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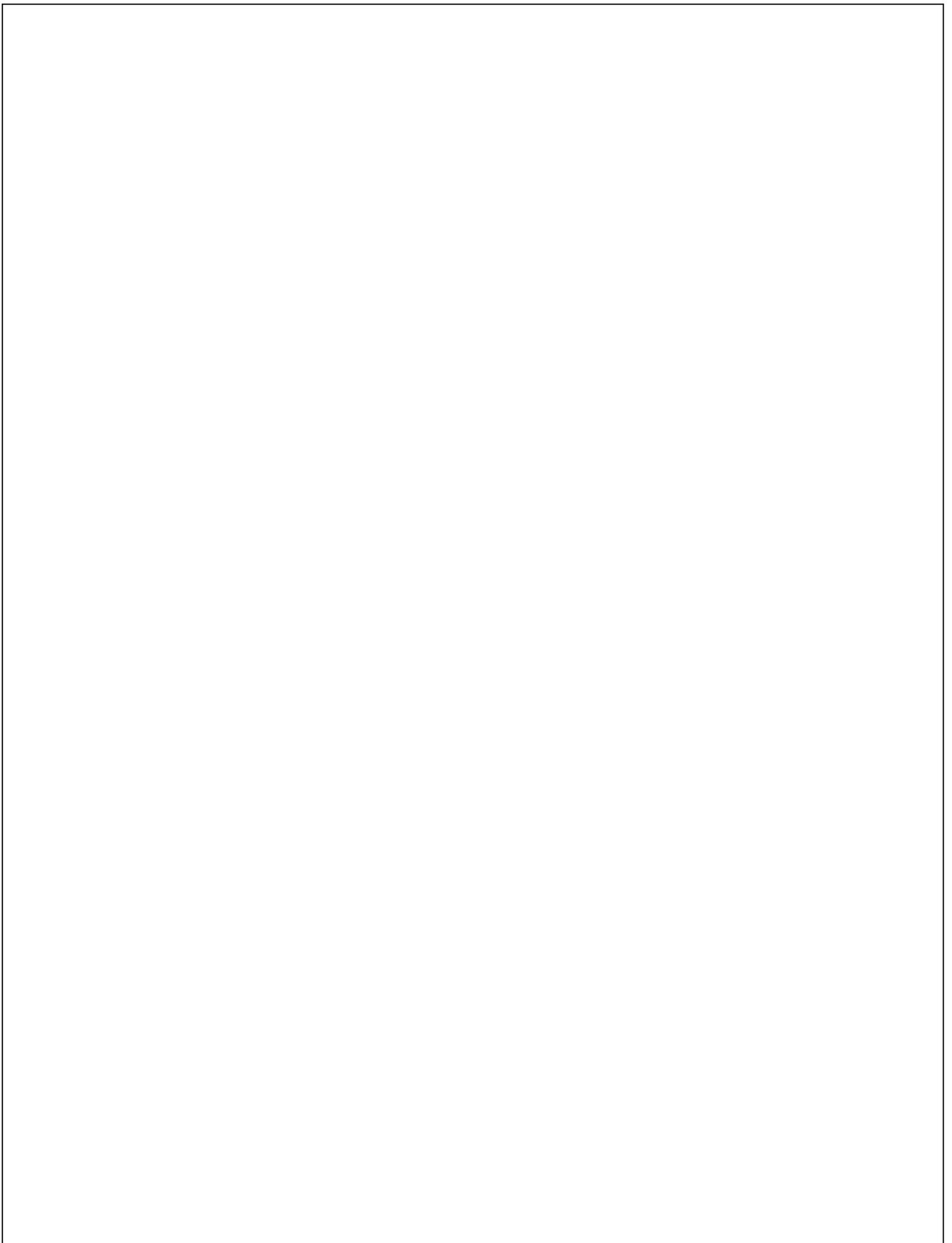
Antibiotic Resistance in Foodborne Pathogens:

