PREVENTING *E. coli* in FOOD

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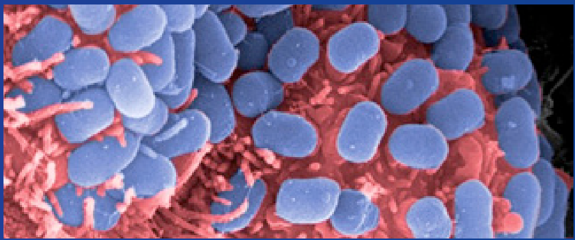


Escherichia coli (E. coli) is a bacterium found in the digestive tract of animals and humans.

Generally harmless, some *E. coli* are pathogenic and can contaminate food, water and the environment.

Hundreds of thousands of people are made ill by *E. coli* each year, with hundreds of them dying.

In recent years, there has been an increase of outbreaks with significant impact on health care systems and agricultural production.

Frequent sources of foodborne infections include unpasteurised dairy products and juice, insufficiently cooked and processed meat, raw fruits and vegetables, and unsanitary handling and storage of prepared foods.

Proper storage and cooking will help prevent foodborne disease including those from pathogenic *E. coli.*

Pathogenic *E. coli* are characterized according to the type of clinical symptoms they cause. The pathogenicity is determined by their genome. *E. coli* can easily exchange genes and generate novel forms of disease.

The source of food contamination is human and animal faeces.

The contamination path can be very complex and involve all aspects of human, animal and plant interfaces and their interactions with the ecosystem. The epidemiology of each pathotype varies with the reservoir host, levels of community sanitation and hygiene, and agriculture and food production systems.

Prevention and control require a multidisciplinary approach in animal and plant production as well as risk-based approaches along the entire food supply chain.

These include the application of Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), Good Hygiene Practices (GHP) and Hazard Analysis Critical Control Point (HACCP) from the farm to the consumer.

To improve the quantity and quality of food, FAO promotes good management practices in the dairy, horticulture and beef sector, often in collaboration with the private sector.

The IDF/FAO Guide to Good Dairy Farming Practice and the FAO Manual for Good Practices for the Meat Industry as well as the development of training material and capacity development interventions in relation to hygienic milk handling and processing, and testing and quality control, are some examples of FAO initiatives to help prevent *E. coli* infections.

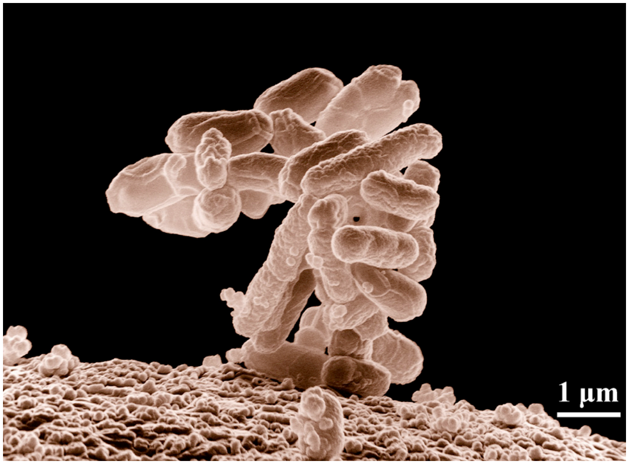
FAO supports veterinary public health systems and services to strengthen veterinary supervision as well as the inspection of animal slaughter, slaughterhouse hygiene and meat.

The sustainable intensification of crop production (Save and Grow, FAO 2011) increases crop yields and reduces the risk from *E. coli* infections. It emphasizes careful monitoring of nitrogen levels to minimize unnecessary applications of pesticides and reduce the risk of outbreaks of plant pathogens while reducing the impact on the environment.

Healthy animals and healthy crops produce safer food and reduce the risks from *E. coli.*

What is *E. coli*?

Escherichia coli, also known as *E. coli*, is a bacterium that is commonly found in the gastrointestinal tract of humans and warm-blooded animals.



Due to its high prevalence in the gut, *E. coli* is used as the preferred indicator to detect and measure faecal contamination in the assessment of food and water safety. Considered as harmless commensals, *E. coli* strains constitute about 1 percent of the normal gut microbial population. While most of the strains within the gut are beneficial human gastrointestinal pathogens, others are harmful.

Pathogenic *E. coli* are distinguished from other *E. coli* by their ability to cause serious illness as a result of their genetic elements for toxin production, adhesion to and invasion of host cells, interference with cell metabolism and tissue destruction.

