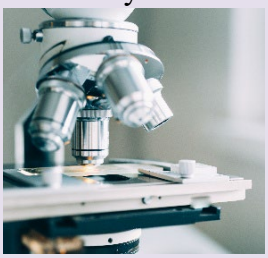
Food for Public Health Series

Shiga Toxin-Producing *Escherichia coli*, an Important Foodborne Pathogen of Public Health Concern

By: Niraj Ghimire, MS, PhD Student
(Conceptualized and edited by: Dr. Aliyar Cyrus Fouladkhah)

Shiga Toxin-Producing *Escherichia coli*

Escherichia coli, a Gram-negative bacterium generally present in the intestines of humans and animals, is benign most of the time. However, some groups of *E. coli* are opportunistic pathogens that can cause infections like diarrhea or urinary tract infections (1). The pathogens causing these serious conditions are classified into different pathotypes based on their virulence and pathogenicity mechanisms such as enteroaggregative *E. coli*, enteropathogenic *E. coli*, and Shiga toxin-producing *E. coli* (2). Among these, Shiga toxin-producing *E. coli* (STEC) are most commonly associated with foodborne diseases.



STEC can excrete a potent exotoxin, called Shiga toxin also known as verotoxin (3). It was not until 1982 that STEC was recognized as a major human pathogen, after *E. coli* O157 caused two outbreaks of hemorrhagic colitis associated with consumption of undercooked ground beef. This point was the milestone in understanding the public health importance of STEC infections (4,5).

In North America, *E. coli* O157 and six serogroups known as "top 6" (O26, O45, O103, O111, O121, and O145) cause most of the STEC infections (6,7). While in European union, most STEC infections are attributed to non-O157 serogroups such as O26, O103, O91, O146, and O145 (8,9). The growing recognition of non-O157 serotypes as significant contributors to STEC infections has increased lately in the United States. According to the CDC, about 64% of STEC infections in the U.S. are caused by strains other than the well-known O157 serogroup. A study of outbreaks from 1900 to 2010 illustrates that 66% of these non-O157 cases were linked to the O111 or O26 strains. Most of these infections, around 84%, were caused by eating contaminated food (7). In countries like Chile, Germany, Japan, Argentina, Australia, Canada, Ireland, and the United States, non-O157 STEC have been a significant cause of intestinal diseases over the past 15 years (10,11).

Prevalence and Distribution of the Pathogen

STEC O157 quickly became a major concern for the food industry and healthcare sector. Since it was first identified, at least 740 outbreaks of STEC O157 have been recorded in the United States over the past 30 years (12). These outbreaks resulted in a total of 13,526 cases, of which 20% (2,765 cases) required hospitalization, 4.8% (653 cases) developed hemolytic uremic syndrome (HUS), and 73 fatalities were reported (13). Hemolytic Uremic Syndrome, (HUS) is commonly associated with STEC infections and is a rare but serious condition characterized by three main features: non-immune hemolytic anemia, low platelet count (thrombocytopenia), and kidney damage (renal impairment) (14).

Various serogroups of STEC have two antigens, namely the O antigen (a somatic antigen part of the bacterial cell wall) and the H antigen (associated with the bacteria's flagella *i.e.* movement), that help to identify the serogroups of STEC (15,16). The differences in the antigens of various serogroups determine how they are perceived immunologically and their ability to cause disease (17). For instance,

the flagella of STEC attach to host proteins such as mucins and mucus, aiding in biofilm formation and colonization of the host (18). Treating STEC infections could be very challenging because antibiotics can make the condition worse by increasing the chance of developing a hemolytic uremic syndrome (HUS). Because of this, doctors usually treat STEC by giving patients plenty of fluids, making sure they eat well, using medicine to relieve pain and reduce fever, and sometimes giving blood transfusions if necessary (19).

Common Foods and Recent Outbreaks

Shiga toxin-producing *E. coli* (STEC) is a major foodborne pathogen linked to a variety of food sources. The World Health Organization (WHO) indicates that the rising number of STEC outbreaks could be caused by eating contaminated fruits and vegetables, which can be cross-contaminated by livestock manure runoff (20). As such, among the foods linked to STEC outbreaks, fruits and vegetables are frequently identified as common vehicles in addition to meat and meat products. Leafy greens are often linked to foodborne outbreaks; romaine lettuce and spinach have been implicated in many recent outbreak episodes. It is estimated that around 25% of foodborne STEC outbreaks include vegetable row crops, with leafy greens playing a major role in these outbreaks (21). Another important food group associated with STEC outbreaks is beef and meat products. Since ground beef is involved in 85% of outbreaks connected to beef, it is particularly of public health concern. When compared to non-O157 strains, the incidence of O157 strains in beef outbreaks is noticeably higher (21). Outbreaks are also caused by dairy products, especially unpasteurized milk (21). Other foods, such as game meat and flour, have been identified as potential reservoirs (22). The wide range of food items that can be impacted by STEC contamination is highlighted by the fact that even a low-moisture commodity such as wheat flour has also been linked to an STEC outbreak (23). Recently, in the US two multistate *E. coli* O157 outbreaks were investigated. The first outbreak struck several states, including AK, AZ, CA, CO, HI, ID, MT, NM, OR, SD, TX, and WA. This outbreak was associated with organic walnuts from California. Blocks and shredded cheese were additionally associated with another recent outbreak with 11 illnesses and 5 hospitalizations (24). Most recently, an outbreak of *E. coli* O157:H7 was linked to eating hamburgers in a fast-food restaurant. The source of the illness was identified as the silvered onions. There were 104 reported cases of illness, 34 hospitalizations, and 1 death across 14 states (25). Another outbreak of *E. coli* O121 infections has been linked to various brands of recalled organic bagged and baby carrots. A total of 39 cases have been reported, including 15 hospitalizations and one death (26).