Evidence of the Need for a
Risk Management Strategy

2012 Edition

March 8, 2012

A CSPI White Paper by
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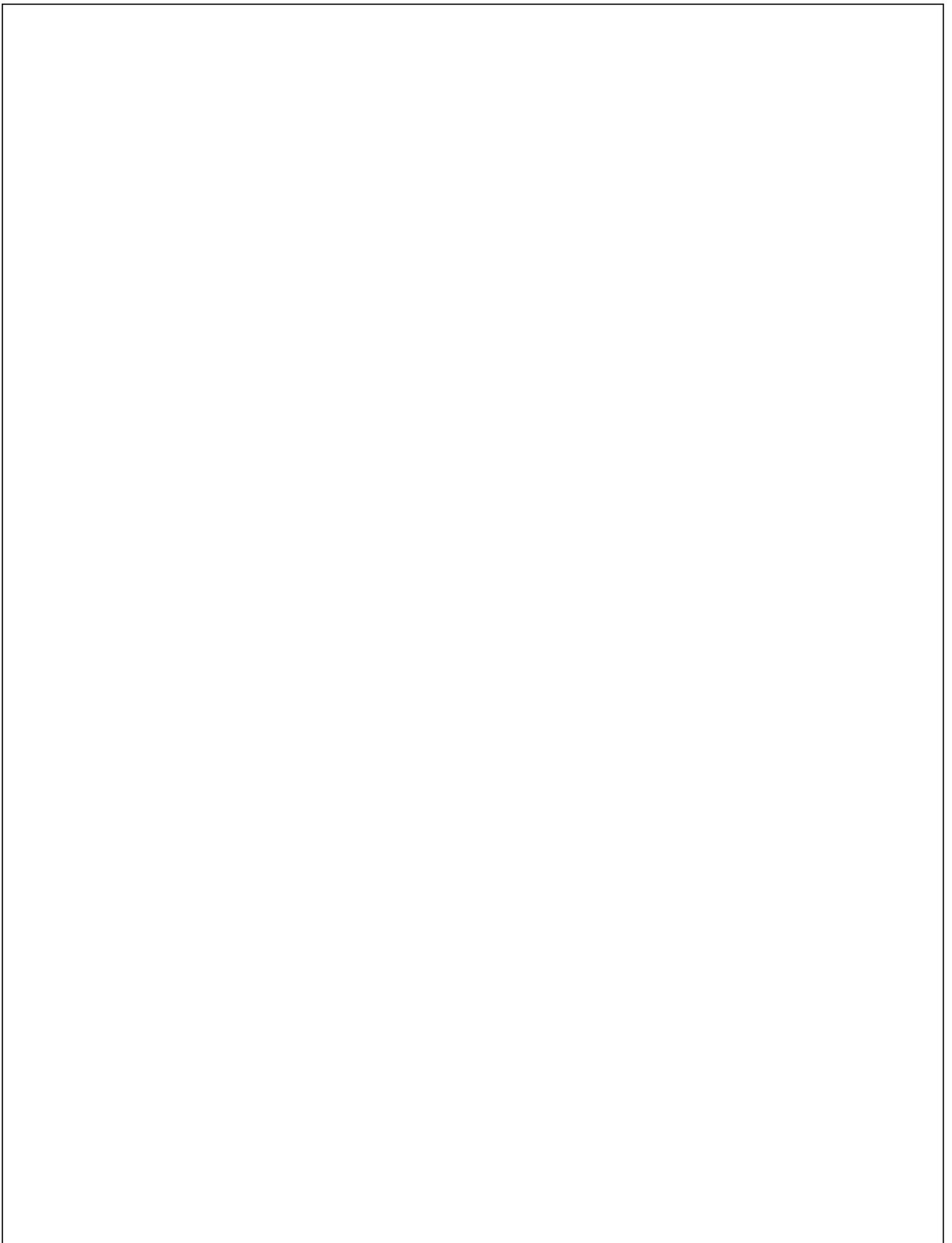
The Center for Science in the Public Interest is a nonprofit health advocacy and education organization focused on food safety, nutrition, and alcohol issues. CSPI is supported principally by the 900,000 subscribers to its Nutrition Action HealthLetter and by foundation grants. We accept no government or industry funding.



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“WHO has long recognized that antibiotic use in food animals, which seems to outweigh antibiotic use for human therapy in many countries, contributes importantly to the public health problem of antibiotic resistance.”

— World Health Organization, 2011



Information on outbreaks of foodborne illness due to antibiotic-resistant bacteria is limited. *Salmonella* and *E. coli* are not routinely tested for antibiotic resistance, and even when tests are performed, results are not required to be reported to the Centers for Disease Control and Prevention (CDC). The Center for Science in the Public Interest (CSPI) documented through literature searches a total of 38 foodborne outbreaks between 1973 and 2011 in which the bacteria identified were resistant to at least one antibiotic (Appendix A). This report illustrates the link between foods, mostly of animal origin, and outbreaks of antibiotic-resistant pathogens in humans. Outbreaks caused by antibiotic-resistant bacteria are not an emerging problem, but an *established* problem that needs more routine scrutiny by public health officials.

The National Antimicrobial Resistance Monitoring System (NARMS) collects data on patterns of emerging resistance from pathogens. NARMS data are not linked to actual outbreaks. Also, CDC does not track and publish outbreaks or sporadic illnesses caused by resistant bacteria, as it does for pathogens in its FoodNet system. Thus, CSPI has developed this preliminary database of outbreaks due to antibiotic-resistant bacteria in the food chain to encourage health officials to track those outbreaks more closely in the future. Cataloging foodborne illness outbreaks is a critical step in documenting the link between administering antibiotics to farm animals and human illness as it relates to antibiotic resistance.

Introduction

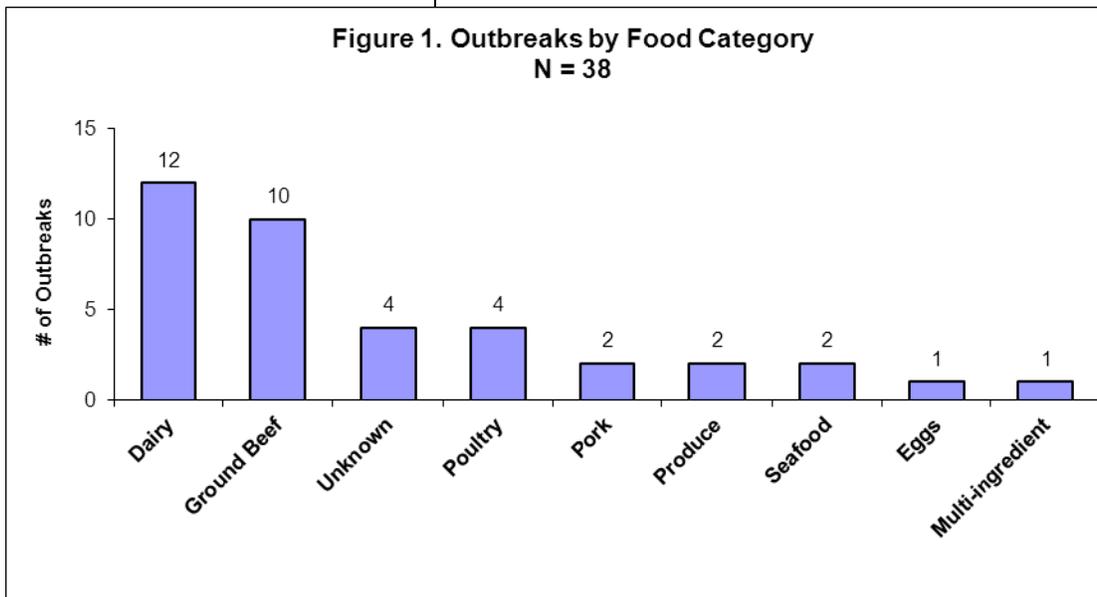
“[T]here is clear evidence of adverse human health consequences due to resistant organisms resulting from non-human usage of antimicrobials. These consequences include infections that would not have otherwise occurred, increased frequency of treatment failures (in some cases death) and increased severity of infections, as documented for instance by fluoroquinolone resistant human Salmonella infections.”

