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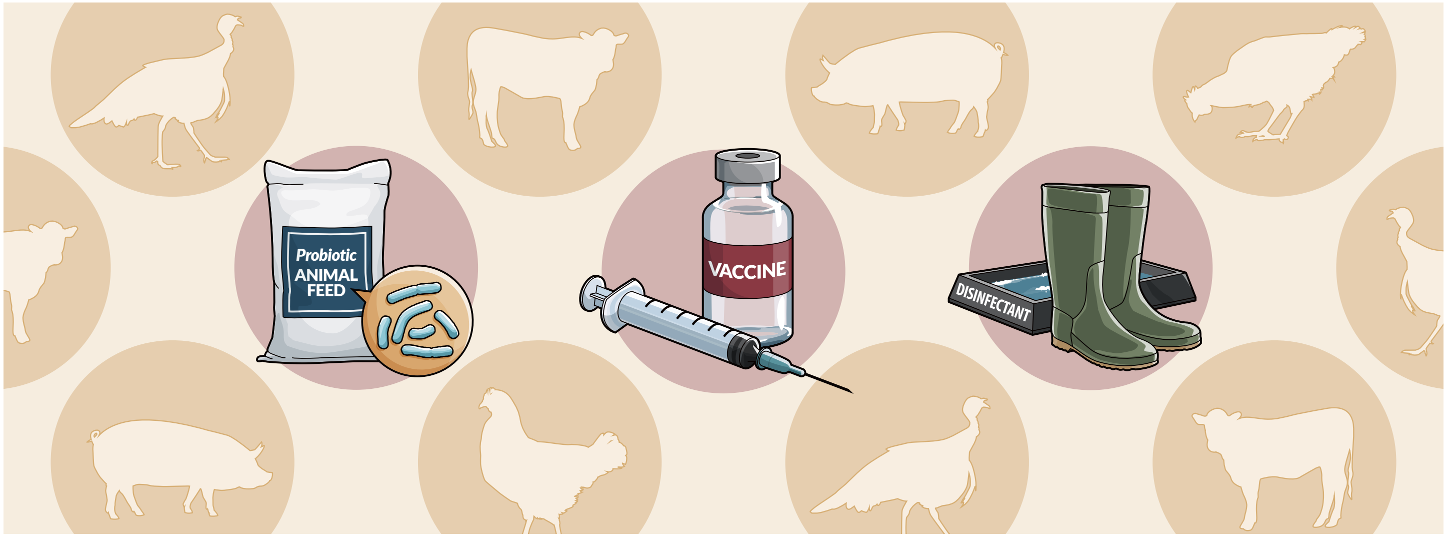


Opportunities to Improve Food Safety From Farm to Fork

What interventions effectively reduce risk of meat and poultry contamination?

Overview

Contaminated meat and poultry products are responsible for an estimated 2 million bacterial illnesses in the United States each year.[1] One analysis conducted jointly by the Centers for Disease Control and Prevention, Food and Drug Administration, and Department of Agriculture indicates that up to 38 percent of *E. coli* O157:H7 infections are attributable to beef, 35 percent of *Campylobacter* cases are linked to chicken and turkey, and 36 percent of *Salmonella* illnesses are associated with chicken, turkey, beef, and pork.[2] Reducing meat and poultry contamination presents a significant opportunity to prevent serious—and sometimes fatal—disease caused by these major foodborne pathogens.

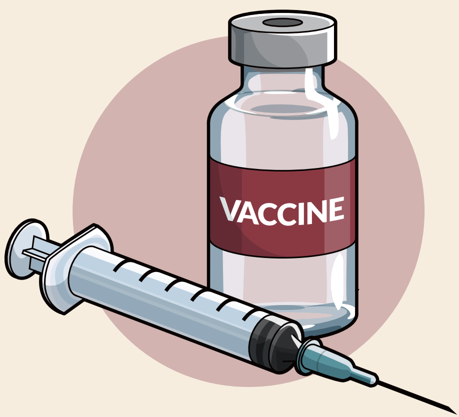
A comprehensive approach to meat and poultry safety must begin at the farm level, because harmful bacteria often originate there and then enter the slaughterhouse with food animals. Although certain interventions and handling practices during and after slaughter can reduce contamination risks, these measures are much more effective when farms and feedlots minimize contamination in their herds and flocks.

