for generic *E. coli* continues every 30 days throughout the growing season, and farm employees monitor and report any potential contamination of the irrigation water system (including fecal contamination of irrigation canals, pipeline breaks, etc.) to their supervisors who in turn report the findings to the Food Safety Director. The Food Safety Director is then responsible for addressing



Figure 2. AZ LGMA Tailgate Training Guide. Photo courtesy of Teressa Lopez.

the contamination issue to ensure that irrigation water quality remains within mandated guidelines.

Though the Food Safety Director is often responsible for maintaining farm operations in a manner that protects the microbial quality of the fresh produce, protection of the product in the field is very much a team effort. Growers generally work with labor contractors that must provide a letter of guarantee that they have a food safety training program in place, and they must provide the grower with documentation showing that all of the contracted field workers have successfully completed that training program. While workers are in the field, supervisors conduct spot checks to ensure compliance with all food safety regulations, and also conduct periodic 'tailgate trainings' to reinforce regulations (Figure 2). No one is allowed to work in the field without training.

During the growing season, food safety personnel and farm managers also conduct field inspections every week for the presence of any potential contaminants. Growers also implement rodent control measures, as well as wildlife deterrence programs for larger mammals and birds. Cleanup crews pick up trash every Monday in every field. If animal intrusion is detected, growers buffer the affected area by surrounding it with flags according to food safety guidelines so that it cannot be harvested, and they destroy any fresh produce growing within that area (Figure 3, Figure 4).



Figure 3. Deer Scat in field. Photo courtesy of Dr. Paula Rivadeneira



Figure 4. Do Not Harvest Flagged Area. Photo courtesy of Dr. Paula Rivadeneira.

In addition to the training and inspections, all growers of leafy greens periodically undergo intensive third-party audits, which typically last an entire week. Auditors visit every field for the grower they are auditing, they walk the perimeter of each field to ensure that the fields are protected from intrusion, and review all documentation prepared by Food Safety Directors to confirm that mandated guidelines are being followed. In addition, the Arizona Department of Agriculture conducts unannounced, surprise audits under the Arizona LGMA to ensure that growers are in compliance with all regulations.

## **Pre-Harvest Inspections**

Pre-harvest inspections are conducted within seven days before harvest. These inspections follow similar guidelines to the pre-season internal farm audit. If an animal intrusion event occurred during the season and required buffering of potentially contaminated produce, the buffered area is closely inspected to determine if it needs to be increased in area or if new buffers need to be added. In addition, most growers conduct pre-harvest pathogen testing. Preharvest pathogen testing consists of sample collection of raw product (e.g. leafy greens) from the field prior to harvest in a randomized pattern. Samples, sometimes up to 60 pieces of leafy greens per acre, are sent to a private laboratory to test for STEC and *Salmonella*. If any of the samples test positive, produce from that field is not harvested.

# Harvest

Though produce safety standards are mandated before and during the growing season, the standards are heightened during harvesting, when the field workers actually touch the product. Harvesting of fields is conducted by harvesting crews specially trained at identifying potential signs of contamination including animal fecal material, debris, animal tracks, trash, etc. (Figure 1). During harvest, the contractors conduct detailed daily tailgate trainings for harvesting crews that cover every aspect of food safety. Such trainings include how to wear proper protective gear and (if applicable) hair nets, the importance of clean clothing, proper handwashing prior to entry in the field and following rest room breaks, and proper harvesting tool sterilization (Figure 5). Field workers are, once again, very much a part of the fresh produce safety "team" because they are often in a position to identify potential field contamination. If an issue arises, such as the identification of fecal material or animal intrusion in the field by harvest crews, the harvesting stops, the supervisor is notified, and the field manager and Food Safety Director make decisions regarding set-back distances for continued harvest, or if harvested product needs to be destroyed (Figure 6).



Figure 5. Handwashing Station Adjacent to the Field. Photo courtesy of Dr. Channah Rock.



Figure 6. Debris (leaves) in Field during Surveillance. Photo courtesy of Dr. Paula Rivadeneira.

# **Post-Harvest Prevention and Control**

# **Cooling Facility**

Once harvested, all produce that leaves the field goes to a cooling facility by truck or trailer. In order to maximize the shelf life, produce has to travel from the field to the cooler (called "cut to cool time") within 4 hours of harvest. While no pathogen testing of product is done at the cooler, managers of cooling facilities conduct routine visual inspections and environmental testing, which includes testing drain and drip pans within the coolers for the presence of *Listeria monocytogenes*, a foodborne pathogen that grows well in cool temperatures. Other preventive controls at the cooling facilities include worker health and hygiene training, rodent control programs, and frequent temperature checks.

