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Preventing Foodborne Illness: *E. coli* "The Big Six"[1]

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This is one in a series of fact sheets discussing common foodborne pathogens of interest to food handlers, processors, and retailers. For the rest of the series, visit http://edis.ifas.ufl.edu/topic_foodborne_illness.

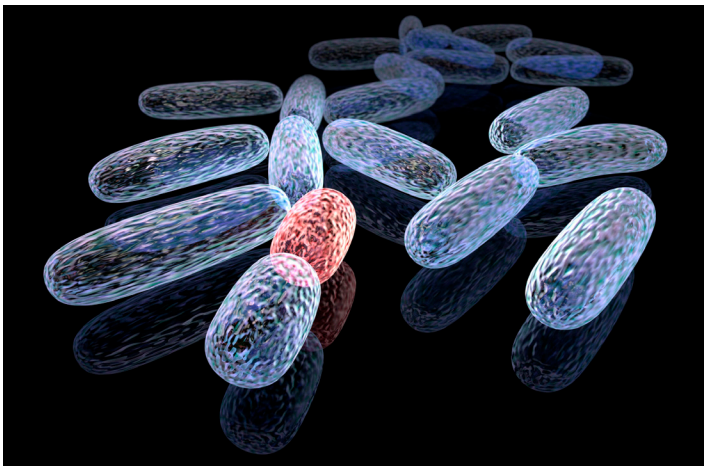

Figure 1. *E. coli* bacterium. Credits: iStock

What is *E. coli*?

Escherichia coli (*E. coli*) is a bacterium from the family *Enterobacteriaceae.* It is usually found in the digestive system of humans and animals and can survive in the environment for extend periods of time (Armstrong et al. 1996; Tuttle et al. 1999). There are hundreds of known *E. coli* strains, with the pathogen *E. coli* O157:H7 being the most widely recognized due to the severity of the food-borne illness it causes (CDC 2015a). Since fecal material can contain pathogens like *E. coli* O157:H7, it is important to thoroughly wash anything that becomes contaminated, such as food and food contact surfaces (Armstrong et al. 1996; Tuttle et al. 1999).

What type of bacterium is *E. coli*?

E. coli are Gram-negative, rod-shaped bacteria. Some pathogenic strains have been variously described as verotoxigenic *E. coli* (VTEC) or Shiga-like toxin-producing *E. coli* (SLTEC). Most recently, the designation has been simplified to Shiga toxin-producing *E. coli* (STEC) in recognition of the similarities of the toxins produced by *E. coli* and *Shigella dysenteriae* (Fischer Walker et al. 2012; Murray et al. 2007). Such potent toxins can cause severe damage to the intestinal lining, even in healthy individuals. *E. coli*-produced toxins are responsible for symptoms such as hemorrhagic colitis. Hemorrhagic colitis is associated with bloody diarrhea and hemolytic uremic syndrome (HUS), which is seen in the very young and can cause renal failure and hemolytic anemia. Both illnesses can be harmful and, in very severe cases, can lead to death (Murray et al. 2007; FDA 2015). Generally, *E. coli* can survive at both low and high temperatures ranging from 7°C (44.6°F) to 50°C (122°F). It can also survive under acidic conditions (at pH levels around 4.4), making it able to survive in mildly acidic food (WHO 2017). These organisms have a low infective dose and can be transmitted from person to person and

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through food products that become contaminated, such as ground beef, unpasteurized juices or milk, and produce (WHO 2017). It is very important to cook meats thoroughly and at a correct temperature (145°F [63°C] or above) (Besser et al. 2001; CDC 2017).

What are the "big six"?

Certain types of *E. coli*, such as O157:H7, can produce Shiga toxins that can cause severe illness. In addition to *E. coli* O157:H7, other *E. coli* serotypes have been shown to produce these toxins and cause foodborne illness. The US Food and Drug Administration (FDA) has identified six serogroups, known as the "big six": *E. coli* O26, O45, O103, O111, O121, and O145. Serogroups are a designation scientists use to group different serovars, or strains, of *E. coli*. The "O" refers to the O (somatic) antigen, a surface structure that differs among serovars of *E. coli* (Murray et al. 2007). These six serovars are the most commonly identified types of non-O157 *E. coli serotypes* found in foods and cause approximately 169,600 cases of foodborne illness in the US each year (CDC 2016a).