— World Health Organization, 2003

Antibiotic-Resistant Foodborne Illness Outbreaks in the United States

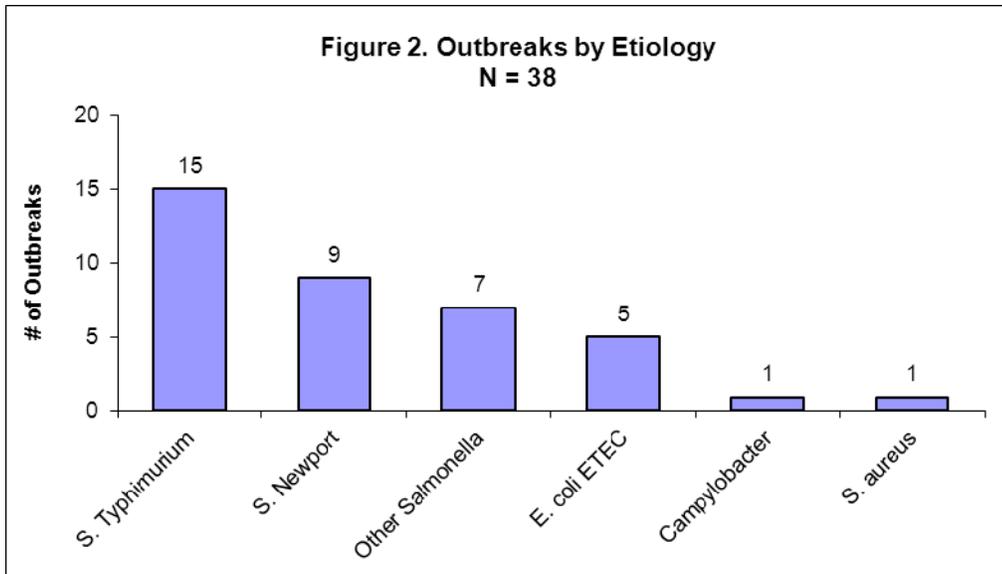
Findings

Of the 38 outbreaks, 45% (17 out of 38) occurred between 2000 and 2011. Whether the larger number of outbreaks in later years is due to increased use of antibiotics or to increased testing and reporting could not be determined. Outbreaks were most common in dairy products (12 outbreaks or 32%) and ground beef (10 outbreaks or 26%). Four outbreaks were linked to poultry, with ground turkey appearing as a new vehicle in two outbreaks in 2011. Pork, produce, and seafood were each implicated in two outbreaks. One outbreak each was linked to eggs and multi-ingredient foods. The food vehicle was unknown in four of the outbreaks (Figure 1).



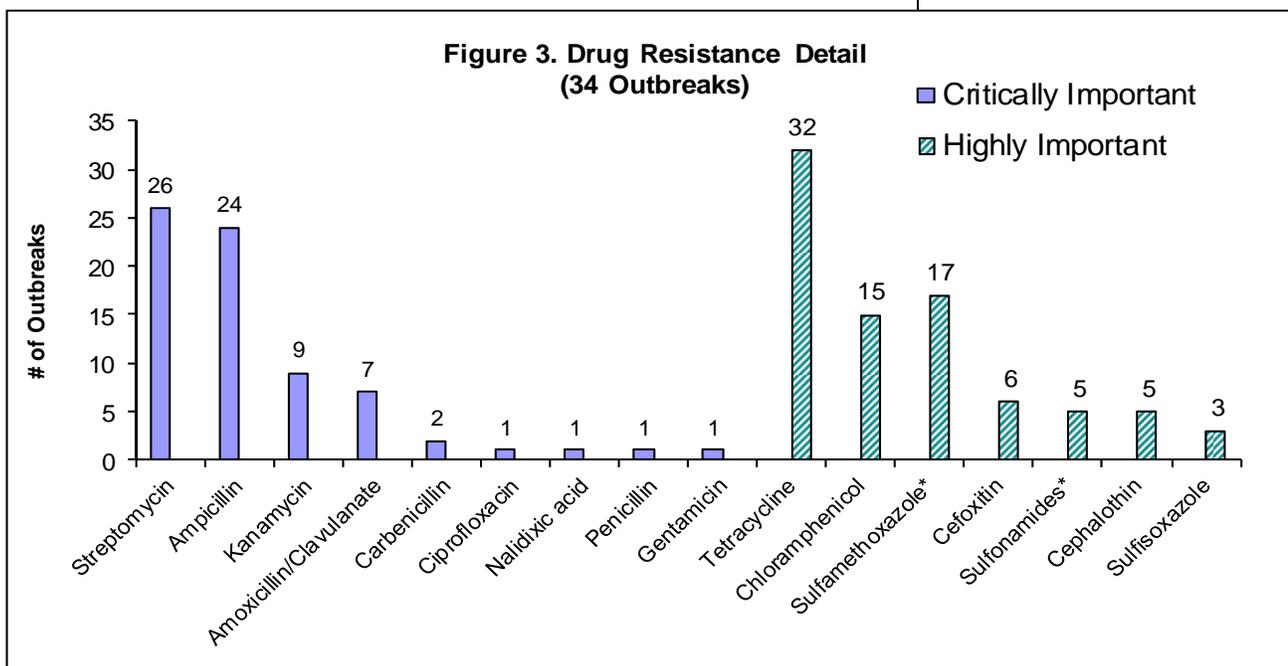
A total of 20,064 people were sickened from these 38 outbreaks, resulting in 3,108 hospitalizations and 27 deaths. That includes an enormous *Salmonella* Typhimurium outbreak caused by milk in 1985 in which 16,659 were sickened, 2,777 were hospitalized, and 18 died.

