



A Guide to *E. coli* O157 in Cattle



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Escherichia coli Defined



Escherichia coli are a large and diverse group of bacteria of the family Enterobacteriaceae commonly found in the lower intestine of warm-blooded organisms like birds and mammals (including cattle and humans).¹ They are Gram-negative, rod-shaped, facultative anaerobe bacteria comprised of literally hundreds of *serotypes*.²

A serotype of *E. coli* is a subgroup within the species that has unique characteristics that distinguish it from other *E. coli* strains. While these differences are often detectable only at the molecular level, they may result in changes to the physiology or life cycle of the bacteria.³ New serotypes of *E. coli* evolve through the natural biological processes of mutation and horizontal gene transfer (the ability to transfer DNA through an existing bacterial population).³

Most *E. coli* strains are harmless as part of the normal flora of the gut and can benefit their hosts by aiding in food digestion, producing vitamin K and B-complex vitamins, and by preventing the establishment of harmful bacteria within the intestine.⁴ Humans, for instance, need *E. coli* and other kinds of bacteria within the intestinal tract to remain healthy.⁴

E. coli is not always confined to the intestine, and its ability to survive for brief periods outside the body makes it an ideal indicator organism to test for fecal contamination in the environment (water, soil, plants) or in food (vegetables, meat, etc.). Furthermore, serotypes of *E. coli* are often host-specific, thus making it possible to determine whether the source of fecal contamination originated from birds, humans or other mammals.



Photomicrograph of *E. coli* O157.
(J. Haney Carr; CDC)

E. coli Facts:

- Rod-shaped intestinal bacterium
- Often have fimbriae, short appendages for attachment
- Environmentally tough
- Can infect virtually all animals
- Hundreds of serotypes identified
- Most strains are harmless, but some can cause illness

E. coli O157

Although most strains of *E. coli* are harmless, others can cause illnesses like diarrhea, urinary tract infections, pneumonia and other clinical disease.¹ As a pathogen, *E. coli* is best known for its ability to cause intestinal disease. Five classes of *E. coli* that cause diarrheal diseases are currently recognized: enterotoxigenic, enteroinvasive, enterohemorrhagic, enteropathogenic and enteroaggregative. Each class falls within a serological subgroup and has distinct features in how it causes sickness.

E. coli O157 is one particular serotype in the enterohemorrhagic category that has become a major concern for cattle producers and their customers because it sometimes causes human illness when introduced into the human intestine (but colonized cattle *do not* get sick). This infamous strain is more specifically identified as *E. coli* O157:H7. Microbiologists generally differentiate *E. coli* strains based on antigens associated with a particular strain, using an “O” and “H” naming system.⁵ The “O” designation describes the particular antigen associated with the cell wall of the microbe, while the “H” designation refers to the particular flagella antigen of the cell. This O:H combination is called the serotype.⁵

The feature that makes enterohemorrhagic bacteria like *E. coli* O157 so problematic is the fact that they produce poisons called **Shiga toxins** that can damage the lining of the human intestine and other tissues.¹ The name “Shiga toxin” is derived from its similarity to a toxin produced by another microbe, *Shigella dysenteriae*. Apparently, the gene encoding Shiga toxin was transferred from *Shigella* to *E. coli* by a virus that infects bacteria (bacteriophage).⁶ *E. coli* bacteria that manufacture these types of toxins are called “Shiga toxin producing *E. coli*,” or **STEC** for short (and STEC that cause hemorrhagic colitis and hemolytic uremic syndrome are called enterohemorrhagic *E. coli*).⁵

E. coli O157:H7 is the most commonly identified STEC in North America, and its name is often shortened to *E. coli* O157, or even just O157.^{1,7} Also, whenever reports of generic *E. coli* infections or outbreaks are in the news, *E. coli* O157 is usually the implicated strain.¹ However, many other kinds (serogroups) of STEC can cause disease and are sometimes referred to as “non-O157 STEC” (e.g., serogroups O26, O111 and O103 are the non-O157 STEC that most often cause human illness in the United States).^{1,3}

A very important feature for understanding *E. coli* O157 is the fact that the bacteria do not cause disease in cattle. Thus, *E. coli* O157 is nonpathogenic for cattle. However, the microbes can be very pathogenic for humans, so ingestion of anything contaminated with *E. coli* O157 can pose a potential threat to human health. Unfortunately, cattle are common hosts of *E. coli* O157, along with many other animals. ■

Spread of *E. coli* O157



Carriers

E. coli O157 bacteria are very common in the environment and can survive quite well in most places animals (including pets) or humans co-exist.⁸ *E. coli* O157 has been found in sheep, horses, goats, elk, pigs, deer, opossums, raccoons, dogs, poultry, wild birds, and houseflies, and researchers have found *E. coli* O157 in most facets throughout the cattle industry systems.⁸ If any animal harbors *E. coli* O157 in its intestinal tract, it can typically “shed” the organism through its feces. Shedding by ruminants is particularly common, suggesting these animals provide a survival niche for the bacteria. Thus, it is not unusual to find *E. coli* O157 in the manure of healthy cattle.⁸

Transmission to Humans

People are at risk of consuming *E. coli* O157 when they eat, drink or touch their hands to something that has been contaminated with animal fecal matter. Once ingested, the bacteria may colonize in the intestines and can potentially cause illness.