Outbreaks Associated with Non-O157:H7 *E. coli*

The most recent outbreak of non-O157 *E. coli* was linked to flour in December 2015. Sixty-three people were reported to be infected with Shiga toxin-producing *E. coli* (STEC) O121 or O26. The outbreak was associated with illnesses in 24 states. One person developed hemolytic uremic syndrome (HUS), but no deaths were reported. All the infected children were reported to be playing with and eating raw dough made from contaminated flour (CDC 2016b).

Recently, consumer trends towards organic and/or locally sourced food have resulted in an increase in restaurants offering fresh and/or healthier food offerings. Unfortunately, organic and/or locally grown food options come with the same safety risks of raw or minimally processed food ingredients. In October of 2015, a multistate outbreak of STEC O26 was linked to a Mexican grill restaurant (CDC 2015b) that led to 55 cases of foodborne illness and 21 hospitalizations. A second outbreak of a rare strain of *E. coli* O26 occurred two months earlier, resulting in five illnesses in three states. The outbreak was also linked to the same Mexican restaurant chain (CDC 2015a).

An outbreak of another STEC strain, O145, occurred during the summer of 2012 (CDC 2012). This outbreak caused 18 people to become ill in nine different states, with one fatality reported. Unfortunately, researchers were unable to determine the source of contamination for this outbreak.

One of the largest outbreaks of non-O157 *E. coli* was in 2011. The outbreak, centered in Germany, affected people in 12 European countries, sickened more than 4,000 people, and killed 49 (Vogel 2011). Investigators concluded that sprouts from fenugreek seeds imported from Egypt were most likely the main source of the outbreak (Buchholz et al. 2011). *Escherichia coli* O104:H4 strain shares the same virulence trait as enteroaggregative *E. coli* (EAEC). Enteroaggregative *E. coli* strain attaches to a type of epithelial cells (HEp-2) in an aggregative manner and produces a Shiga toxin-like toxin (Dulguer et al. 2003). This outbreak had a hemolytic uremic syndrome (HUS) rate 70 times higher than had been previously recorded (Frank et al. 2011). More than 3,800 people became ill (845 of which contracted HUS) and 54 people died (Frank et al. 2011). Researchers are still attempting to understand why this strain of *E. coli* is much more virulent than other strains.

Many of the food items linked to *E. coli* O157:H7 outbreaks have also been associated with non-*E. coli* O157:H7, as well. Since 2010, major outbreaks have been associated with both sprouts and lettuce (CDC 2016a). However, beef, other meat products, milk, and even water are also potential sources of contamination (Arthur et al. 2002; Rounds et al. 2012). Livestock and runoff from animal farms have been implicated as the main source of agricultural contamination, but contamination can also occur during processing.

Along with many foodborne outbreaks associated with non-O157, there have been numerous product recalls involving non-O157 contaminated products that have not resulted in consumer illnesses. The USDA's Food Safety and Inspection Services (FSIS) issued three recalls in 2007 for non-O157 contamination of meat products. The most recent recall was for 5,620 pounds of veal, beef, and pork products, as they may contain *E. coli* O111. To get the latest information on food recalls you can visit the FDA and USDA websites to view current recalls and alerts (FDA 2017b; USDA 2017).

- FDA (https://www.fda.gov/Safety/Recalls/)
- USDA (https://www.fsis.usda.gov/wps/portal/fsis/topics/recalls-and-public-health-alerts)

How are the "big six" *E. coli* bacterium spread?

Monitoring the "big six" is relatively new, so determining how they are spread is challenging. For the few cases in which the source was determined, non-O157:H7 *E. coli* was mainly spread through person-to-person contact, and to a lesser extent, through dairy, meat, and water. This is quite different from O157:H7, which is mainly spread through water, meat, and dairy products (Kaspar et al. 2010).

A few years back, surveillance for the "big six" was limited, but this has changed recently with the new USDA-FSIS regulations. As of June 2012, the USDA Food Safety and Inspection Service (FSIS) began testing facilities for both O157:H7 and the "big six" in ground beef (USDA 2012).

Symptoms of STEC *E. coli* Infections

The acute disease associated with this organism is named hemorrhagic colitis. The symptoms characteristic to this disease are watery and/or bloody diarrhea, fever, nausea, severe abdominal cramping, and vomiting (Fischer Walker et al. 2012; Tarr 1995). Because most people recover from this infection on their own, treatment is usually not necessary. Symptoms can appear within hours or up to several days after ingestion of the bacteria, and the illness usually lasts 5–10 days. Some individuals may develop HUS. In the very young, this disorder can cause renal failure, hemolytic anemia, or even permanent loss of kidney function (Fischer Walker et al. 2012; Tarr 1995). These same symptoms also occur in the elderly, as well as thrombotic thrombocytopenic purpura (TTP) (HUS with additional neurological dysfunction and/or fever) (Tarr 1995).