Salmonella was implicated in 31 of the 38 outbreaks (82%), causing 19,462 illnesses. The most frequently identified *Salmonella* serotype was *S. Typhimurium*, which was implicated in 15 outbreaks causing 17,830 illnesses (40% of total outbreaks, including the large outbreak in 1985). *S. Newport* was identified in nine outbreaks with 586 illnesses (24% of total outbreaks), followed by *S. Heidelberg* which was implicated in two outbreaks. Other *Salmonella* serotypes were implicated in five outbreaks. Several serotypes of enterotoxigenic *Escherichia coli* (ETEC) were identified in five outbreaks, resulting in 446 illnesses. *Campylobacter jejuni* and *Staphylococcus aureus* were responsible for one outbreak each, with 128 and 3 illnesses, respectively (Figure 2).

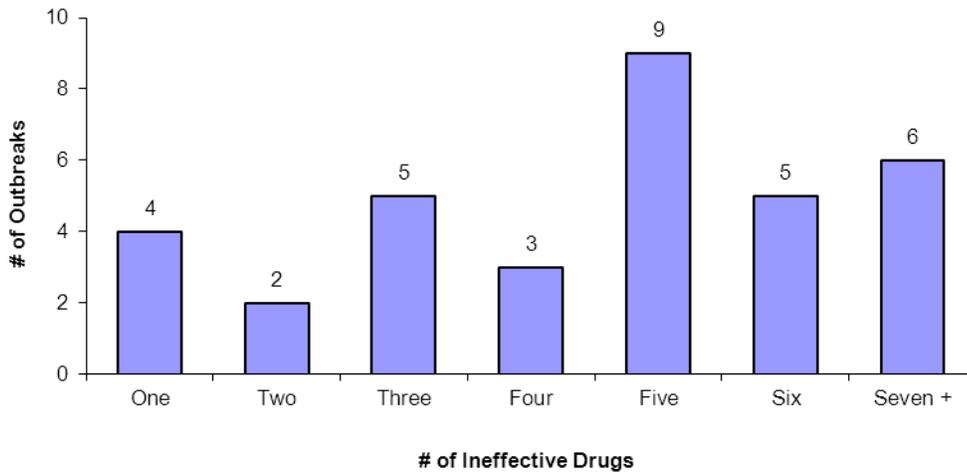


For the 34 outbreaks for which antibiotic-resistance patterns were determined, the responsible bacteria displayed resistance to a total of 15 different antibiotics and to at least one sulfonamide.* Of those antibiotics, nine are classified by the World Health Organization (WHO) as ‘critically important’ to human medicine and seven as ‘highly important’ to human medicine. Bacteria showed resistance to tetracycline in 32 outbreaks. Resistances to streptomycin and ampicillin, both classified as critically important antibiotics, were the next most common (Figure 3).

* Sulfonamides are a class of drug, not a specific antibiotic. Sulfonamide resistance was listed in five outbreaks. Resistance to sulfamethoxazole, a member of that class, was reported in 17 additional outbreaks.



**Figure 4. Resistances per Outbreak
N=34**



Twenty outbreaks involved a pathogen that was resistant to at least five antibiotics (Figure 4). Ten of the 20 occurred between 2000 and 2011.

Meat-Related Outbreaks

CSPI identified a total of 16 outbreaks related to meat products: ten in ground beef, four in poultry, and two in pork. Of the ground beef-related outbreaks, *S. Newport* was implicated in seven outbreaks and *S. Typhimurium* in three. Meat outbreaks were associated with 1,518 illnesses, 155 hospitalizations, and 8 deaths.

Dairy-Related Outbreaks

Of the 12 outbreaks related to dairy products, seven were associated with milk and five with cheese products. In ten of the outbreaks, the vehicle was described as unpasteurized or raw milk and/or cheese made from unpasteurized milk. Pasteurized milk was responsible for two of the dairy-related outbreaks, including the large 1985 outbreak. All outbreaks related to dairy products were caused by *Salmonella*—nine by *S. Typhimurium*, two by *S. Newport*, and one by *S. Dublin*. Dairy-related outbreaks sickened at least 17,125, hospitalized 2,860, and killed 19.

Development of Antibiotic-Resistant Bacteria in People Who Live on Farms

In a study done in the 1970s, isolates from chickens on a farm and from people who lived on the farm were tested and found to have low initial levels of tetracycline-resistant E. coli bacteria. Within two weeks after the chickens were fed tetracycline-supplemented feed, 90 percent of the chickens were excreting bacteria that were resistant to tetracycline. Although the chickens were exposed only to tetracycline, many of the bacteria developed resistance to four antibiotics. Within six months, seven of the 11 people who lived on the farm were excreting antibiotic-resistant E. coli bacteria. When these people were retested six months after the tetracycline-supplemented feed was discontinued, no detectable tetracycline-resistant organisms were found in eight of ten people (Levy et al., 1976).