How do people become exposed to *E. coli*?

E. coli is almost exclusively of faecal origin, and it is transmitted through faecal contamination of foods and water, as well as cross-contamination, or by direct human contact during food preparation. Meanwhile, the primary exposure route appears to be through consumption of contaminated foods, such as raw or undercooked ground meat products, raw milk and fresh produce.

Regardless of the severity or absence of disease symptoms, infected individuals and animals can shed up to 10^6 to 10^9 colony-forming units (cfu) per gram of faeces, and shedding of *E. coli* can also occur from asymptomatic carriers.

What symptoms does *E. coli* cause?

Different strains of *E. coli* that cause human diseases are classified according to the type of disease symptoms that they cause in humans. These strain types can be divided into six groups or pathotypes, although characteristics are not exclusive and may be shared by more than one group (pathotype). Shigatoxigenic *E. coli* (STEC) is one of the pathotypes. It causes symptoms ranging from mild to severe and bloody diarrhoea. In up to 10 percent of patients (particularly young children and the elderly), the infection may lead to a life-threatening disease, such as haemolytic uraemic syndrome (HUS). Enterohaemorrhagic *E. coli* (EHEC) are a subset of STEC typically associated with bloody diarrhoea and HUS, which produce cytotoxins, known as verotoxins (VT) or Shiga-like toxins (Stx). In relation to public health, *E. coli* (O157:H7) strain is the most important EHEC serotype linked to foodborne disease, resulting in a high incidence of EHEC infections and deaths each year.

Emerging disease challenges

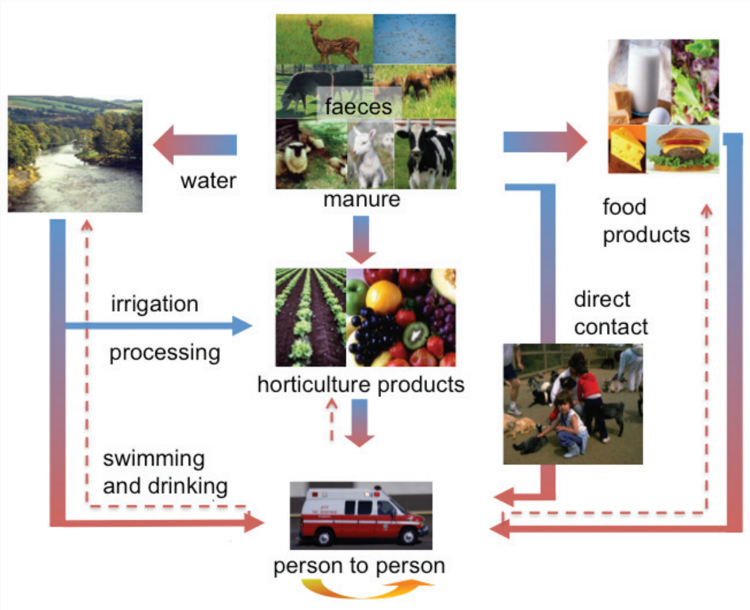
E. coli can exchange genetic material via mobile genetic elements, such as plasmids and bacteriophages, and can adapt to new and stressful environments. These factors are believed to contribute to the emergence of intestinal pathogenic types, some with enhanced survival and persistence in food systems or pathogenicity. The relative ease with which *E. coli* bacteria exchange genetic material was demonstrated in the case of the *E. coli* (0104:H4) strain responsible for the outbreak in Germany in May/June 2011. It was found to carry genetic material from both the enteroaggregative (from humans) and enterohemorrhagic (from animals) strains. In addition, the strain is resistant to many antimicrobials.

How is food contaminated?