High-Risk Populations for *E. coli* Infections

E. coli infections can be serious for healthy people of any age, but it is more likely to cause severe illness in the very young (those under age five), the elderly, and immune-compromised patients (Tarr 1995; CDC 2016a). Workers in certain industries also have a higher risk of infection; those working in slaughterhouses, farms, hospitals, nursing homes, nursery schools, and food preparation locations are more susceptible to infection than the rest of the population (Keene et al. 1994).

Minimizing the Risk of *E. coli* in Food Processing Plants and Other Food Establishments

Sanitation Methods

CLEAN

Use hot, soapy water and an appropriate sanitizer to wash hands and surfaces that contact food. Wash hands, cutting boards, dishes, and utensils after they come in contact with raw food. Clean liquid spills in the refrigerator, especially spills from products associated with *E. coli*.

- Ensure employees wash their hands before, during, and after handling any food, particularly raw meat and poultry.
- Sanitize all utensils, cutting boards, and work surfaces before and after use with an approved sanitizing agent.
- Clean surfaces that may have come into contact with possible sources of *E. coli* contamination, such as refrigerator shelves.
- Wash all vegetables and fruits thoroughly before consumption.

SEPARATE

Treat all RTE (ready-to-eat) foods, raw meat, poultry, and seafood as possible sources of contamination. Keep these foods separate from items that traditionally do not get cooked or potentially can be eaten raw, such as vegetables, fruits, and other already-prepared, edible foods. This reduces the chance of cross-contamination.

- Use separate utensils for both raw and cooked foods.
- Store meats and other potential sources of contamination in areas below cooked or RTE foods.
- Rewrap open packages carefully or store in leak-proof containers to prevent cross-contamination.

COOK

Always heat foods to safe temperatures. The 2013 FDA Food Code recommends cooking to an internal temperature of 145°F (63°C) or above for 15 seconds for most potentially hazardous foods (refer to Sections 3–4: *Destruction of Organisms of Public Health Concern*, Subparts 3-401 and 3-501 for specific details on cooking temperatures) (FDA 2013).

The best measures to control *E. coli* are proper cooking, preventing cross-contamination of raw and cooked food,

proper personal hygiene, and good sanitation. In addition, make sure to follow these recommendations to reduce the incidence of foodborne *E. coli* contamination:

- Don't store food in the temperature danger zone between 41°F (5°C) and 135°F (57°C) (FDA 2013). Refrigeration should be at 41°F (5°C) or colder. All food should be refrigerated promptly (FDA 2013).
- Completely cook or boil foods like hot dogs and poultry products until they become steaming hot, meaning 165°F (74°C) or above.

STORAGE

Limit the amount of time food is exposed to room temperature to two hours or less before returning perishables and RTE foods to the refrigerator or freezer.

- Cover all food to prevent cross-contamination.
- Place uncooked meat, poultry, fish, or other raw products below cooked or RTE foods in the refrigerator to prevent cross-contamination.
- Maintain the refrigerator temperature at or below 41°F (5°C), and keep refrigerator clean.
- Follow the "use by" or "best by" dates on refrigerated items.

Current Good Manufacturing Practices for Food Product Receiving, Handling, Processing, and Storage

The FDA defines Current Good Manufacturing Practices for food (CGMPs) in title 21 of the CFR (Code of Federal Regulations) part 117 (FDA 2017a). These CGMPs outline the minimum required general sanitation practices in FDA-inspected food handling and processing facilities. It is recommended that more specific and stringent standard operating procedures (SOPs) be developed for individual facilities. In addition, the sanitation recommendations for food service and retail food facilities outlined in the FDA 2013 Food Code have been adopted into many states and local regulations (FDA 2013). Because of the variation in Food Code adoption, each facility must check with the appropriate state and/or local regulatory authority. The Florida Statues can be found online at http://www.leg.state.fl.us/statutes/. Title 33, Chapter 509 specifies some of these regulations.