E. coli O157 can be transmitted through contaminated food and water, directly from one person to another, and even through occupational exposure.⁸ Most foodborne outbreaks have been traced to products derived from cattle, especially ground beef and raw milk.⁹ Food products from other species also may transmit the organism, as demonstrated by the frequent contamination of lamb meat in some countries and even an outbreak linked to venison jerky.⁹ Meat likely becomes contaminated at the time of slaughter, and grinding may compound the problem by introducing the pathogen into the interior of the meat, where it is more likely to survive cooking.⁹ Outbreaks involving commercial salami highlight the tolerance of *E. coli* O157 to acid and its ability to survive fermentation and drying. In addition, several outbreaks have been traced to cooked meats, probably due to cross-contamination.⁹

Spread of *E. coli* O157

Fruits and vegetables have accounted for a growing number of outbreaks. Fresh produce or fruit products such as lettuce, apple cider, unpasteurized fruit juice, alfalfa sprouts, and radish sprouts have been implicated.⁹ A noteworthy example was an *E. coli* O157:H7 outbreak in the autumn of 2006 associated with contaminated baby spinach that resulted in 205 confirmed illnesses and three deaths.¹⁰ While some produce-associated outbreaks may be due to cross-contamination from meat products, others are more likely to reflect direct contamination in the field with feces of wild or domestic animals. Sprouts may pose a special hazard since pathogens present in trace amounts in seed may replicate during sprouting.

Waterborne *E. coli* O157 outbreaks have occurred due to drinking tainted water and swimming in contaminated water (including underchlorinated swimming pools). Person-to-person transmission has occurred in daycare centers and chronic care facilities, settings that combine a high potential for transmission with people at increased risk of illness. Occupational exposure among nurses and microbiologists also has been documented. These waterborne and person-to-person instances of disease transmission suggest that *E. coli* O157 requires a low infectious dose, a conclusion supported by one outbreak traced to salami in which the average infectious dose was estimated at fewer than 50 organisms. ■



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Cattle as a Reservoir of *E. coli* O157

E. coli O157 bacteria do not cause disease in cattle, but healthy cattle can represent a major reservoir for potential human infection⁹ (Figure 2). Although various STEC strains have been isolated from a diversity of animal species, the bacteria have been found to be more prevalent in ruminants (more than 435 serotypes of STEC have been recovered from cattle). Furthermore, most human illnesses due to STEC infection have been traced to cattle, their manure or their edible products, especially beef.¹¹

Figure 1: Potential sources of *E. coli* infection.

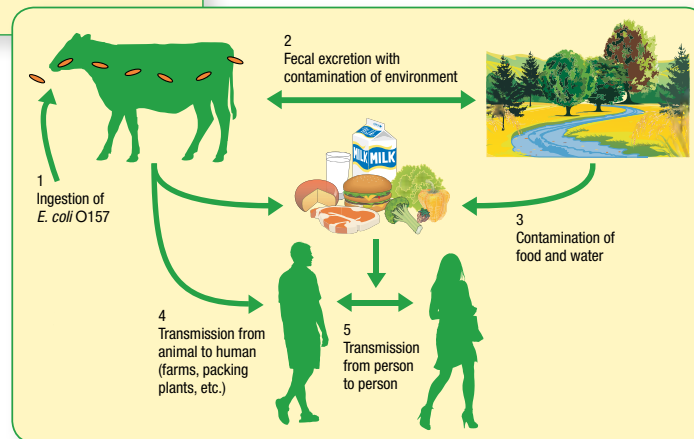
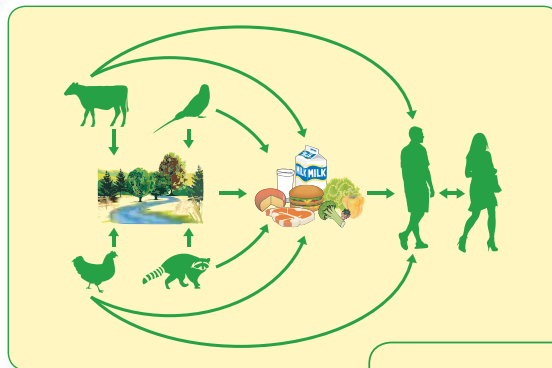


Figure 2: The role of cattle as reservoir of *E. coli* O157.¹²

Production Classes of Cattle

A wide distribution of STEC among various cattle production categories has been demonstrated based on bacterial detection in bulls, cows, heifers, steers, calves, feedlots and grazing animals.³

The frequency that *E. coli* O157:H7 has been reported in cattle ranges from 0 percent to 41.5 percent of the animals tested. A three-decade review of published reports summarized the prevalence of STEC in beef cattle manure and hides (Table 1).¹³ The prevalence rates of *E. coli* O157 generally ranged from 0.3 percent to 19.7 percent in feedlot cattle, 0.7 percent to 27.3 percent in cattle on irrigated pasture, 0.9 percent to 6.9 percent in cattle grazing rangeland forages, and 0.2 percent to 27.8 percent at slaughter.¹¹ These observations suggest that cattle grazing dense vegetation on pasture have a high potential for colonization and recolonization with *E. coli* O157, but not so much on rangeland where cattle travel in large, less-dense areas seeking edible vegetation.¹³

Several research studies investigating *E. coli* O157 in cow/calf herds provide insight into how cattle become initially exposed to the pathogen.⁸ One study found that nearly 87 percent of studied ranches had at least one calf shedding *E. coli* O157, and at least 83 percent of all studied calves had been colonized with *E. coli* O157 prior to weaning.⁸ Calves from every sampled ranch had *E. coli* O157 antibodies in their bloodstreams, suggesting prior colonization even if they were not currently shedding *E. coli* O157.⁸ Another study evaluated calves from birth to weaning. By 1 week of age, 25 percent of calves were shedding *E. coli* O157, and at 2 weeks of age, up to 14 percent were still shedding the pathogen.⁸

TABLE 1: Prevalence Rates of *E. coli* O157¹³

CATEGORY	RANGE
Feedlot cattle:	0.3% - 19.7%
Cattle on irrigated pasture:	0.7% - 27.3%
Cattle grazing rangeland forages:	0.9% - 6.9%
Cattle at slaughter:	0.2% - 27.8%

Cattle as a Reservoir of *E. coli* O157

Shedding

The concentration at which STEC are shed in manure varies from animal to animal, as demonstrated by a U.S. study in which a range from 100 to 100,000 colony-forming units (CFU) of *E. coli* O157:H7 per gram of wet feces was reported.¹⁴ Although *E. coli* O157:H7 has been detected in cattle feces at concentrations up to 10,000,000 CFU/g, the concentrations in most cases are less than 10 to 100 CFU/g.^{15,16}

Shedding of *E. coli* O157:H7 and other serotypes of STEC appears to be related to weaning and age. The lowest rates occur in calves before weaning (nonruminating phase), and the highest rates in calves during the post-weaning period, while rates are intermediate in adult cattle.