Background

The discovery of antibacterial agents in the first half of the 20th century radically changed the outcome of common human diseases. Many illnesses that are now readily treatable were deadly before antibiotics became available. The ability of bacteria to evolve mechanisms to resist attack by antimicrobials¹ was recognized soon after the widespread deployment of the first antibiotics.

Resistance is an inevitable consequence of antibiotic use; the more antibiotics are used, the more bacteria will develop resistance. In recent years, scientists have begun to understand the sophisticated biochemical mechanisms that allow bacteria to fend off or neutralize antibiotics. Antibiotic resistance is recognized as a growing problem that poses a major threat to the continued effectiveness of antibiotics used to treat human and veterinary illnesses. Further exacerbating the problem, pharmaceutical companies are developing fewer new antibiotics to replace those that are no longer effective (Silbergeld et al., 2008).

Numerous studies have documented direct transference of antibiotic-resistant bacteria from animals to humans. Researchers have found that when antibiotics were administered to animals to treat infections, the prevalence of antibiotic-resistant *E. coli* and *Campylobacter* bacteria also increased in humans (GAO, 2004). Other studies have confirmed that antibiotic-resistant *Campylobacter*, *Salmonella* Typhimurium DT 104, and *Salmonella* Newport have moved from animals to humans through foods of animal origin (Smith et al., 1999; Ribot et al., 2002). Reflecting the fact that bacteria can develop resistance to numerous antibiotics at the same time, one group of related antibiotic-resistant *Salmonella* Newport strains is resistant to most available antimicrobial agents approved for the treatment of salmonellosis, particularly in children (Gupta et al., 2003).

The human health consequences of these resistant organisms include more serious infections and increased frequency of treatment failures. Patients may experience prolonged duration of illness, increased frequency of bloodstream infections, increased hospitalization, and increased mortality (Angulo et al., 2004).

¹ The term “antimicrobial” is a broad term referring to substances that act against a variety of microorganisms, including bacteria, viruses, parasites, and fungi. The term “antibiotic” is a narrower term referring to substances used to treat bacterial infections. Classically, antibiotics were produced by a microorganism, but now both manufactured and naturally-occurring substances that kill bacteria are called antibiotics. Most of the concern with antimicrobial use in agriculture is with bacterial resistance, so “antibiotic” is used in this report.

Antibiotics Important in Human Medicine

Health-care costs increase with longer hospital stays and the need for more expensive antibiotics to fight resistant pathogens. The antibiotics used to treat resistant pathogens can be more toxic, with more serious side effects in the patients.

The reported outbreaks demonstrate the problem of antibiotic resistance in foodborne pathogens, but the risk-management strategy is complicated by the division of authority among several federal agencies and the diverse stakeholders, particularly the drug manufacturers and cattle, hog, and poultry industries. To help determine the cause and identify potential solutions, information is required on the types and quantities of antibiotics sold for use in food-producing animals, the species they are used in, when they are administered, the purpose of their use (disease treatment, disease prevention, or growth promotion), and the method used to administer them. Denmark collects antibiotic prescription information from veterinary pharmacies, feed mills, veterinarians, and private companies on the intended species and age group to receive the antibiotic, disease being treated, and dose. Such data have allowed Danish researchers to determine how changes in the use of antibiotics in animals affect the emergence of antibiotic-resistant bacteria (GAO, 2011).

Many of the antibiotics used for food-producing animals are the same, or belong to the same classes, as those used in human medicine. Resistance to one antibiotic in a class often results in resistance to all drugs in that class, further compounding the problem. In addition, the genes that can render a bacterium resistant are selected for and can even be shared by different species through horizontal gene transfer. Widespread use of these antibiotics in agriculture can render them ineffective against human illnesses.

The WHO has developed criteria for ranking antimicrobials according to their importance in human medicine. The rankings are regularly reviewed by WHO's Advisory Group on Integrated Surveillance of Antimicrobial Resistance (AGISAR). This ranking of different drugs was developed strictly from a human health perspective for governments and other stakeholders to use when developing risk management strategies concerning the use of antimicrobials in food animals.

“People infected with drug-resistant organisms are more likely to have longer and more expensive hospital stays, and may be more likely to die as a result of the infection. When the drug of choice for treating their infection doesn't work, they require treatment with second- or third-choice drugs that may be less effective, more toxic, and more expensive.”

— Centers for Disease Control and Prevention, 2010

The WHO divides antimicrobials into three categories: critically important, highly important, and important, based on their overall importance to human health (WHO, 2009). WHO ranks antimicrobial agents as critically important when:

- 1) they are the sole or one of few options for treatment of human infections, and
- 2) they are used to treat diseases caused by organisms that may be transmitted via non-human sources or organisms that may acquire resistance genes from non-human sources.

Antimicrobials that meet either criterion are ranked as highly important, while antimicrobials that meet neither criterion are ranked as important.

In 2003, the Food and Drug Administration (FDA) also compiled a list ranking antimicrobial drugs according to their importance in human medicine (FDA, 2003). However, the FDA focused on antibiotics used to treat foodborne illness in humans, rather than on the broader spectrum of human disease. For example, FDA ranks fourth-generation cephalosporins, which are an important treatment for pneumonia and one of the few therapies for cancer patients with complications from chemotherapy, as highly important, while WHO ranks them as critically important (GAO, 2011).

