COMMENTARY

E coli and Food Safety: It's a Jungle Out There

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April 23, 2018

Foodborne illnesses are a substantial yet largely preventable health burden worldwide. We previously reviewed food safety in the United States[1] and harked back to the classic book, *The Jungle,* which portrayed the unsanitary conditions and practices prevalent in industrialized American cities in the early 1900s.[2] While this had a significant impact on reformation of the meatpacking industry, how far have we come since the conditions reported by Upton Sinclair? One indicator of progress is whether we have adequately responded to the lessons learned. In this context, we will focus specifically on foodborne *Escherichia coli* infections.

E coli Outbreaks and Renewed Efforts for Safety

In 1993, an *E coli* outbreak in four states affected more than 700 people and was associated with 171 hospitalizations, including four deaths in children, attributed to hemolytic-uremic syndrome (HUS); the common source of their illnesses was traced to Shiga toxin–producing *E coli* (STEC) serogroup O157–contaminated hamburgers sold at Jack in the Box restaurants.[3,4]

This dramatic, widely publicized case series served to increase public awareness and concern about unsanitary practices in the fast-food industry.[5] That outbreak, in part, spurred significant improvements in efforts to ensure safe food, including enhanced federal food safety regulations, more stringent industry practices, and intensified policies by the Centers for Disease Control and Prevention (CDC), the US Department of Agriculture (USDA), and the US Food and Drug Administration (FDA).[6] This has been accompanied by advances in food science and by more rapid and precise pathogen detection, food monitoring, and surveillance.[7-9]

Key efforts to improve food safety have included the following[6]:

- *E coli* O157:H7 was declared an adulterant in ground beef, and other non-O157 STECs have been added to the list of adulterants;
- *E coli* O157:H7 was raised to reportable disease status at all state health departments;
- The CDC developed pulsed-field gel electrophoresis (PFGE) to detect and track bacterial isolates; PulseNet became the national molecular subtyping network for foodborne disease surveillance[8,10];
- Research was undertaken to determine ways to reduce *E coli* in cattle and slaughterhouses;
- Testing for *E coli* O157:H7 in ground beef was initiated;
- Consumer education programs about potential dangers in ground beef and instructions for safe handling and optimal cooking were created;
- The recommended temperature for cooking ground beef was increased by the FDA; and
- Safe production facilities via the USDA Food Safety and Inspection Service (FSIS) and the Hazard Analysis and Critical Control Point (HACCP) were ensured.[11]

Infections caused by *E coli* serogroup O157 declined after targeted interventions to reduce contamination of ground beef were implemented.[8] So, where do we stand in regard to food safety policy and in the detection and prevention of illness due to *E coli* in the United States?

We will specifically review the history of infection due to STEC O157:H7; however, we will also discuss serogroups of STEC other than serogroup O157 (eg, STEC O26:H11), which are highly pathogenic, capable of causing HUS, and have been associated with foodborne bacterial gastrointestinal illnesses and outbreaks in the United States.[9,12-14]

Food Safety Policy: Where Do We Stand?

The Foodborne Diseases Active Surveillance Network (FoodNet) conducts active, population-based surveillance at 10 US geographic areas sites for laboratory-confirmed infections commonly transmitted through food and monitors trends in enteric

illnesses and identifies their sources. According to FoodNet, the incidence of STEC O157 declined in 2014 compared with previous survey years.[13,15,16] However, despite ongoing food safety efforts, the incidence of infection remains high, indicating that further prevention measures are needed to make food safer and to achieve national health objectives.

Tracking Outbreaks

To develop effective prevention measures, it is important to understand the percentage of foodborne illnesses associated with specific foods. Three federal agencies—the CDC, the FDA, and the USDA-FSIS—teamed up to create the Interagency Food Safety Analytics Collaboration (IFSAC). The goal is to improve coordination of federal food safety analytic efforts and to address cross-cutting priorities for food safety data collection, analysis, and use.[17] This includes foodborne illness source attribution (ie, approximating common food sources responsible for specific foodborne illnesses) and providing timely estimates of the food sources of four priority foodborne pathogens: *Salmonella*, *E coli* O157, *Listeria monocytogenes*, and *Campylobacter*.

A Cookie Monster

Neil and colleagues[18] investigated a multistate outbreak of *E coli* O157:H7 infections in May 2009. Outbreak-associated cases were identified using serotyping and molecular subtyping procedures as well as traceback investigation and product testing. Ultimately, 77 patients with *E coli* infection were identified from 30 states; 35 were hospitalized and 10 developed HUS. Of note, 66% of affected persons were younger than 19 years and 71% were female. In a matched case-control study, 94% had consumed ready-to-bake commercial prepackaged raw cookie dough, compared with 11% of control subjects; no other reported exposures were significantly associated with this illness. The FDA and the CDC notified the manufacturer of the investigation of this product in the reported *E coli* O157:H7 illnesses.

The investigation led to a voluntary recall in June 2009 of 3.6 million packages of cookie dough by Nestlé USA, product reformulation, and institution of procedures to enhance quality-assurance protocols (eg, testing ingredients prior to use, rigorous environmental sampling).[19,20] This STEC outbreak associated with consuming uncooked ready-to-bake commercial prepackaged cookie dough also indicated the need for more effective consumer education about the risks of eating unbaked cookie dough.