How Consumers Can Protect Themselves

Ensuring safe handling of food is an important factor to eat healthily. To diminish the risk of foodborne illness, we can follow some basic food safety principles at home which include proper

cleaning, separating, cooking, and chilling that cumulatively contribute to food safety in domestic environment. The spread of foodborne microorganisms including STEC can be curtailed by cleaning the hands and surfaces regularly. Pathogenic bacteria can be eliminated by proper cooking of the food to a safe internal temperature and refrigerating them as soon as possible. We can minimize the risk of getting sick if we avoid eating raw or undercooked meat, eggs, or unpasteurized dairy products. Specially the population group of pregnant women, young children, older adults, and people with compromised immune system (the immunocompromised) are more prone to foodborne illness. Therefore, special care should be taken by these individuals as well as those preparing food for them to strictly follow the food safety guidelines (27).

Conclusion

Shiga toxin-producing *E. coli* (STEC) is a significant concern for food safety and the public's

health. The main source of STEC in the food chain is livestock, especially ground beef. In the U.S. wild animals also play a role in spreading the bacteria into the environment. STEC can survive in animal waste for long periods, contaminating soil and water as a major risk factor in spreading the contamination. Leafy greens like Romaine lettuce and spinach are frequently linked to outbreaks, with raw and unpasteurized juices and dairy products also being common vehicles for this opportunistic and prevalent pathogen of public health concern.