Beef cattle shed more STEC in warmer months, which is consistent with the timing of most human illness outbreaks.¹⁷ Testing of U.S. beef cattle over a one-year period revealed the highest (9 percent) and lowest (5 percent) prevalence rates for the fall and winter, respectively.¹⁷ Another study involving testing of Midwestern cattle at slaughter found *E. coli* O157:H7 to be more prevalent in the summer than in winter (12.9 percent vs. 0.3 percent).¹⁸

Environmental studies also have shown that the organisms can persist in manure, water troughs and other places on cattle farms.⁹ Thus, water runoff from feedlots or pastures represents another significant concern for spreading *E. coli* O157 shed by cattle.⁹

Carcass and Beef Product Contamination

The prevalence of *E. coli* O157 in cattle manure has been correlated with subsequent beef carcass contamination.¹⁹ STEC contamination usually occurs during removal of the hide or the gastrointestinal tract, and the site and extent of carcass contamination subsequently affects the prevalence of STEC in various beef products.¹⁸ Cattle hides have been identified as an important source of microbial contamination of carcasses, and *E. coli* O157:H7 is no exception, having been shown to be easily transferred from cattle hides to the carcass.¹⁸

Another review of three decades of published reports investigated STEC prevalence in food facilities and beef products (Table 2).²⁰ Results showed *E. coli* O157 prevalence rates can vary widely and be high.²⁰ ■

TABLE 2: Reported Prevalence Rates of *E. coli* O157 from Multiple Studies in Various Countries*

BEEF PRODUCTS	RANGE
Whole carcasses:	0.01% - 43.4%
Ground beef:	0.1% - 54.2%
Sausage:	0.1% - 4.4%
Unspecified retail cuts:	1.1% - 36.0%

*Data are included from some studies where O157 isolates were not typed for the H antigen. Data from 19 of the 30 studies represented are from small sample sizes of \leq 341 samples.

Human Sickness



Infection with *E. coli* O157 can induce serious disease in humans, particularly in children, seniors or those with weakened immune systems.⁴ For these individuals, *E. coli* O157 can become life threatening by causing kidney failure in a relatively short period of time.⁴

Symptoms, Description, Pathology

Over the past three decades, *E. coli* O157:H7 has evolved from a clinical novelty to a global public-health concern.⁹ The organism was first recognized as a human pathogen in 1982 when it was implicated in two outbreaks of hemorrhagic colitis,²¹ a distinctive illness characterized by abdominal cramps and bloody stools but with little or no fever. The next year, an association between infection with *E. coli* that produce Shiga toxins (including *E. coli* O157:H7) and post-diarrheal hemolytic uremic syndrome (HUS) was reported (a clinical condition technically defined by acute renal injury, thrombocytopenia and microangiopathic hemolytic anemia).²² *E. coli* O157:H7 became the first of several enterohemorrhagic strains that are now believed to account for more than 90 percent of all HUS cases in industrialized countries.²³ Thus, the clinical signs of *E. coli* O157 infection range from symptom-free to nonbloody diarrhea, hemorrhagic colitis, HUS and death.⁹

Though the mechanisms by which *E. coli* O157 causes colitis and HUS are not fully understood, the organisms are believed to adhere closely to mucosal cells lining the large intestine and disrupt the brush border, which alone may be sufficient to produce nonbloody diarrhea (Figure 2). Of course, the Shiga toxins also come into play. These toxins have both local and systemic effects on the intestine and are probably critical to the development of bloody diarrhea.¹¹ The more serious HUS illness is primarily a disease of the kidney microvasculature, thought to develop when Shiga toxins produced by *E. coli* in the intestine enter the blood and damage endothelial cells of the kidneys.²⁴ Although the kidneys are the main target, other organs, including the brain, may be affected, resulting in a wide range of complications.²⁴