Recipe for Disaster?

One lingering issue in this outbreak was that the exact source and route of product contamination remained undetermined. However, in June 2016, the FDA, along with the CDC and state and local officials, investigated an outbreak of infections that once again illustrated the dangers of eating raw dough—but this time they were able to more precisely pinpoint the source.

This outbreak of STEC serogroup O121 and O26 infections was linked to contaminated flour.[21] Fifty-six cases were identified in 24 states. Univariable exact conditional logistic regression models found that one flour brand and the tasting of unbaked homemade batter or dough were significantly associated with infection. Outbreak strains were isolated using laboratory testing on flour samples, and whole-genome sequencing revealed that the isolates from clinical and food samples were genetically closely related to one another. A common flour production facility was identified using traceback investigation.[21,22]

STEC was identified as one of a group of pathogens that can contaminate raw flour.[13,21,22] Contamination can occur at any step in the process of transferring food from the farm to the dining table (ie, production, processing, distribution, or preparation).[23] Flour is a raw, minimally processed agricultural product and is not processed to kill bacteria. Pathogenic microorganisms associated with animal feces could contaminate the field and thus travel with the harvested grain. The usual bactericidal processes applied during food preparation or processing (eg, boiling, baking, roasting, microwaving) are not applicable to flour and raw dough.[21,22]

Contaminated Romaine Lettuce

At present, most outbreak-associated illnesses are being linked to seeded vegetables (eg, cucumbers, tomatoes), pork, and vegetable row crops (leafy vegetables).[9,24] In 2011, Slayton and colleagues[12] identified 58 cases of *E coli* infection in 10 states; 67% were hospitalized and 6.4% developed HUS. This multistate outbreak of STEC O157:H7 infections was associated with consumption of romaine lettuce. Unfortunately, we did not heed the lessons learned from this experience. There have been several similar outbreaks since that time. Most recently, in late 2017, the CDC, along with the FDA, multistate outbreak of Shiga toxin–producing *E coli* O157:H7 infections in 15 states linked to romaine lettuce.[25] The type of *E coli* implicated was similar to that implicated in an outbreak in Canada, in which the Public Health Agency of Canada identified romaine lettuce as the source.[26] These outbreaks indicate the challenges associated with leafy vegetable harvesting, distribution, and in home/restaurant preparation—and the opportunities for improvement.

Detection and Prevention

New detection modalities and improved understanding of the epidemiologic features of foodborne STEC infections can inform food safety and other prevention efforts.[27]

Polymerase chain reaction (PCR) and genome sequencing approaches facilitate surveillance and enhance the response to

outbreaks of non-O157 STEC.[14]

Culture-independent diagnostic tests (CIDTs), which are increasingly used by clinical laboratories to detect enteric infections, provide timely information for clinical management of foodborne infections.[28] However, the increasing use of highly sensitive CIDTs creates logistical issues regarding interpretation of public health surveillance and monitoring data.[13,27,28] Ideally, CIDT-positive specimens should be reflex-cultured to obtain isolates for determining pathogen subtypes and antimicrobial resistance, to monitor trends, and to detect outbreaks.[13,27,28]

For the detection of both O157 and non-O157 STEC infections, clinical laboratories should test all stool specimens submitted for diagnosis of acute community-acquired diarrhea for O157 STEC and for Shiga toxin; isolates should be sent to a public health laboratory for serotyping and subtyping.[27]

The concept of prevention is not new, but there is an intensified federal focus on strategies to improve food safety and to reduce foodborne disease.

Regulations from the FDA and the USDA—the Food Safety Modernization Act (FSMA) are designed to reduce contamination of produce.[29,30] The FSMA granted the FDA power to improve the safe production and harvesting of produce by creating standards for environmental factors, including staff hygiene, microbial levels in agricultural water, uses of animal waste in growing foods, and equipment sanitation.[29,30] Produce regulations establish standards for growing, harvesting, packing, and storing produce on farms in the United States, including requirements for water quality, employee health and hygiene, and manure and compost use. In addition, under the FSMA, the FDA has the authority to recall a hazardous food product.

The Bottom Line

As in the days of *The Jungle*, a universal goal must be to provide safe, nutritious food. We are all accountable; individuals, families, schools, industry, and the government can do more to keep food safe and to act promptly to protect consumers' health.

The CDC offers common-sense tips for safe food handling in the home (eg, avoid ingestion of raw meat; cook products at proper temperatures; wash hands, work surfaces, and utensils). Food industries can prevent or limit the size of outbreaks by making food safety a core part of their culture; their goal must be to meet or exceed food safety regulations and standards.[30] Measures to improve food safety should include maintaining records to enable the rapid tracing of foods and the use of suppliers who apply best practices to food processing.

Let us not repeat the history of *E coli* tragedies.

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Detection and Prevention

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Cite this article: E coli and Food Safety: It's a Jungle Out There - *Medscape* - Apr 23, 2018.