Cited Literature

1. Denamur, E., Clermont, O., Bonacorsi, S., & Gordon, D., 2021. ***The population genetics of pathogenic Escherichia coli.*** Nature Reviews Microbiology, 19(1), 37-54.
2. Koutsoumanis, K., Allende, A., Alvarez-Ordóñez, A., Bover-Cid, S., Chemaly, M., Davies, R., DeCesare, A., Herman, L., Hilbert, F., Lindqvist, R., Nauta, M., Peixe, L., Ru, G., Simmons, M., Skandamis, P., Suffredini, E., Jenkins, C., Monteiro Pires, S., Morabito, S., Niskanen, T., Scheutz, F., da Silva Felício, M.T., Messens, W., Bolton, D., 2020. ***Pathogenicity assessment of Shiga toxin-producing Escherichia coli (STEC) and the public health risk posed by contamination of food with STEC***. EFSA Journal, 18(1), e05967.
3. O'Brien, A. D., LaVeck, G. D., Thompson, M. R., & Formal, S. B., 1982. ***Production of Shigella dysenteriae type 1-like cytotoxin by Escherichia coli.*** The Journal of Infectious Diseases, 146(6), 763-769.
4. Levine, M. M., Xu, J. G., Kaper, J. B., Lior, H., Prado, V., Tall, B., Nataro, J., Karch, H., & Wachsmuth, K., 1987. ***A DNA probe to identify enterohemorrhagic Escherichia coli of 0157: H7 and other serotypes that cause hemorrhagic colitis and hemolytic uremic syndrome***. Journal of Infectious Diseases, 156(1), 175-182.
5. Nataro, J. P., & Kaper, J. B., 1998. ***Diarrheagenic escherichia coli.*** Clinical Microbiology Reviews, 11(1), 142-201.
6. Brooks, J. T., Sowers, E. G., Wells, J. G., Greene, K. D., Griffin, P. M., Hoekstra, R. M., & Strockbine, N. A., 2005. ***Non-O157 Shiga toxin–producing Escherichia coli infections in the United States, 1983–2002***. The Journal of Infectious Diseases, 192(8), 1422-1429.
7. Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M. A., Roy, S. L., Jones, J. L., & Griffin, P. M., 2011. ***Foodborne illness acquired in the United States--major pathogens***. Emerging Infectious Diseases, 17(1), 7–15.
8. Momtaz, H., Farzan, R., Rahimi, E., Safarpoor Dehkordi, F., & Souod, N., 2012. ***Molecular characterization of Shiga Toxin-Producing Escherichia coli isolated from ruminant and donkey raw milk samples and traditional dairy products in Iran.*** The Scientific World Journal, 2012(1), 231342.
9. European Food Safety Authority and European Centre for Disease Prevention and Control (EFSA and ECDC) 2019. ***The European Union one health 2018 zoonoses report***. EFSA journal, 17(12), e05926.
10. Brusa, V., Restovich, V., Galli, L., Teitelbaum, D., Signorini, M., Brasesco, H., Londero, A., García, D., Padola, N. L., Superno, V., Sanz, M., Petroli, S., Costa, M., Bruzzone, M., Sucari, A., Ferreghini, M., Linares, L., Suberbie, G., Rodríguez, R., & Leotta, G. A., 2017. ***Isolation and characterization of non-O157 Shiga toxin-producing Escherichia coli from beef carcasses, cuts and trimmings of abattoirs in Argentina.*** PLOS ONE, 12(8), e0183248.
11. Essendoubi, S., Stashko, N., So, I., Gensler, G., Rolheiser, D., & Mainali, C., 2019. ***Prevalence of Shiga toxin-producing Escherichia coli (STEC) O157: H7, six non-O157 STECs, and Salmonella on beef carcasses in provincially licensed abattoirs in Alberta, Canada.*** Food Control, 105, 226-232.
12. Kim, J. S., Lee, M. S., & Kim, J. H., 2020. ***Recent Updates on Outbreaks of Shiga Toxin-Producing Escherichia coli and Its Potential Reservoirs***. Frontiers in Cellular and Infection Microbiology, 10, 273.
13. Heiman, K. E., Mody, R. K., Johnson, S. D., Griffin, P. M., & Gould, L. H., 2015. ***Escherichia coli O157 outbreaks in the United States, 2003–2012***. Emerging Infectious Diseases, 21(8), 1293.
14. Noris, M., & Remuzzi, G. (2005). ***Hemolytic uremic syndrome.*** Journal of the American Society of Nephrology, 16(4), 1035-1050.
15. Zhang, X., Payne, M., Kaur, S., & Lan, R., 2022. ***Improved genomic identification, clustering, and serotyping of Shiga toxin-producing Escherichia coli using cluster/serotype-specific gene markers.*** Frontiers in Cellular and Infection Microbiology, 11, 772574.
16. FAO/WHO Stec Expert Group., 2019. ***Hazard identification and characterization: criteria for categorizing shiga toxin–producing Escherichia coli on a risk basis.*** Journal of Food Protection, 82(1), 7-21.
17. Beutin, L., Krause, G., Zimmermann, S., Kaulfuss, S., & Gleier, K., 2004. ***Characterization of Shiga toxin-producing Escherichia coli strains isolated from human patients in Germany over a 3-year period***. Journal of Clinical Microbiology, 42(3), 1099-1108.
18. Erdem, A. L., Avelino, F., Xicohtencatl-Cortes, J., & Girón, J. A., 2007. ***Host protein binding and adhesive properties of H6 and H7 flagella of attaching and effacing Escherichia coli.*** Journal of Bacteriology, 189(20), 7426-7435.
19. Smith, K. E., Wilker, P. R., Reiter, P. L., Hedican, E. B., Bender, J. B., & Hedberg, C. W., 2012. ***Antibiotic treatment of Escherichia coli O157 infection and the risk of hemolytic uremic syndrome, Minnesota.*** The Pediatric Infectious Disease Journal, 31(1), 37-41.
20. World Health Organization 2018. ***E. coli. World Health Organization.*** Retrieved September 17, 2024, from https://www.who.int/news-room/fact-sheets/detail/e-coli
21. Tack, D. M., Kisselburgh, H. M., Richardson, L. C., Geissler, A., Griffin, P. M., Payne, D. C., & Gleason, B. L., 2021. ***Shiga***

Toxin-Producing Escherichia coli Outbreaks in the United States, 2010-2017. Microorganisms, 9(7), 1529.

22. Miko, A., Pries, K., Haby, S., Steege, K., Albrecht, N., Krause, G., & Beutin, L. (2009). ***Assessment of Shiga toxin-producing Escherichia coli isolates from wildlife meat as potential pathogens for humans.*** Applied and Environmental Microbiology, 75(20), 6462-6470.
23. Crowe, S. J., Bottichio, L., Shade, L. N., Whitney, B. M., Corral, N., Melius, B.…& Neil, K. P., 2017. ***Shiga toxin–producing E. coli infections associated with flour.*** New England Journal of Medicine, 377(21), 2036-2043.
24. Food and Drug Administration (FDA) 2024. ***Outbreak investigation of E. coli O157 in bulk organic walnuts—April 2024***. Retrieved September 17, 2024, from https://www.fda.gov/food/outbreaks-foodborne-illness/outbreak-investigation-e-coli-o157h7-bulk-organic-walnuts-april-2024
25. Centers for Disease Control and Prevention (CDC) 2024a. ***E. coli O157 outbreaks***. Centers for Disease Control and Prevention. https://www.cdc.gov/ecoli/outbreaks/e-coli-O157.html
26. Centers for Disease Control and Prevention (CDC) 2024b. ***E. coli O121 outbreaks***. Centers for Disease Control and Prevention. https://www.cdc.gov/ecoli/outbreaks/e-coli-o121.html
27. U.S. Department of Agriculture, Food Safety and Inspection Service. (n.d.). ***Steps to keep food safe***. FoodSafety.gov. https://www.fsis.usda.gov/food-safety/safe-food-handling-and-preparation/food-safety-basics/steps-keep-food-safe

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