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Human Sickness

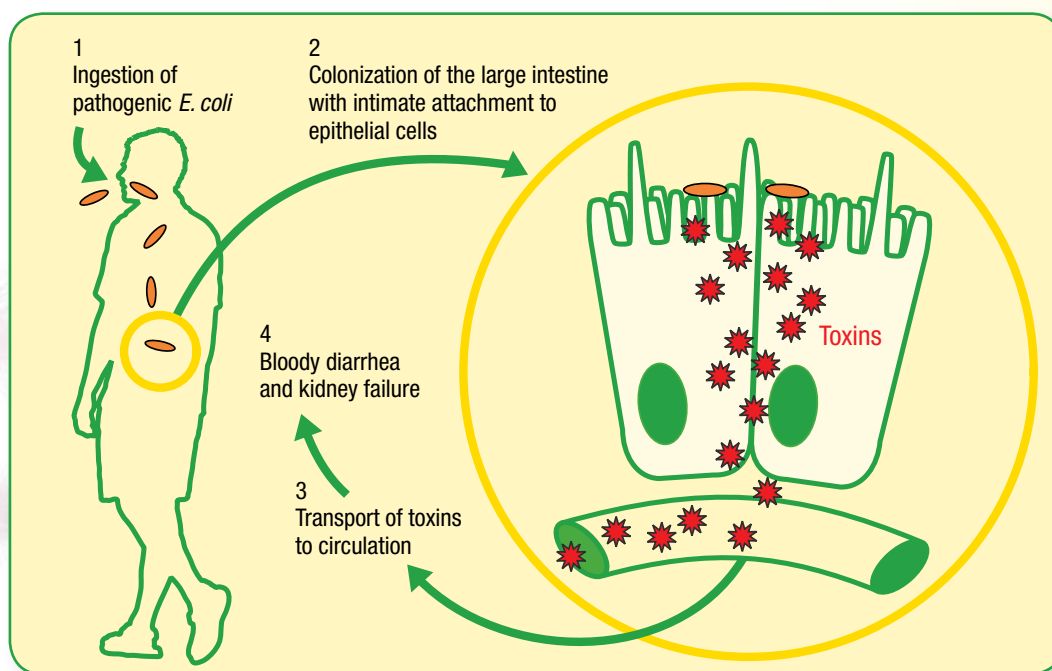


Figure 2: Sequence and mechanism of *E. coli* O157 pathology in humans.¹²

Disease Progression

The overall progression of human illness due to *E. coli* O157:H7 infection is summarized in Figure 3. The average interval between bacterial exposure and illness is three days (range of one to eight days).⁹ Most patients with hemorrhagic colitis recover within seven days.⁹ More than 70 percent of patients report bloody diarrhea, although lower frequencies have been reported in some outbreaks.⁹ Vomiting occurs in 30 percent to 60 percent of cases, and fever (usually low grade) has been documented in 30 percent of cases.⁹

The percentage of cases that progress to HUS ranges from 3 percent to 7 percent in sporadic cases, and about 20 percent or more in some outbreaks.⁹ HUS is typically diagnosed six days after the onset of diarrhea, and clinical outcomes include the following:⁹

- About 50 percent of patients need dialysis⁹
- 75 percent require red blood cell transfusions⁹
- 25 percent develop neurological complications, such as stroke, seizure or coma⁹
- About 3 percent to 5 percent die early; a similar percentage develop end-stage renal disease.⁹

Factors reported to increase the risk of developing HUS include bloody diarrhea,⁹ use of antimotility agents, fever, vomiting, elevated serum leukocyte count, age extremes (especially children younger than 5 years) and female gender.

Human Sickness

E. coli O157 infection is usually confirmed by culturing bacteria from the stool of an infected person.²⁴ Treatment of *E. coli* O157 infections with antimicrobial agents is controversial. Studies suggest antimicrobial therapy may increase the release of Shiga toxin and thus increase the risk of HUS.²⁴ Apart from good supportive care like hydration and nutrition, there is no specific therapy for *E. coli* O157:H7 infection.²⁴

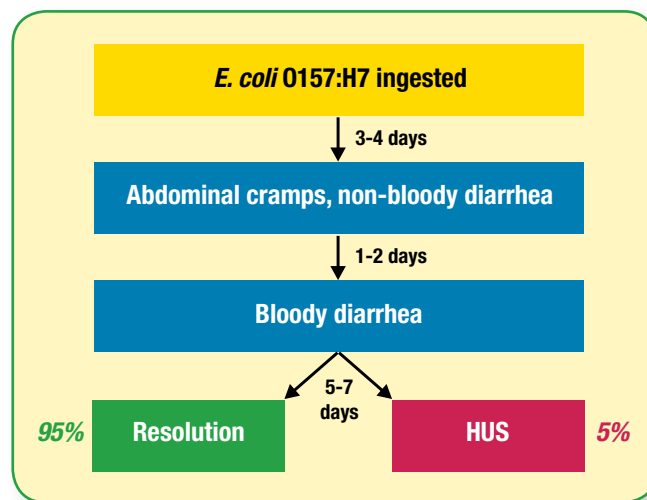


Figure 3: Disease progression of *E. coli* O157:H7 infection in humans.⁹

Prevalence

Human infection with *E. coli* O157 has been reported from more than 30 countries on six continents, with annual incidence rates of eight per 100,000 population or more reported in several regions, including the United States.⁹ High rates also are present in regions of South America, especially Argentina, where HUS is endemic.

Outbreaks of *E. coli* O157:H7 infection can be widespread and exert big impacts. Examples include the illness of more than 5,000 Japanese schoolchildren, the death of 20 people in central Scotland, and the recall of 25 million pounds of ground beef in the United States.⁹ Human infection with *E. coli* O157 is more common in warm summer months (and shedding by animals also is seasonal), suggesting that climatic factors play an important role in determining the incidence of human infection.¹⁸

Again, *E. coli* O157:H7 is not the only strain that can make humans sick. More than 50 percent of non-O157 STEC strains also are known for their ability to cause illness, and some of these strains have triggered major outbreaks. Worldwide, many additional STEC serotypes (e.g., members of serogroups O26, O91, O103, O111, O118, O145 and O166) have been isolated from beef and caused human illnesses ranging from bloody diarrhea and hemorrhagic colitis to the life-threatening HUS.¹¹

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Human Sickness

Prevention

Eating undercooked ground beef is one of the most important risk factors for acquiring *E. coli* O157.²⁴ All ground beef and hamburger should be thoroughly cooked (160 F), and no hamburger should be eaten if it is still pink in the middle.²⁴ Food preparation always should be aimed at avoiding the spread of harmful bacteria in the kitchen.²⁴ Raw meat should be stored separate from ready-to-eat foods; hands, counters, cutting boards and utensils should be washed with hot soapy water after touching raw meat; and cooked hamburgers or ground beef should not be placed on the unwashed plate that held raw meat.²⁴ Fruits and vegetables should be thoroughly washed.²⁴ Children younger than age 5, immunocompromised people and the elderly should avoid eating alfalfa sprouts.²⁴

Liquids also can spread *E. coli* O157, so only pasteurized milk, juice or cider should be consumed, as well as only clean, purified water (municipal water or bottled water).²⁴ Swallowing lake or pool water while swimming should be avoided, especially water in public swimming pools.²⁴