Integrated Antibiotic-Resistance Surveillance in the United States

The United States has established an integrated surveillance system for monitoring antibiotic resistance in humans, in food-producing animals, and in retail meats. In 1996, the Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the United States Department of Agriculture (USDA) established the National Antimicrobial Resistance Monitoring System (NARMS) for Enteric Bacteria to collect antibiotic resistance data. In the human component, participating state health departments submit Salmonella, Campylobacter, Shigella, and E. coli O157 isolates from human infections to CDC. In the animal component, USDA tests isolates from slaughter and processing plants, and from diagnostic laboratories for Salmonella, Campylobacter, Enterococcus and E. coli. FDA tests samples of meat purchased at grocery stores for Salmonella, Campylobacter, Enterococcus, and E. coli. The resulting information helps to identify and analyze trends in antimicrobial resistance and to determine if hazards are moving through animals into the food chain. However, those data have not been linked to actual foodborne illness outbreaks tracked by CDC and state and local health agencies. Without such a linkage the data is insufficient to identify foodborne outbreaks caused by antibiotic-resistant pathogens.

Antibiotic Use in Food-Producing Animals

Antibiotics are used in food-producing animals to treat or prevent illnesses, for example, during the weaning period of young animals. They may also be used for long periods at low levels to promote growth, increase feed efficiency, or compensate for unsanitary growing conditions on concentrated animal feeding operations (CAFOs). Increased feed efficiency means animals require less feed per pound of weight gain, which translates to lower costs for producers. Many animal producers believe the use of antibiotics for growth promotion also prevents disease (GAO, 2011).

“In light of the risk that antimicrobial resistance poses to public health, FDA believes the use of medically important antimicrobial drugs in food-producing animals for production purposes (e.g., to promote growth or improve feed efficiency) represents an injudicious use of these important drugs.”

— Food and Drug Administration, 2010

In the industrial model of animal husbandry, large numbers of pigs, chickens, or cattle are raised in confined areas. In the pork and chicken industries, large-scale concentrated housing systems reduce costs for labor, feed, and housing. However, the increased stress of crowding and unsanitary conditions makes animals more susceptible to the

spread of infectious diseases. Many producers commonly administer an antibiotic to an entire flock or herd via feed or water, but that gives them less control over the dosage consumed by individual animals. The nontherapeutic² use of antibiotics, sometimes administered throughout an animal’s life, is among the practices of greatest concern for the development of antibiotic resistance.

Quinolone-resistant Camplobacter jejuni in the U.S.

Emergence of quinolone-resistant Camplobacter jejuni in the U.S. coincided with the approval of fluoroquinolones for use in poultry in 1995. Rates of resistance to fluoroquinolones among human C. jejuni isolates rose sharply during this period as well. Quinolones had been used in human medicine in the U.S. since 1985 with almost no resistance noted. Researchers in Minnesota found an association between molecular subtypes of quinolone-resistant C. jejuni strains found in humans and those found in retail chicken products. Epidemiologic and laboratory data from the Netherlands, Spain, Taiwan, and the United Kingdom also point to the use of flouroquinolones in poultry as a primary factor in the higher rates of quinolone-resistant C. jejuni in humans (Smith 1999).

² Nontherapeutic refers to use when animals are treated in the absence of bacterial disease or exposure to disease.

Exacerbating the problem is that farmers in the United States can obtain many antibiotics for their animals without a prescription, and can administer those drugs without veterinary advice or oversight. That over-the-counter use has produced little reliable historical data regarding the use of antibiotics in food animal production. Beginning in 2008, however, antibiotic drug manufacturers were required to report annually to the FDA the amount of drugs they sold or distributed for use in food-producing animals (FDA, 2010a, FDA, 2011a). For the first two years for which data are available, 2009 and 2010, the total quantity of antibiotics distributed for use in all food-producing animal species was approximately 29 million pounds of active ingredient. The data was not broken down by species, by route of administration, or by purpose of use (Table 1). Analysis of this data reveals that food animals consume approximately 80% of all antibiotics sold in the United States, and that 65% of the antibiotics used in animal agriculture are either identical or similar to those used in human medicine (FDA 2010a, FDA 2010c).

Table 1. Antimicrobial Drugs Approved for Domestic Use in Humans and Food-Producing Animals*. Sales and Distribution Data Reported to FDA by Drug Class.

	2009 Animal Annual Totals (LBS)	2010 Animal Annual Totals (LBS)	2009 Human Annual Total (LBS)**
Aminoglycosides	748,862	442,675	20,682
Cephalosporins	91,113	54,207	1,101,465
Ionophores	8,246,671	8,424,167	0
Lincosamides	255,377	340,952	153,744
Macrolides	1,900,352	1,219,661	388,626
Penicillins	1,345,953	1,920,112	3,217,027
Sulfas	1,141,715	1,116,020	1,039,352
Tetracyclines	10,167,481	12,328,521	289,108
Other (Not Independently Reported (NIR))**	4,910,501	3,345,398	1,102,567
Total	28,808,024	29,191,712	7,312,570

* For all classes except aminoglycosides and ionophores, data includes antimicrobial drug products which are approved and labeled for use in both food- and non- food-producing animals.

** NIR is used for antimicrobial classes with fewer than three sponsors actively marketing products. This category includes fluoroquinolones and streptogramins.

*** Human drug use data is based on data from the IMS Health, IMS National Sales Perspectives™.

The use of aminoglycosides in food-producing animals, which includes the WHO critically important antibiotic gentamicin, as well as the highly important antibiotic neomycin, appears to have decreased from 2009 to 2010, based on these distribution and sales reports. There was also a decrease in the use of macrolides, which includes the critically important antibiotic erythromycin. For penicillins, which includes critically important antibiotics amoxicillin, ampicillin, and penicillin, as well as the highly important antibiotic cloxacillin, use appears to have increased from 2009 to 2010. There was also a major increase in the distribution of tetracyclines, which includes the critically important antibiotics chlortetracycline, oxytetracycline, and tetracycline.