Faecal contamination pathways

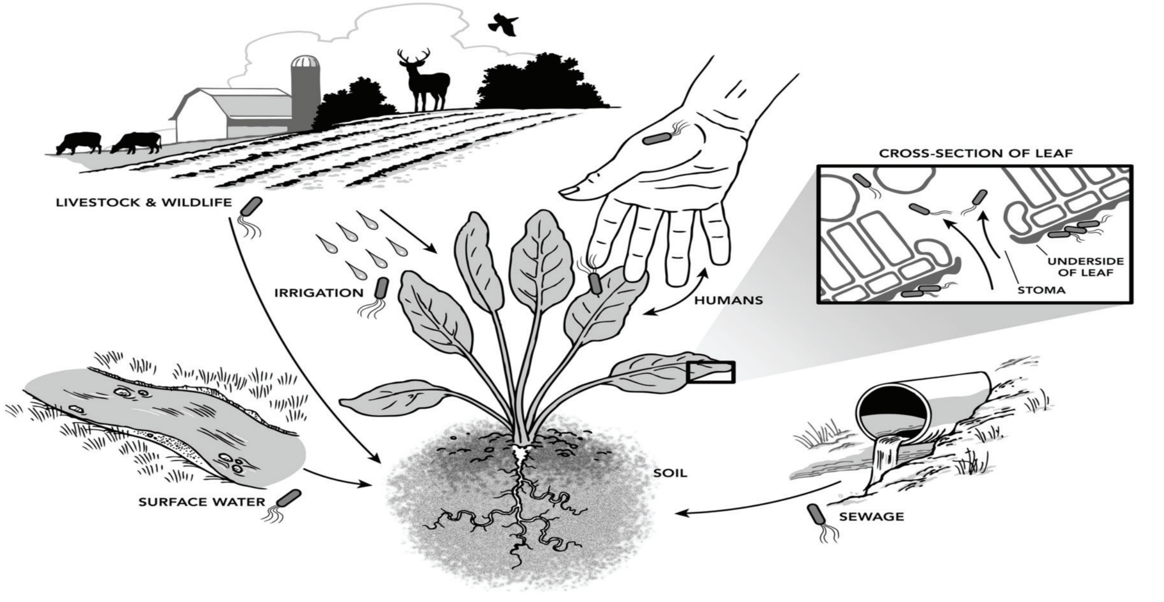
The epidemiology of foodborne pathogenic *E. coli* varies throughout the world. In communities with poor sanitation and hygiene, enterotoxigenic *E. coli* (ETEC), enteroinvasive *E. coli* (EIEC) and enteropathogenic *E. coli* (EPEC) are prevalent. They are acquired by consumption of contaminated food and water and by cross-contamination through direct human contact. Foodborne pathogenic *E. coli* have emerged paradoxically in communities with better developed sanitation and hygiene. However, the pathotypes differ (e.g. STEC, EHEC and enteroaggregative *E. coli* [EAggEC]) and the transmission pathways often include raw or inadequately processed animal or horticulture products, contact with animal manure, contaminated water and cross-contamination with raw food.

STEC transmission



The pathogenic *E. coli* are excreted in the faeces of either ill or healthy hosts. Ruminants and wildlife appear to be major reservoirs of STEC and EHEC, while the human host may be more important for other pathotypes. Because of the wide dissemination of human and animal faecal material into the environment, the bacteria have the potential to be present in areas used for food production. For example, *E. coli* may be found in animal manure and sewage (until fully composted), farm and peri-urban environments contaminated by humans, livestock, wild animals and birds, manure amended soils and contaminated water sources.

***E. coli* (0157:H7) contamination pathway via the interacting animal, human, crop and environment domains**



Source: Jeffrey Lejeune – 'the many ways food can get tainted from farm to fork'

What foods could be contaminated?

A wide range of foods may be a vehicle for pathogenic *E. coli* in association with their respective ecologies. Food may be contaminated and/or cross-contaminated during growth and harvest (horticulture products), collection (milk) or slaughter (meat). Further contamination can occur during post-harvest handling, transport, processing and unhygienic food handling during preparation.

Factors contributing to the persistence of *E. coli* in food systems include inadequate control of processing parameters (e.g. cooking temperature, pH value, water activity and storage at warm temperatures for sufficient time to allow growth).

Examples of contaminated foods include: raw/under-processed meat (fermented meat, undercooked ground beef, etc.), unpasteurised dairy products (cheese, milk, etc.), unpasteurised fruit juices and raw vegetables (sprouted seeds, lettuce, spinach, cantaloupe, mushrooms, etc.).

Foodstuff of animal origin

Ruminants, mainly cattle, are recognized as the primary natural reservoir of STEC, and EHEC (O157:H7), in particular. Although some strains are known to cause diarrhoea in calves, the others appear to be commensal inhabitants of the gut of animals and do not cause clinical disease. Pigs and poultry have not been identified as major sources of STEC for human infection in Europe.

Fresh meat and raw milk are, nevertheless, considered as common vehicles for *E. coli*, particularly for the EHEC (0157:H7) strain. Contamination of meat usually occurs during animal slaughter, as a result of poor slaughter practices, abattoir hygiene and animal handling practices. Therefore, slaughterhouse practices most likely to contaminate meat involve: removal of animal hide, spillage from the gut of animals and overall sanitary conditions on the abattoir grounds.