Hand washing is critical for anyone (especially children) visiting a petting zoo or handling animals, and for people with diarrhea or parents changing soiled diapers.²⁴ ■



Costs to the Cattle Industry



Since outbreaks of *E. coli* O157 are often traced back to cattle, every incident where *E. coli* O157 turns up in the food supply fosters great concern for both the general public and the cattle industry. Research has shown that beef product recalls following outbreaks have a negative effect on demand for beef.⁸ For instance, boneless beef prices declined an average of 2.5 percent in the five days following one recall.²⁵ From 1991 through 1999, beef recalls due to safety concerns were estimated to cost the industry as much as \$1.6 billion in lost demand.²⁵

Producers have invested \$20 million in checkoff funds during the last decade in beef safety research, while the top 10 beef-packing companies spent \$400 million on beef safety research.²⁶ Packers also have incurred an estimated \$250 million in increased operating costs due to changes at processing plants aimed at improving beef safety.²⁶ Government and industry have spent at least \$65 million since 1993 on *E. coli* O157 research, with the USDA Agricultural Research Service spending \$49 million from 1993 to 2002 to research food safety.²⁶ Table 3 summarizes an estimate of the overall cost of *E. coli* O157 to the cattle industry.

TABLE 3: Industry Costs of *E. coli* O157 (1993-2002).²⁶

CATEGORY	COSTS
Impact on consumer demand:	\$1,584,000,000
Impact on boneless beef prices:	\$172,000,000
Capital expenditures and increased operating costs by top 30 packers:	\$750,000,000
Recall costs incurred by packers:	\$100,000,000
Government and industry research:	\$65,000,000
Total	\$2,671,000,000

American beef producers feed millions of people worldwide and enjoy a unique reputation for wholesome and safe products.⁸ Still, any threat to the safety or well-being of beef threatens the industry's reputation and producers' livelihoods, and *E. coli* O157 clearly costs the cattle industry a staggering amount of money (nearly \$3 billion). Therefore, it is in the interest of every cattle producer to employ all available tools that can help reduce the chance of *E. coli* O157 entering the food supply. Pre- and post-harvest control measures that effectively decrease *E. coli* O157 in cattle and eliminate contamination of beef products during processing are essential steps toward sustaining a competitive cattle industry.¹¹ ■

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Preharvest Control



As discussed, *E. coli* O157 is an important foodborne pathogen, its prevalence in cattle manure has been correlated with subsequent beef carcass contamination, and manure can be a source of *E. coli* O157 contamination of water and produce.¹⁹ Therefore, a reduction in on-farm, preharvest *E. coli* O157 prevalence in cattle will likely help reduce the risk of disease outbreaks. Unfortunately, such reductions have proven difficult.

Practices fundamental to every livestock operation and should be incorporated as a foundation for any specific *E. coli* O157 control strategy.⁸ Although cleanliness of production areas has not been demonstrated to directly affect the incidence of *E. coli* O157, good practices certainly lay a foundation for optimal animal health and welfare.⁸

Most of the research about *E. coli* O157 preharvest control has been conducted in feedlots mainly because feeding comes right before harvesting in the beef production chain.²⁷ Unfortunately, scientists have not found reliable management practices (e.g., housing, pen cleaning, feed/water management) that predictably and effectively reduce *E. coli* O157 in production settings with the exception of feeding a particular strain of beneficial bacteria (probiotic; significantly reduced shedding).⁴ Still, equipment used to clean pens, move waste or move dead animals should not be used for ration preparation without prior cleaning and disinfecting, and feedlot operators should attempt to limit the transport of bacteria to the packing plant by removing visible manure from cattle trailers and disinfecting trailers/trucks prior to loading cattle.⁴

The discovery of on-farm, preharvest strategies for reducing *E. coli* O157 remains a crucial research priority for the cattle industry, and several promising intervention strategies are in the development phase.²⁶ Notably, one technology is available, with the possibility of giving producers the ability to consistently decrease *E. coli* O157 in live cattle.

Vaccination for Preharvest Control

Vaccination offers an opportunity for preharvest control of *E. coli* O157. For the entire cattle industry's reputation as providers of safe food, producers can vaccinate their animals to help reduce the quantity of *E. coli* O157 cattle carry into the packing plant and thus help limit the potential for *E. coli* O157 foodborne outbreaks in people.^{4*}

Commercial vaccines can fall into three general categories: modified-live, killed and bacterial extracts. Modified-live vaccines do not cause disease in the vaccinated animal. Killed vaccines contain inactivated (bacterin) or viruses. The third category, subunit vaccines, are composed of dead bacterial fractions or surface antigens instead of actual whole cells, and this brings us to a technology that offers opportunity for effective *E. coli* O157 control in cattle.

SRP® Vaccines

Just like the cattle they colonize, *E. coli* O157 bacteria require iron for growth and survival. Iron is an essential nutrient for cattle, and once ingested, it becomes bound to high-affinity soluble proteins that promote formation of red blood cells and other critical cellular functions. Likewise, many types of microorganisms need iron for a variety of functions, and a level of at least one micromolar iron is needed for optimum microbial growth.²⁸ However, there is only a finite amount of usable iron available in the host animal, so this environmental restriction has prompted some bacteria to form their own special iron-gathering protein systems to compete with cattle for available iron.