References

- Angulo F.J., Nargund, V.N., and Chiller, T.C. 2004. Evidence of an Association Between Use of Anti-microbial Agents in Food Animals and Anti-microbial Resistance Among Bacteria Isolated from Humans and the Human Health Consequences of Such Resistance. *J. Vet. Med. B Infect. Dis. Vet. Public Health*, 51, 374-379.
- Centers for Disease Control and Prevention. *About Antimicrobial Resistance: A Brief Overview*. Retrieved July 22, 2010 from CDC website at <http://cdc.gov/drugresistance/about.html>
- Food and Drug Administration (FDA). 2011. *2010 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals*. Available from the FDA website at <http://www.fda.gov/downloads/ForIndustry/UserFees/AnimalDrugUserFeeActADUFA/UCM277657.pdf>
- Food and Drug Administration (FDA). 2011. *National Antimicrobial Resistance Monitoring System – Enteric Bacteria (NARMS): 2009 Executive Report*. Available from the FDA website at <http://www.fda.gov/downloads/AnimalVeterinary/SafetyHealth/AntimicrobialResistance/NationalAntimicrobialResistanceMonitoringSystem/UCM268954.pdf>
- Food and Drug Administration (FDA). 2010. *2009 Summary Report on Antimicrobials Sold or Distributed for Use in Food-Producing Animals*. Available from the FDA website at <http://www.fda.gov/downloads/ForIndustry/UserFees/AnimalDrugUserFeeActADUFA/UCM231851.pdf>
- Food and Drug Administration (FDA). 2010, June. *The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals*. (Draft Guidance #209). Available from the FDA website at <http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM216936.pdf>
- Food and Drug Administration (FDA). 2010. *Estimates of Antibacterial Drug Sales in Human Medicine*. Available from the FDA website at <http://www.fda.gov/Drugs/DrugSafety/InformationbyDrugClass/ucm261160.htm>
- Food and Drug Administration (FDA). 2003. *Guidance for Industry #152. Evaluating the Safety of Antimicrobial New Animal Drugs with Regard to Their Microbiological Effects on Bacteria of Human Health Concern*. Available from the FDA website at <http://www.fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM052519.pdf>
- Gupta, A., Fontana, J., Crowe, C., Bolstorff, B., Stout, A., Van Duyne, S., Hoekstra, M.P., Whichard, J.M., Barrett, T.J., and Angulo, F.J. 2003. Emergence of Multidrug-Resistant *Salmonella enterica* Serotype Newport Infections. *Journal of Infectious Diseases*, 188, 1707-1716
- Levy, S.B., FitzGerald, G.B., and Macone, A.B. 1976. Changes in Intestinal Flora of Farm Personnel after Introduction of a Tetracycline-Supplemented Feed on a Farm. *New England Journal of Medicine*, 295, 583-588.
- Ribot, E.M., Wierzbica, R.K., Angulo, F.J., and Barrett, T.J. 2002. *Salmonella enterica* serotype Typhimurium DT104 Isolated from Humans, United States, 1985, 1990, and 1995. *Emerging Infectious Diseases*, 8(4), 387-391.
- Silbergeld, E.K., Price, L., and Graham, J. 2008. *Antimicrobial Resistance and Human Health*. Retrieved from Pew Commission on Industrial Farm Animal Production website: http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Industrial_Agriculture/PCIFAP_AntbioRprtvt.pdf
- Smith, K.E., Besser, J.M., Hedberg, C.W., Leano, F.T., Bender J.B., Wicklund, J.H., Johnson, B.P., Moore, K.A., and Osterholm, M.T. 1999. Quinolone-resistant *Campylobacter jejuni* infections in Minnesota, 1992-1998. *New England Journal of Medicine*, 340.
- U.S. Government Accountability Office (GAO). 2011. *Agencies Have Made Limited Progress Addressing Antibiotic Use in Animals*. GAO-11-801. Available from the GAO website at <http://gao.gov/assets/330/323090.pdf>
- U.S. Government Accountability Office (GAO). 2004. *Federal Agencies Need to Better Focus Efforts to Address Risk to Humans from Antibiotic Use in Animals*. GAO-04-490. Available from the GAO website at <http://www.gao.gov/new.items/d04490.pdf>
- World Health Organization (WHO). Regional Office for Europe. 2011. *Tackling antibiotic resistance from a food safety perspective in Europe*. Available from the WHO website at http://www.euro.who.int/__data/assets/pdf_file/0005/136454/e94889.pdf
- World Health Organization (WHO). 2009. *Report of the 1st Meeting of the WHO Advisory Group on Integrated Surveillance of Antimicrobial Resistance*. Available from the WHO website at <http://apps.who.int/medicinedocs/index/assoc/s16735e/s16735e.pdf>
- World Health Organization (WHO). 2003. *Joint FAO/OIE/WHO Expert Workshop on non-Human Antimicrobial Usage and Antimicrobial Resistance: Scientific assessment*. Available from the WHO website at <http://www.who.int/foodsafety/publications/micro/en/amr.pdf>