Fresh produce and sprouts

E. coli shed by animals and humans in their faeces may enter crop agro-ecosystems through manure, irrigation water, contaminated seeds, wildlife and insect pests, or nematode vectors. Consequently, contaminated fresh produce has become much more important as a cause of epidemics of human pathogenic bacteria, including *E. coli* of different pathotypes. Survival and growth of *E. coli* populations on crop plants and in the soil of crop fields has been proven. *E. coli* have been shown to survive in contaminated soil for up to 20 months, and thus may remain an environmental contaminant for a prolonged period of time. What is more, survival on crop leaves and roots can be higher than in soil alone. Younger leaves tend to provide a better habitat than older leaves, and leaves with higher levels of nitrogen, damaged leaves and fruits are able to support faster multiplication and increased survival of *E. coli*.

In recent years, the popularity of sprouted seeds has increased significantly owing to their nutritional value. However, reports of foodborne outbreaks associated with such raw vegetable sprouts have raised concerns among public health agencies and consumers.

Processed food

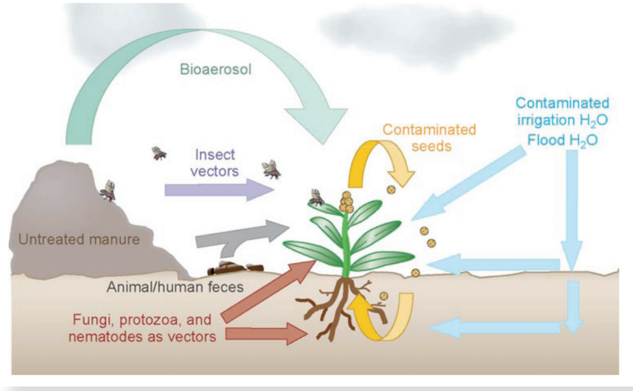
Processed food can be contaminated by raw materials, unsanitary water treatment and handling, as well as by cross-contamination. The bacteria can continue to grow in food, unless relevant process parameters are controlled, such as pH value, water activity, temperature and time. Only a few bacterial cells surviving in food can be sufficient to cause illness.

Control of pathogenic *E. coli* in food and water

As the key points of control tend to vary with the respective pathotype, the knowledge of local foodborne disease epidemiology is essential in establishing an appropriate and effective food safety programme. This requires a multidisciplinary approach that focuses on the interactions that take place among humans, animals and plants within their ecosystems.

Human enteric pathogens on plants in field crops

Major food safety risks, could be managed with sustainable crop production intensification through ecosystem approach



Control points along the food chain should be targeted that will ensure the greatest reduction of risk to public health. Risk mitigation steps ought to be taken by following recognized codes of good practice and relevant recommendations of the veterinary and public health services. For pathotypes, such as STEC/EHEC, the farm-to-consumer pathway needs to be analysed. At the pre-harvest stage, such steps include minimizing colonization of cattle herds and prevention of manure contamination of crops, and at the post-harvest stage, they include slaughterhouse and milking shed hygiene and handling during packing of produce.

Pathogenic *E. coli* behave similarly to generic *E. coli* and are able to persist and grow in many foods. They grow prolifically during sprouted seeds production, so that minimizing initial seed contamination and limiting subsequent growth are important controls. Some *E. coli* strains can elicit stress responses that enhance their growth and persistence, e.g. STEC may tolerate acid conditions in fruit juice and fermented meat and dairy products. Multiple hurdles may be required during processing to provide the required level of protection. As *E. coli* are destroyed by thorough heating during cooking, a controlled heat treatment is an effective means of elimination. Therefore, challenges are presented for foods that are to be eaten raw or with minimal processing.

Pre-harvest interventions in farm animal production

Strategies that will reduce shedding in live animals offer methods to reduce pathogen populations in food animals before they enter the food chain. For example, abruptly switching cattle from a high grain ration to a high-quality hay-based diet has been shown to reduce generic *E. coli* and *E. coli* (O157:H7) populations. However, switching feedlot cattle from grain-based to hay-based diets prior to slaughter may not be practical. The feeding of probiotic *Lactobacillus acidophilus* has been proven effective and has been adopted for the pre-harvest control for *E. coli* (O157:H7) in cattle. Further research is needed to elucidate the mechanism (e.g., competitive exclusion, physical removal, forage quality, tannins, lignin, other phenolics, etc.) by which forage-feeding impacts the microbial ecology of the bovine intestinal tract, including the ecology of *E. coli* and *E. coli* (O157:H7) populations, so that economically viable and practical dietary modifications can be implemented. At present, areas of investigation include feed and water hygiene, but also dietary supplements and vaccination. All these control measures are still in the experimental stages of development, although a vaccine against *E. coli* (O157:H7) is commercially available. Current research is aimed at improving the understanding of the factors that cause individual animals to shed high numbers of the pathogenic *E. coli* (super-shedders). The research also focuses on the identification of such animals and the farm holdings which are the source. This would allow more risk-based controls to be applied to limit the risks of contamination from such animals or holdings.