To accomplish this task, bacteria like *E. coli* O157 generate specialized transport proteins called **siderophores** (siderophore is a Greek term for “iron carrier”) and have **siderophore receptors** located on their outer surfaces.²⁸ Siderophore receptors belong to a class of tube-shaped proteins called **porins**, which transport nutrients through the bacterial cell wall and into the cell. The role of these proteins and receptors is to scavenge iron from the host and make it available to the microbial cell (Figures 4–6). Although research in this field began about five decades ago, interest has grown with the realization that most aerobic and facultative anaerobic microorganisms synthesize at least one siderophore and

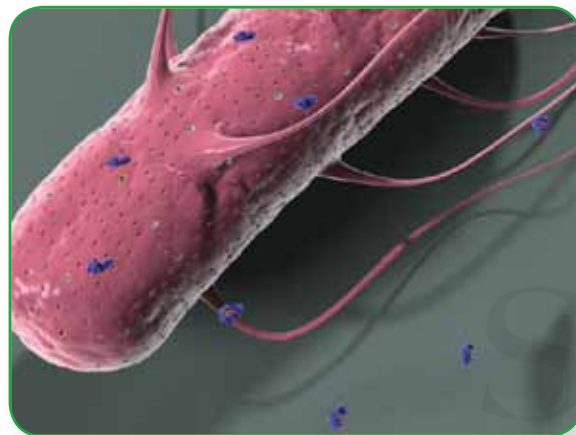


Figure 4: *E. coli* cells release siderophore proteins (blue) to scavenge for iron.

*This product license is conditional. Efficacy and potency test studies are in progress.

Preharvest Control

the fact that siderophores have been related to virulence mechanisms in pathogens of both animals and plants.²⁸

These discoveries provided an opportunity to disrupt this vital nutrient-supply system for pathogens like *E. coli* O157. Together, siderophore receptors and porins can be extracted from bacteria to form a bacterial extract vaccine (Figure 7). This has been accomplished by the Epitopix company. The vaccines utilize SRP® (siderophore receptors and porins) technology. Two conditionally licensed vaccines are available and are exclusively distributed by Pfizer Animal Health for use in cattle, to reduce the prevalence of the *E. coli* O157 (Escherichia Coli Bacterial Extract vaccine) and carrier state, and for the reduction in amount of *E. coli* O157 shed in feces to minimize *E. coli* O157 exposure and infection of herd mates, another product to aid in the control of disease and shedding caused by infection with *Salmonella* Newport.

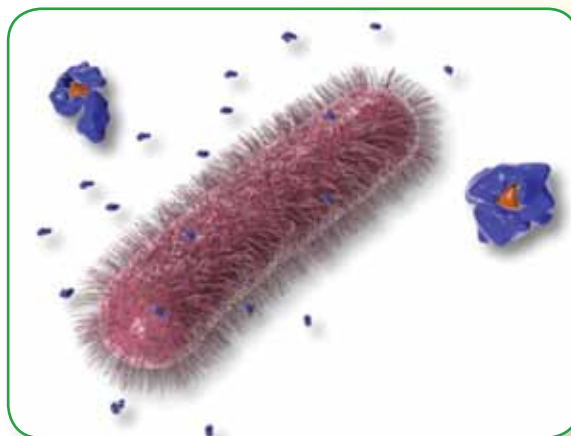


Figure 5: Siderophore proteins (blue) bind to iron, forming siderophore/iron complexes.

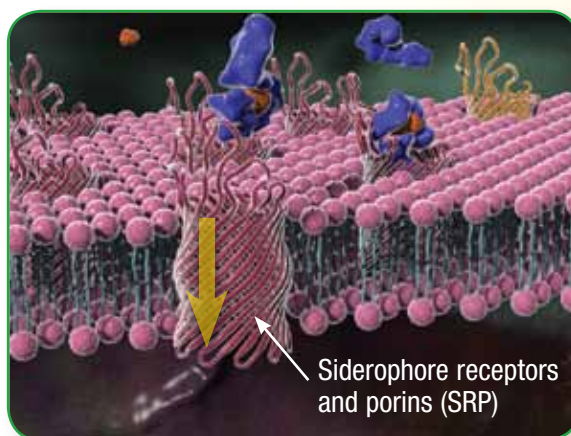


Figure 6: SRP transport siderophore/iron complexes through the cell wall of *E. coli* O157.



Figure 7: Escherichia Coli Bacterial Extract vaccine* contains SRP proteins.

*This product license is conditional.
Efficacy and potency test studies are in progress.

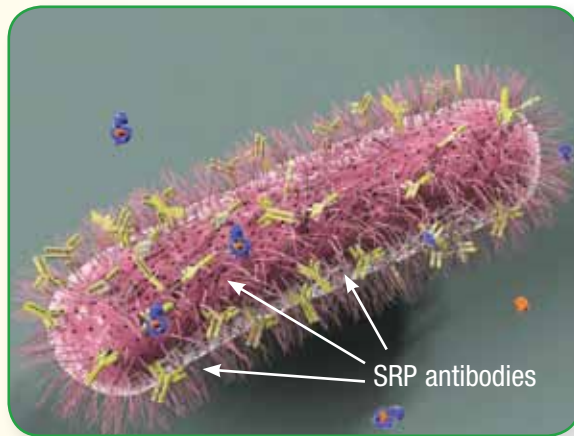


Figure 8: SRP antibodies that cattle generate after vaccination bind to SRP of *E. coli* O157.

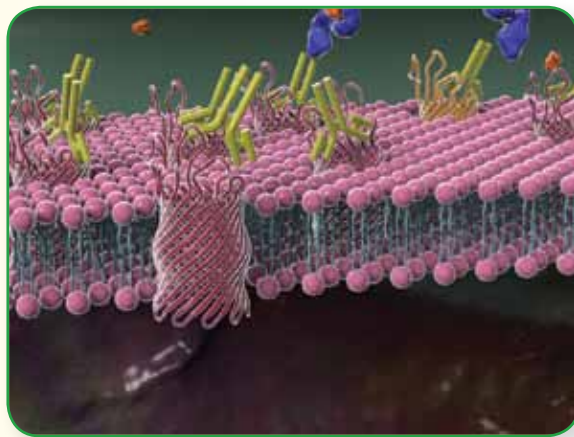


Figure 9: Antibodies blocking SRP help prevent transport of siderophore/iron complexes into cell.