In a 2017 report, "Food Safety From Farm to Fork: Interventions on Farms and Feedlots Can Improve U.S. Meat and Poultry Safety," The Pew Charitable Trusts examined existing food safety control measures aimed at reducing *Salmonella*, *Campylobacter*, and *E. coli* O157:H7 contamination of cattle, chicken, and swine before slaughter. This issue brief outlines the interventions that were found to be effective on farms, many of which can be implemented with products already available to U.S. livestock businesses. It's time to seize these opportunities to decrease foodborne illnesses linked to meat and poultry.

Types of On-Farm Interventions

Pre-harvest, or on-farm, interventions fall into three general categories and include products (such as vaccines for animals) and management practices on farms and feedlots. By various means, these measures reduce the risk of microbial contamination of food animals, and the meat and poultry products derived from them, as well as the public health risk of foodborne infections.

Procommensal strategies indirectly inhibit the pathogen by favoring competition with nonpathogenic bacteria. Examples are probiotics and prebiotics in animal feed.



Anti-pathogenic strategies work through direct interaction with the pathogen or by priming the animal's immune response to fight it. Examples are vaccines, antimicrobials, sodium chlorate, and essential oils.

Exposure-reduction strategies decrease the risk that pathogens will be introduced or spread within the herd or flock by animals or people. Examples are biosecurity protocols that decontaminate workers' clothes and tools; limiting access of vermin, insects, and farm personnel to animal housing; feed and water hygiene; isolation of infected animals; and adequate housing.

Good animal husbandry is a prerequisite for on-farm food safety

Implementation of exposure-reduction strategies such as storing animal feed under hygienic conditions and controlling vermin provides a vital foundation for all food safety efforts on farms. Such practices, often called biosecurity measures, are also important for livestock businesses because they help prevent the spread of foreign animal illnesses such as avian influenza, African swine fever, and foot-and-mouth disease. The effectiveness of such programs in controlling food safety hazards has been well-demonstrated in other countries. However, scientific research quantifying the efficacy of individual exposure-reduction interventions is limited. For these reasons, this issue brief assumes that these programs are a prerequisite for livestock production and focuses on approaches and products that have been shown to be effective against specific foodborne pathogens on farms.

Countries Find Success With Farm-Focused Strategies

Several countries have achieved major improvements in the safety of meat and poultry products from prevention-based systems that combine exposure-reduction strategies with other types of interventions. Sweden, Finland, Norway, and Denmark have implemented successful food safety control programs to reduce *Salmonella* contamination on poultry and swine.[3] These countries require strict, on-farm biosecurity measures including cleaning and disinfecting animal housing, extensive testing and monitoring for *Salmonella* in the animals and feed, culling of infected breeding animals, and separate handling of *Salmonella*-positive flocks or herds at slaughter. The results have been impressive. No *Salmonella* was detected in a sample of 4,033 Swedish poultry carcasses in 2017; less than 1 percent of Norwegian and Finnish poultry flocks were contaminated with the pathogen in 2016; and up to 600,000 human infections from the bacterium were avoided in Denmark from 1994 to 2005.[4] By contrast, among USDA-regulated raw poultry products, *Salmonella* contaminates about 5 percent of whole chicken carcasses, 15 percent of chicken parts such as legs, breasts and wings, and 40 percent of ground chicken.[5] Data from European pathogen surveillance programs also demonstrate that effective biosecurity measures for swine operations are associated with a lower probability of the herds testing positive for *Salmonella*.[6]

How the interventions were selected

The availability and type of research on pre-harvest interventions vary broadly. Certain species, products, and practices have been studied more often than others. For instance, with cattle, more research is available for interventions targeting *E. coli* than *Salmonella*. No single pre-harvest intervention completely eliminates contamination risks; however, reductions in contamination can have substantial public health benefits even if residual bacteria remain.[7] Successful pre-harvest programs are typically based on a combination of interventions. For example, exposure-reduction strategies and pathogen surveillance are used in conjunction with vaccines and probiotics.