Effective prevention and control of contamination in abattoirs requires the application of good hygiene practices, the application of Hazard Analysis and Critical Control Point (HACCP)-based management practices and risk-based meat inspection practices to minimize faecal contamination of carcasses. In an effort to improve quantity and quality of food, FAO is promoting good management practices in the dairy and beef sector, often in collaboration with the private sector. Examples include the preparation of manuals such as the IDF/FAO Guide to Good Dairy Farming Practice or the development of training material and capacity building interventions in relation to hygienic milk handling and processing but also testing and quality control.

For the meat sector, the FAO manual "Good practices for the meat industry" available in electronic format is highly recommended. Other documents related to slaughterhouse management and slaughterhouse cleaning and disinfection are also available. FAO is involved in projects to strengthen veterinary public health systems and services, pertaining to issues of veterinary supervision and inspection of animal slaughter, meat inspection and slaughterhouse hygiene.

Pre-harvest strategies in fresh produce and sprout production

Appropriate on-farm manure storage and handling procedures with no run offs from farms are important. In addition, crop management can reduce some of the factors associated with *E. coli* populations and should reduce the risks of epidemics in humans. The findings that arise from ecosystem approaches suggest that it is possible to reduce the survival and growth of *E. coli* populations in crops by adopting good agricultural practices. These could include reducing the overuse of nitrogenous fertilizer, applying only treated or well-processed manure with a higher C/N ratio, applying compost, ensuring that seeds are not contaminated before planting, encouraging better animal and human hygiene in the field and irrigating with clean water. These practices, intended to reduce risks from *E. coli*, also support sustainable intensification of crop production. Save and Grow Systems (FAO 2011) emphasize careful monitoring of nitrogen levels so as to reduce risks from outbreaks of plant pathogens and pollution. This is one way to increase crop yields and reduce risks from *E. coli* (and other human pathogenic enteric bacteria).

Outbreak investigations have indicated that pathogens found on sprouts most likely originated from the seeds. The seed may become contaminated in the field or during harvesting, storage or transportation. During the germination process in sprout production, low levels of pathogens present on seeds may quickly reach levels high enough to cause disease. Guidance is available under the Codex Code of Hygienic Practice for Fresh Fruits and Vegetables, Annex for Sprout Production (document CAC/RCP 53-2003), which can be downloaded from the Web site or obtained upon request from the Secretariat of the Codex Alimentarius Commission (codex@fao.org).

Food processing and preparation

For prevention of post-harvest contamination and cross-contamination along the food supply chain, it is necessary to apply the principles of good hygiene and manufacturing practices and those of the Hazard Analysis Critical Control Point (HACCP) system. In addition, appropriate retail and consumer behaviours are also essential.

To ensure that those who come directly or indirectly in contact with food are not likely to contaminate it with pathogenic *E. coli*, food handlers should follow the recommended Codex Alimentarius Code of Practice, General Principles of Food Hygiene.

Household and food service hygiene

The World Health Organization (WHO) guide, entitled Five Keys to Safer Food, provides an outline of good food hygiene practices that will help prevent disease transmission. Good food hygiene practice, as described in the WHO Five Keys to Safer Food, can prevent the transmission of pathogens responsible for many foodborne diseases and also protect against foodborne diseases caused by pathogenic *E. coli*. These recommendations should be followed at the household consumer level. With respect to best household hygiene practices, it is highly recommended to ensure that the food is "cook[ed] thoroughly" reaching a temperature of 70°C.

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FOOD CHAIN CRISIS
Management Framework

The **Food Chain Crisis Management Framework (FCC)** is the primary instrument of the Food and Agriculture Organization of the United Nations (FAO) to address the risks to the human food chain in an integrated and interdisciplinary manner.

The FCC supports FAO member countries in the global governance of threats to the human food chain at all stages from production to consumption.

www.fao.org/foodchain