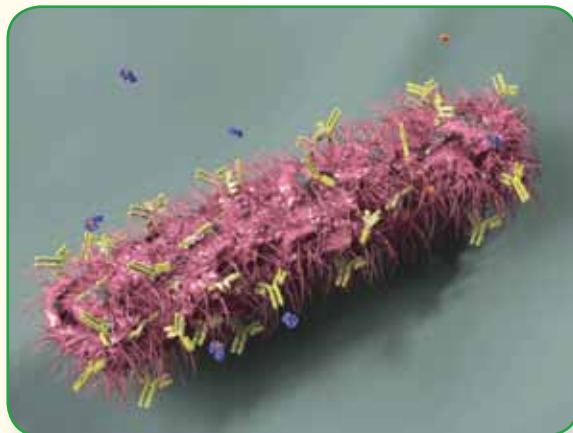


Figure 10: Starved for iron, *E. coli* O157 soon die due to lack of this essential nutrient.

With the SRP technology work by stimulating production of antibodies in cattle, as part of their normal immune response, that help disable the *E. coli* O157 cell wall SRP system required for acquisition of elemental iron (Figure 8). These antibodies help prevent siderophore/iron complexes from passing through the SRP, so bacteria are deprived of iron and die (Figures 9, 10).

SRP® technology targets *E. coli* O157 serotypes because they all use siderophore receptor and porin proteins to capture iron. As a result, SRP helps provide protection against *E. coli* O157 pathogens.

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Preharvest Control

One of Pfizer Animal Health's SRP® vaccines (Escherichia Coli Bacterial Extract vaccine*) is conditionally licensed for use in healthy cattle 5 months of age or older to reduce prevalence of the *E. coli* O157 carrier state and for reduction in the amount of *E. coli* O157 shed in feces to minimize *E. coli* O157 exposure and infection of herd mates. This conditionally licensed vaccine is being adopted by cattle producers as a part of their herd health programs to help preserve food safety by reducing *E. coli* O157 levels in cattle. ■

*This product license is conditional. Efficacy and potency test studies are in progress.



Post-harvest Control



“Post-harvest” refers to the time period after cattle arrive at the packing plant. A wide variety of practices intended to reduce *E. coli* O157 at slaughter and during the manufacture of beef products are in use at packing plants, and research is beginning to show significant reductions in *E. coli* O157 at this level.⁴ In response to regulatory requirements enacted during the 1990s, packers are using vacuum steaming and hot-water washing of carcasses to remove contaminants and are complying with written sanitation standard operating procedures.⁴ Packers also have developed and implemented “hazard analysis critical control point” systems and strive daily to meet performance standards for verifying their effectiveness.⁴

Some specific methods currently used in packing plants include:

- Spot carcass decontamination (using various tools, including knives and hand-held steam vacuums, to remove visible contaminants to meet zero-tolerance performance standards)⁸
- Chemical decontamination (application of various chemical mixtures to the hide or carcass, using spray rinsing cabinets or other spray and/or washing methods)⁸
- Thermal decontamination (treatment of carcasses with high-pressure, hot-water rinse exceeding 165 F, or exposing carcasses to pressurized steam)⁸
- Irradiation of case-ready products⁸

Each of these post-harvest intervention methods have been extensively researched and shown to help reduce pathogen loads.⁸ Other technologies like ionizing radiation, hydrostatic pressure, electric fields, pulsed light, sonication or microwaves also have been proposed for use in packing plants to help reduce meat contamination. If fewer *E. coli* O157 pathogens enter the packing plant in or on cattle (preharvest), controlling their occurrence post-harvest in beef products will be more effective, resulting in a safer end product for consumers. ■

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Key Points Overview



- Although most strains of *E. coli* are harmless, the emergence of *E. coli* O157 is a serious concern for both the general public and cattle producers.
- *E. coli* O157 sometimes causes human illness when introduced into the human intestine (Shiga toxins damage the intestinal lining and other tissues), but infected cattle do not get sick.
- *E. coli* O157 bacteria are common in the environment and can be transmitted through contaminated food and water or directly between people.
- Cattle are a major reservoir of *E. coli* O157, with bacteria found in bulls, cows, heifers, steers, calves, feedlots and grazing animals.
- Most human illnesses due to bacteria like *E. coli* O157 can be traced to cattle, their manure or edible products, or other food products.
- Contamination of carcasses or beef products usually occurs during removal of the hide or the gastrointestinal tract.
- *E. coli* O157 can induce serious human disease, including nonbloody diarrhea, hemorrhagic colitis, hemolytic uremic syndrome and death.
- Undercooked ground beef and raw milk can be major risk factors for acquiring *E. coli* O157, so hamburger should always be thoroughly cooked and milk should be pasteurized.
- *E. coli* O157 has cost the cattle industry nearly \$3 billion over the last decade.
- SRP vaccine technology targets *E. coli* O157 by helping interfere with their ability to acquire iron needed for sustenance (siderophore receptors and porins).
- Vaccination of animals with the Escherichia Coli Bacterial Extract vaccine* offers unprecedented opportunity for effectively reducing the prevalence of the *E. coli* O157 carrier state.
- Producers, packers and retailers can work together to help control *E. coli* O157, using all available technologies that help limit the ongoing threats posed by these bacteria. ■



*This product license is conditional. Efficacy and potency test studies are in progress.