With these factors in mind, Pew selected the interventions discussed in this brief for two reasons. First, the intervention is available to livestock producers in the U.S. and can be used in an animal agriculture setting. Secondly, strong scientific evidence (based on experimental studies, field trials, or systematic reviews) demonstrates that use of these interventions results in consistent reductions in the target pathogen.

What works

Probiotics

Probiotics are composed of live beneficial microorganisms that can colonize an animal's lower intestinal tract and thereby prevent growth of pathogenic bacteria such as *E. coli* and *Salmonella*. Certain probiotics may be referred to by other terms, such as direct-fed microbials (DFMs) or competitive exclusion products. DFMs are probiotics that are added to feed and enhance an animal's gut health, provide nutrients, and prevent or reduce the growth of pathogens. Competitive exclusion products may be delivered through feed or sprayed on animals. These are typically given at birth or hatching to help prevent pathogens from colonizing the gastrointestinal tract.[8] Despite their wide use, the current regulatory system can make it difficult for certain probiotics to obtain approval.

Effects on *E. coli* O157:H7 in cattle

A 2011 Animal and Plant Health Inspection Service feedlot survey found that 28.5 percent of large feedlots (more than 1,000 cattle) in the U.S. use probiotics.[9] DFMs have been shown to significantly reduce fecal shedding of *E. coli* in cattle.[10] A meta-analysis that assessed the efficacy of DFMs fed to cattle found that the odds of fecal *E. coli* O157:H7 shedding were reduced by approximately 54 percent compared with placebo or no treatment.[11]

Probiotics are used commercially by the cattle industry to increase growth rate and milk production.[12] These benefits can help offset the costs of adding probiotics to animal feed, improving the economic feasibility of this practice as a food safety intervention.[13] However, microbes in probiotics can transmit genes that confer resistance to a variety of antibiotics, so the absence of antibiotic resistance genes in the formulations must be ensured.[14]

Effects on *Salmonella* in chicken

Probiotics can be administered to poultry to reduce the prevalence of *Salmonella*. Defined probiotics may consist of *Lactobacillus* species, heat-stable *Bacillus* species that can be given in heat-treated pelleted feed, or other microorganisms. A systematic review of commercial products found that defined direct-fed probiotics products are effective at reducing *Salmonella*. As in cattle, the economic benefits of the use of probiotics in poultry may offset the cost, thus making probiotics a practical pre-harvest intervention in broiler chickens.

Vaccines

Vaccines are widely used to prevent viral and bacterial infections in animals and are an effective approach for pre-harvest food safety.[17] Vaccination prevents infection by stimulating the animal's immune system using an agent that resembles the disease-causing pathogen.

Effects on *E. coli* O157:H7 in cattle

Commercial *E. coli* O157:H7 vaccines have been demonstrated to significantly reduce fecal shedding in cattle.[18] One commercially available cattle vaccine was found to reduce the concentration of *E. coli* O157:H7 in fecal samples by 98 percent in large field trials with more than 2,500 cattle.[19] Additionally, a mathematical model estimated that giving all cattle a vaccine that reduces fecal shedding by 50 percent could prevent up to 83 percent of human foodborne infections.[20]

Although studies demonstrate the efficacy of vaccination as a pre-harvest intervention, there are economic barriers to their use. The 2011 feedlot survey indicated that only 2.4 percent of U.S. feedlots with more than 1,000 head of cattle administered an *E. coli* O157:H7 vaccine.[21] One study estimated a vaccination cost of $8 to $15 per animal.[22] Vaccination may also negatively affect how quickly the cattle grow; however, this was a novel finding of one feedlot study, and further research is warranted.[23] Additionally, the operations bearing the cost of vaccines are not able to realize any benefits from vaccination that occur further down the supply chain.[24]