## **Produce Processing Plant**

Produce processing plants specific to leafy greens may then take the fresh product from the cooling facilities and put it through cleaning, chopping, and bagging to create ready to eat products. As salad components pass through the processing plant, temperature of the product is checked regularly, sorters sift out foreign objects, and metal detectors ensure that no metallic objects are mixed into the bagged product.

One of the most important steps in processing leafy greens and other produce eaten raw is the washing process. Many salad processors use a triple wash process, which involves

passing the greens through successive baths of water with some form of disinfectant (such as chlorine) before they are dried and packaged. The wash water baths aim to dislodge debris (such as particles of soil) from the leaves and disinfect the product in case there is unidentified bacterial contamination. During the wash procedure, pH, temperature, oxidation reduction potential, and residual disinfectant levels in wash water are tested and maintained to standards that eliminate pathogens. Processing plants also conduct worker health and hygiene trainings on a routine basis and maintain rodent control programs. Additionally, all food contact surfaces must be cleaned and sanitized according to industry standards to ensure no cross-contamination occurs. Often surfaces are "swabbed" for ATP (Adenosine Tri-Phosphate), an energy source for bacteria, as an indicator of surface cleanliness. The presence of ATP on a surface indicates improper cleaning and the potential presence of contamination, including food residue, allergens, and/or bacteria. Lastly, the final product is randomly tested for pathogens so any potentially contaminated product can be removed from circulation before leaving the facility.

# **Distribution Center and Shipping**

From the processing plant, produce then goes through a distribution center, where it is sorted for shipping throughout the United States and the world. Temperature is a key factor in maintaining shelf life and quality specifically for leafy green produce and thus, temperature is closely monitored in the distribution center and temperature loggers are placed in shipping trucks. Once the product is loaded, the truck is sealed with a tamper proof closure as a biosecurity measure.

# **End Users**

## Restaurants

After the journey from field to cooler, to processing center and to distribution center, the fresh produce is finally distributed locally (through a restaurant or supermarket) and ends up on your table. There is no mandated testing at local distribution facilities and, though responsible restaurant owners will make certain that their employees follow food safety guidelines, the consumer often has no knowledge of fresh produce safety procedures that are in place in restaurant kitchens. But there are still simple steps that diners can take to protect themselves. First, every restaurant in the United States must display their health inspection scores, and often pride themselves upon receiving and "A". Second, look around the restaurant. Does is appear to be clean? Does the bathroom have adequate soap and warm water to ensure that employees are washing their hands after use? Are workers and servers wearing clean clothes, hair nets, and appear to be free of illness? Are the floors washed and free of clutter?

Finally, a common source of foodborne illness is restaurant "to go" containers, which can sometimes sit in hot cars before refrigeration. The United States Centers for Disease Control recommends that all "to go" containers be refrigerated within two hours of leaving the restaurant (or within one hour if ambient temperatures are above 90 degrees). Even after refrigeration, leftover food should be consumed within three to four days (CDC, 2018a).

# **Home Kitchens**

Following a supermarket purchase, what can consumers do in their homes to enhance the safety of fresh produce? First and foremost, consumers MUST realize that, food safety starts in the field for fresh vegetables and produce, especially those eaten raw such as whole head lettuces, peppers and cucumbers. Survival of microorganisms on produce is not the result of poor hygiene – more realistically, consumers must realize that their produce is grown in soil, which is, by nature, "dirty" and may contain microorganisms. It is very possible that, even with all of the safety measures in place, microorganisms survive the processing. And yes, some of these microorganisms could be pathogens.

When a bag of vegetables indicates that it has been triple washed, it has been. Following the protocols listed in the produce processing plant, as described earlier, ensures that the produce company is following strict procedures so the consumer can consume the ready prepared product with ease. If the produce is not ready prepared, it is up to the consumer to tend to their produce before consuming it. Prior to preparing foods, the CDC advises consumers to thoroughly wash hands, and to wash and scrub produce under running water before eating, cutting, or cooking (CDC, 2018b).

## What else can a consumer do?

- Keep leafy greens and other produce refrigerated at the proper temperature (40° F or below) within 2 hours of purchasing, or within 1 hour if temperatures are above 90° F (CDC, 2018b).
- Do not eat wilted, slimy, discolored, or expired produce.
- Do not chop or prepare produce on a dirty cutting board or on the same cutting board with other products that could be contaminated with pathogens, such as raw or undercooked meat products.
- When storing produce, do not keep them next to or below raw meats. The juices from the meats could drip onto the produce and cause cross-contamination.

Though foodborne outbreaks periodically make the news in the United States, professionals at every step of the farm-to-fork continuum work hard to enhance the safety of our food supply. As the final step in that continuum, the consumer should work as part of the food safety "team" and take these easy steps. This will reduce foodborne outbreaks and contribute to healthier consumers.

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