References

- Centers for Disease Control and Prevention. *Escherichia coli* O157:H7. Edited July 21, 2010. Available at: www.cdc.gov/nczved/divisions/dfbmd/diseases/ecoli_o157h7/#what. Accessed Jan. 14, 2011.
- Online Textbook of Bacteriology. University of Wisconsin-Madison Department of Bacteriology. 2008. Available at: www.textbookofbacteriology.net/e.coli.html. Accessed Jan. 14, 2011.
- Gyles CL. Shiga toxin-producing *Escherichia coli*: an overview. *J Anim Sci* 2007;85:E45-E62.
- Facts for beef producers: A basic look at *E. coli* O157. National Cattlemen's Beef Association. 2004. Available at: www.beefresearch.org/CMDocs/BeefResearch/E.%20Coli%20a%20Basic%20Look.pdf. Accessed Jan. 14, 2011.
- Wikipedia. *E. coli*. Last edited May 5, 2011. Available at: http://en.wikipedia.org/wiki/Escherichia_coli and http://en.wikipedia.org/wiki/Escherichia_coli_O157:H7. Accessed Jan. 14, 2011.
- Brüssow H, Canchaya C, Hardt WD. Phages and the evolution of bacterial pathogens: from genomic rearrangements to lysogenic conversion. *Microbiol Mol Biol Rev* 2004;68:560-602.
- CO Dept. of Public Health. STEC (Shiga toxin-producing *E. coli*) Reporting Issues. May 2008. Available at: www.cdph.state.co.us/dc/Epidemiology/manual/STEC%20reporting%20in%20CO.pdf. Accessed Jan. 14, 2011.
- E. coli* O157 solutions: the pre-harvest commitment. National Cattlemen's Beef Association, 2004. Available at: <http://www.beefresearch.org/CMDocs/BeefResearch/E.%20coliO157%20Solutions%20The%20Pre-Harvest%20Commitment%20-%202004.pdf>. Accessed Jan. 14, 2011.
- Mead PS, Griffin PM. *Escherichia coli* O157:H7. *Lancet* 1998;352:1207-1212.
- US Food and Drug Administration. FDA finalizes report on 2006 spinach outbreak. *FDA News Release* March 23, 2007. Available at: www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/2007/ucm108873.htm. Accessed Jan. 14, 2011.
- Hussein HS. Prevalence and pathogenicity of Shiga toxin-producing *Escherichia coli* in beef cattle and their products. *J Anim Sci* 2007;85:E63-E72.
- Adapted from www.ecl-lab.com/en/ecoli/pathogenesis.asp.
- Hussein HS, Bollinger LM. Prevalence of Shiga toxin-producing *Escherichia coli* in beef cattle. *J Food Prot* 2005;68:2224-2241.
- Zhao T, Doyle MP, Shere J, Garber L. Prevalence of *Escherichia coli* O157:H7 in a survey of dairy herds. *Appl Environ Microbiol* 1995;61:1290-1293.
- Fegan N, Vanderlinde P, Higgs G, Desmarchelier P. The prevalence and concentration of *Escherichia coli* O157 in faeces of cattle from different production systems at slaughter. *J Appl Microbiol* 2004;97:362-370.
- Widiasih DA, Ido N, Omoe K, et al. Duration and magnitude of faecal shedding of Shiga toxin-producing *Escherichia coli* from naturally infected cattle. *Epidemiol Infect* 2004;132:67-75.
- Cobbold RN, Rice DH, Szymanski M, et al. Comparison of Shiga-toxigenic *Escherichia coli* prevalences among dairy, feedlot, and cow-calf herds in Washington State. *Appl Environ Microbiol* 2004;70:4375-4378.
- Barkocy-Gallagher GA, Arthur TM, Rivera-Betancourt M, et al. Seasonal prevalence of Shiga toxin-producing *Escherichia coli*, including O157:H7 and non-O157:H7 serotypes, and *Salmonella* in commercial beef processing plants. *J Food Prot* 2003;66:1978-1986.
- Elder RO, Keen JE, Siragusa GR, et al. Correlation of enterohemorrhagic *Escherichia coli* O157 prevalence in feces, hides, and carcasses of beef cattle during processing. *Proc Natl Acad Sci USA* 2000;97:2999-3003.
- Hussein HS, Bollinger LM. Prevalence of Shiga toxin-producing *Escherichia coli* in beef. *Meat Science* 2005;71:676-689.
- Riley LW, Remis RS, Helgerson SD, et al. Hemorrhagic colitis associated with a rare *Escherichia coli* serotype. *N Engl J Med* 1983;308:681-685.
- Karmali MA, Steele BT, Petric M, Lim C. Sporadic cases of haemolytic-uraemic syndrome associated with faecal cytotoxin and cytotoxin-producing *Escherichia coli* in stools. *Lancet* 1983;321:619-20.
- Siegler RL. The hemolytic uremic syndrome. *Pediatr Clin North Am* 1995;42:1505-1529.
- Marler W. About Food Poisoning. Last edited July 27, 2008. Available at: http://knol.google.com/k/about-food-poisoning#E%282E%29_coli_O157%283A%29H7. Accessed Jan. 14, 2011.
- Schroeder T. Facts for beef producers: A basic look at *E. coli* O157. National Cattlemen's Beef Association. 2004. Available at: <http://www.beefresearch.org/CMDocs/BeefResearch/E.%20Coli%20a%20Basic%20Look.pdf>. Accessed Jan. 14, 2011.
- Kay S. Facts for beef producers: A basic look at *E. coli* O157. National Cattlemen's Beef Association. 2004. Available at: <http://www.beefresearch.org/CMDocs/BeefResearch/E.%20Coli%20a%20Basic%20Look.pdf>. Accessed Jan. 14, 2011.
- Fox JT, Thomson DU, Drouillard JS, et al. Efficacy of *Escherichia coli* O157:H7 siderophore receptor/porin proteins-based vaccine in feedlot cattle naturally shedding *E. coli* O157. *Foodborne Path Dis* 2009;6:893-899.
- Neilands JB. Siderophores: structure and function of microbial iron transport compounds. *J Biol Chem* 1995;270:26723-26726.

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