Appendix A. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
1973	ME	<i>S. Typhimurium</i>	Eggs	32			unknown		
1975	MD, FL, CO	<i>S. Newport</i>	Ground beef	27			streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1977	KY	<i>S. Typhimurium</i>	Raw milk	3			ampicillin	penicillin	critically important
							carbenicillin	penicillin	critically important
							kanamycin	aminoglycosides	highly important
							penicillin	penicillin	critically important
							streptomycin	aminoglycosides	critically important
							tetracycline	tetracycline	highly important
1979	CA, OR	<i>S. Dublin</i>	Raw milk	39			unknown		
1980	MT	<i>S. Typhimurium</i>	Raw milk				unknown		
1983	AZ	<i>S. Typhimurium</i>	Raw milk	12		1	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamides*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1983	MN, SD, NE, IA	<i>S. Newport</i>	Ground beef	18	11	1	ampicillin	penicillin	critically important
							carbenicillin	penicillin	critically important
							tetracycline	tetracycline	highly important
1984	OR	<i>S. Typhimurium</i>	Salad bar	715	45	0	tetracycline	tetracycline	highly important
							streptomycin	aminoglycosides	critically important
1985	CA	<i>S. Newport</i>	Ground beef	298	22	2	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1985	IL	<i>S. Typhimurium</i>	Pasteurized milk	16659	2777	18	ampicillin	penicillin	critically important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1987	GA	<i>S. Havana</i>	Chicken	73	36	1	tetracycline	tetracycline	highly important
1994	WI	<i>E. coli</i> 0153:H45 (ETEC)	Unknown, banquet food	205			ampicillin	penicillin	critically important
							tetracycline	tetracycline	highly important
							sulfisoxazole	sulfonamides	highly important
							streptomycin	aminoglycosides	critically important
1995	AZ	<i>S. Stanley</i>	Alfalfa sprouts	19	5		kanamycin	aminoglycosides	highly important
							tetracycline	tetracycline	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
1996	NE	<i>S. Typhimurium</i> DT104	Unknown, chocolate milk suspected	19	0	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamides*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	WA	<i>S. Typhimurium</i> DT104	Mexican-style soft cheese (queso fresco) (raw milk)	89	5	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important

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Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
1997	CA	S. Typhimurium DT104	Mexican-style cheese (raw milk)	79	13		ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamides*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	CA	S. Typhimurium var Copenhagen DT104b	Mexican-style cheese (raw milk)	31	14		ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamides*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	MD	S. Heidelberg	Pork	706		2	kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	highly important
							tetracycline	tetracycline	highly important
1997	VT	S. Typhimurium	Raw milk	9	1		ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1998	NY	S. enterica Serotype 4,5,12:i:-	Unknown, dinner reception multiple foods suspected	86	31	0	ampicillin	penicillin	critically important
							streptomycin	aminoglycosides	critically important
							sulfonamides*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
1998	KS	Campylobacter jejuni	Unknown, gravy, potato, pineapple	128	2	0	ciprofloxacin	fluoroquinolone	critically important
							tetracycline	tetracycline	highly important
2000	TN	Staphylococcus aureus (MRSA)	Pork, barbeque, vegetable	3	0	0	methicillin	penicillin	*
2000	PA, NJ	S. Typhimurium	Pasteurized milk	93	6	0	ampicillin	penicillin	critically important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2001	CT	S. Newport	Italian-style soft cheese (raw milk)	26	8	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							cephalothin	cephalosporin (1G)	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2001	WI	E. coli O169:H41/ST (ETEC)	Quesadilla, fajitas, nacho chips, beans	21			tetracycline	tetracycline	highly important
2002	NY, MI, PA, OH, CT	S. Newport	Ground beef	47	17	1	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin	*
							cephalothin	cephalosporin (1G)	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important

Appendix A. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
							kanamycin (2/3 resistant)	aminoglycosides	highly important
							ceftriaxone (2)	cephalosporin (3G)	critically important
2002	OR	<i>E. coli</i> O27:H7/ST (ETEC)	Chicken lasagna	49	0	0	streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2003	TN	<i>E. coli</i> 0169:H49	Catfish,	41			tetracycline	tetracycline	highly important
2003	ME, MA, NH, VT, CT, RI, NY, PA, NJ	<i>S. Typhimurium</i> DT104	Ground beef	56	11	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2004	NV	<i>E. coli</i> O6:H16 (ETEC)	Shrimp	130	0	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							nalidixic acid	quinolone	critically important
							streptomycin	aminoglycosides	critically important
							sulfisoxazole	sulfonamides	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
2007	IL	<i>S. Newport</i>	Mexican-style cheese (cotija), (raw milk)	85	36	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2007	CA, AZ, HI, NV, NM	<i>S. Newport</i> (resistant)	Ground beef	43	15		unknown		
2009	CO, KS, MS, NE, NM, UT, WY	<i>S. Typhimurium</i> DT104	Ground beef	14	6	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2009	AZ, CA, CO, UT	<i>S. Newport</i>	Ground beef	40			amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							cephalothin	cephalosporin (1G)	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2009	AZ, NM	<i>S. Newport</i>	Ground beef	2			amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							cephalothin	cephalosporin (1G)	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important

Appendix A. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
2011	CA, AZ, WI, CO, WA, OH, GA, IL, MS, MO	S. Hadar	Ground turkey (Jennie-O ground turkey burgers)	12	3		ampicillin, amoxicillin/clavulanate, cephalothin, tetracycline	penicillin penicillin cephalosporin tetracycline	critically important critically important highly important highly important
2011	26 States	S. Heidelberg	Ground turkey (Cargill)	136	37	1	ampicillin, streptomycin, tetracycline, gentamicin	penicillin aminoglycosides tetracycline aminoglycosides	critically important critically important highly important critically important
2011	7 states - HI, KY, MA, ME, NH, NY, VT	S. Typhimurium	Ground beef	19	7		amoxicillin/clavulanate, ampicillin, ceftriaxone, cefoxitin, kanamycin, streptomycin, sulfisoxazole, tetracycline	penicillin penicillin cephalosporin cephamycin aminoglycosides aminoglycosides sulfonamides tetracycline	critically important critically important critically important highly important highly important critically important highly important highly important
		* Not on WHO's list of antimicrobials used in human medicine							
		Source: Center for Science in the Public Interest							
Totals				20064	3108	27			