Effects on *Salmonella* in chicken

Studies have demonstrated the efficacy of vaccinating broiler-breeders (the parents of chickens destined for slaughter) to reduce *Salmonella* prevalence and concentration in their progeny.[25] One study found that poultry companies in the United States with vaccination programs for breeders saw a significant reduction in the prevalence of *Salmonella* on birds entering the slaughterhouse.[26] Other researchers found that the amount of *Salmonella* sampled from the housing environment and after slaughter was 50 percent lower for broiler chickens from vaccinated breeders.[27] Vaccinating breeders may be more economical than targeting the intervention at their offspring, because an average breeder will lay up to 180 broiler eggs per year.[28]

Like cattle vaccines, poultry vaccination can yield substantial public health benefits. The World Health Organization found that reducing the prevalence of *Salmonella*-contaminated chicken by half would reduce the risk of illness from eating a serving of chicken by as much as 50 percent.[29] A significant decline in human *Salmonella enteritidis* infections in the United Kingdom and other European countries has been attributed to vaccination of egg-laying hens.[30]

A limitation of *Salmonella* vaccines is a lack of coverage for multiple strains. Autogenous vaccines that are made from killed pathogens and are tailored to the disease risks on a given operation target specific pathogens but provide no or very limited cross-protection for other strains. Live vaccines offer more cross-protection but are available for only a few *Salmonella* serotypes.[31]

Other promising approaches on the horizon

Some pre-harvest practices are effective but are not used in the U.S. or need further research trials in farms and feedlots. For example, sodium chlorate has been found to reduce *Salmonella* in chickens, *E. coli* in cattle, and *Salmonella* and *E. coli* in swine when administered through water and feed.[32] However, more studies are needed on commercial farms, and sodium chlorate has not been approved for use in the United States.

Similarly, the amount of scientific evidence supporting *Salmonella* vaccines for swine is relatively small compared with that available for the intervention in other food animals. The literature nonetheless indicates that vaccination of pigs can improve the safety of pork products. Vaccines that target the types of *Salmonella* that cause disease in swine and are a food safety risk to humans are commercially available.[33] However, more well-designed controlled trials are needed.

Campylobacter has proved more challenging to control with discrete pre-harvest interventions and might be reduced only through on-farm biosecurity measures.[34] Sweden has had success with *Campylobacter* reduction in poultry flocks using hygiene measures on the farm. *Campylobacter*-positive flocks decreased from 50 percent to 10 percent from 1991 to 2006 as a result of strategies that included rodent and bird barriers as well as employee protocols that kept contamination from entering facilities on shoes and clothes.[35] Although studies have established some relationship between *Campylobacter* infection and the bacterium's presence in ponds, puddles, and other water sources on farms, more research is needed to fully understand these and other potential sources of contamination and routes of transmission to animals.[36]

Conclusion

Strong scientific evidence supports the effectiveness of probiotics and vaccines in reducing foodborne pathogens, and commercial products are already available. Use of these interventions can make a significant public health impact if adopted across all farms or feedlots.

Pre-harvest measures are the first step to effectively controlling food safety hazards and improving public health, and they should begin as far up the supply chain as possible—ideally with breeding flocks or herds from which the food-producing animals are derived. *Salmonella* infections in broiler-breeder chicken flocks and breeder pig herds can be transmitted to chicks and piglets, underscoring the need for efficient control measures earlier in the production chain.[37] Ultimately, successful pre-harvest programs target specific food animal species and their production systems; combine multiple interventions such as probiotics and vaccines; and include biosecurity and farm management practices, feed and water safety, and pathogen surveillance. These are fundamental parts of a comprehensive farm-to-fork approach that can significantly reduce the public health risk associated with meat and poultry consumption.

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