In addition to setting and adhering to strict sanitation requirements in the facility, a retail establishment should also develop SOPs for receiving and storing food products and ingredients. If food processing is being done, appropriate controls and requirements should be established and strictly followed. The FDA Food Code 2013 outlines appropriate processing and cooking requirements for many food products processed in a retail facility. However, processing certain high-risk food products (e.g., sushi, fresh juice, specialty meats, and others) in the retail establishment rather than in a more traditional processing facility requires additional controls and the issuance of a "variance" by the regulatory authority before processing can occur (FDA 2013). The growing retail practice of cooking/preparing/packaging foods traditionally processed in controlled plant environments raises food safety concerns. Any processing of food at the retail level needs to be closely monitored.

As an establishment becomes cleaner, it becomes harder to detect foodborne pathogens. At this point, testing becomes more limited in its ability to prevent foodborne illness. This is why food safety programs that promote and monitor the use of barriers and/or hurdles are so important. When instituted properly, these activities reduce the risk of foodborne illness. Nothing can be done to completely eliminate bacterial contamination short of extreme processing, such as high temperature processing under pressure (i.e., canning) or irradiation. (FDA 2017c; Tauxe 2001).

Receiving

Specifications for receiving can be found in Section 3-202.11 of the 2013 Food Code (FDA 2013). The following guidelines cover the basic points that should be addressed:

- Potentially Hazardous Foods (PHF) should be at a temperature of 41°F (5°C) or below when received, unless specified by law (e.g., milk, shellfish).
- Raw shell eggs should be received at an ambient air temperature of 45°F (7°C) or less.
- PHFs that are received hot should be at a temperature of 135°F (57°C) or above.
- PHFs should be received with no evidence of temperature abuse, such as evidence of thawing.

Processing

One of the easiest ways to prevent foodborne illnesses is ensuring that foods are cooked thoroughly. It should be noted that certain foods typically served uncooked, such as fresh vegetables, would obviously not benefit from the cooking process. For these items, other factors such as

sanitation, worker hygiene, and proper storage take on much greater importance.

- Cook eggs, fish, whole meat steak, chop (beef, pork, veal, and lamb), or foods containing these items to an internal temperature of 145°F (63°C) or above for a minimum of 15 seconds.
- Cook ground meat (all meat or fish) products to an internal temperature of 155°F (68°C) or above for a minimum of 15 seconds.
- Cook poultry (including whole or ground turkey, chicken, and duck) to an internal temperature of 165°F (74°C) or above for a minimum of 15 seconds.
- Reheat previously cooked material to an internal temperature of 165°F (74°C) (FDA 2013).

Storage

Once a product has been received and/or processed, it now will be displayed or stored. There are some general guidelines governing these practices as well.

- Frozen food should remain frozen until it is used.
- If frozen food is displayed in a refrigerated case, the food should remain at 41°F (5°C) or below.
- Frozen food should be thawed at a temperature of 41°F (5°C) or below. Food can also be thawed under running water at a temperature of 70°F (21°C) or below. The product can be thawed as part of the cooking process.
- Product must be cooled adequately. Refer to sections 3-501.14 and 3-501.15 of the 2013 Food Code.
- Hold cooked product above 135°F (57°C) while displaying, and under 41°F (5°C) while storing.
- Properly label all stored products (FDA 2013).

Personal Hygiene

Wash your hands! The major cause of foodborne illness in retail establishments comes from poor personal hygiene, particularly a lack of proper hand washing. Dirty hands can contaminate food. Although hands may look clean, the bacteria that cause illness are too small to be seen. Whenever you are preparing food and come in contact with items not part of the assembly process, *rewash your hands*. The same is true *even* when wearing gloves. **There is no "five-second rule" when it comes to food safety!** Millions of bacteria and other germs can be transferred on contact. You should wash your hands in all of the following situations:

- Before handling, preparing, or serving food
- Before handling clean utensils or dishware
- After using the restroom
- After touching your face, cuts, or sores
- After smoking, eating, or drinking
- After handling raw meat, especially poultry
- After touching unclean equipment, working surfaces, soiled clothing, soiled wiping cloths, etc.
- After collecting and/or taking out the garbage

Your facility may have even stricter requirements that you must comply with to ensure food safety.

What is the proper procedure for hand washing?

- Wet your hands with warm water.
- Apply soap and wash your hands for 20 seconds.
- Rinse and dry with a single-use paper towel.
- Use the paper towel to shut off the water.

Resources

"Current Good Manufacturing Practice in Manufacturing, Packing, or Holding Human Food," Title 21 Code of Federal Regulations, Pt. 110. 2009 ed. Accessed February 2013. http://www.access.gpo.gov/nara/cfr/waisidx_09/21cfr110_09.html.

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