



ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

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*A CSPI White Paper by
Caroline Smith DeWaal, J.D., and Susan Vaughn Grooters, M.P.H.*

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

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Center for Science in the Public Interest

1220 L Street N.W., Suite 300

Washington, DC 20005

Tel 202.332.9110

www.cspinet.org

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ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

Table of Contents

Executive Summary _____	1
Introduction _____	2
Findings _____	3
Background _____	7
Antimicrobial Drug Sales and Distribution Data _____	11
References _____	12
Appendix - Foodborne Outbreak Line Listing _____	14

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

Executive Summary

The illnesses, hospitalizations, and deaths reported as part of this white paper are those from antibiotic resistant foodborne pathogens. Overall, those outbreaks reveal that antibiotic resistant foodborne pathogens can, and do, contaminate our food supply. The resulting illnesses become difficult to treat as the antibiotics needed to treat them are more limited.

This report details antibiotic-resistant foodborne outbreaks from 1973 to 2011. In total, 55 outbreaks were identified. Food items most likely associated with antibiotic resistant pathogens included dairy products, ground beef, and poultry. These three food categories were implicated in more than half of reported outbreaks (31 of 55). *Salmonella* spp. was the most common cause of antibiotic-resistant outbreaks identified (48 of 55). Pathogens exhibiting multi-drug resistance to five or more antibiotics were identified in more than half of the outbreaks (31 of 55, 56%).

A Public Health Crisis

"[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

Managing antibiotic resistance, with a voluntary approach

In April of 2012, the FDA issued a plan to address antimicrobial resistance in the food supply, with the release of guidance for industry: *The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals* (GFI 209). The FDA's strategy is to limit use of antimicrobials in food-producing animals that are also important in human health, and ultimately to curb the development of antimicrobial resistance. Using a voluntary approach, the guidance encourages drug companies to change the labeling of medically important antimicrobials in food-producing animals to prevent their use in animals for growth promotion or increased feed efficiency. This voluntary approach is flawed in light of FDA's public health mission. Legislation such as "The Preservation of Antibiotics for the Medical Treatment Act" would provide clearer standards to limit the use of eight classes of antibiotics, deemed critically important for use in human medicine, that are also used in animal agriculture. This Act provides a more rigorous measure to address the problem of antibiotic resistance by specifically addressing uses of antibiotics in animal agriculture that are critical to treatment of human disease.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

Introduction

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 - and prevention - by public health officials. 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) in this white paper describes a total of 55 foodborne outbreaks between 1973 and 2011 that were caused by bacteria resistant to at least one antibiotic.

The National Antimicrobial Resistance Monitoring System (NARMS) collects data on patterns of resistance in pathogens, but those data are not linked to actual outbreaks. Also, CDC does not track and publish information about outbreaks or sporadic illnesses caused by resistant bacteria, as it does for pathogens in its FoodNet system. Thus, in the absence of other data, CSPI has developed a database of outbreaks due to antibiotic-resistant bacteria in the food chain to inform health officials and the public and to encourage careful tracking of those outbreaks in the future. Cataloging foodborne illness outbreaks associated with antibiotic-resistant pathogens is a critical step in understanding the link between administering antibiotics to farm animals and human illness and, ultimately, preventing the problem.

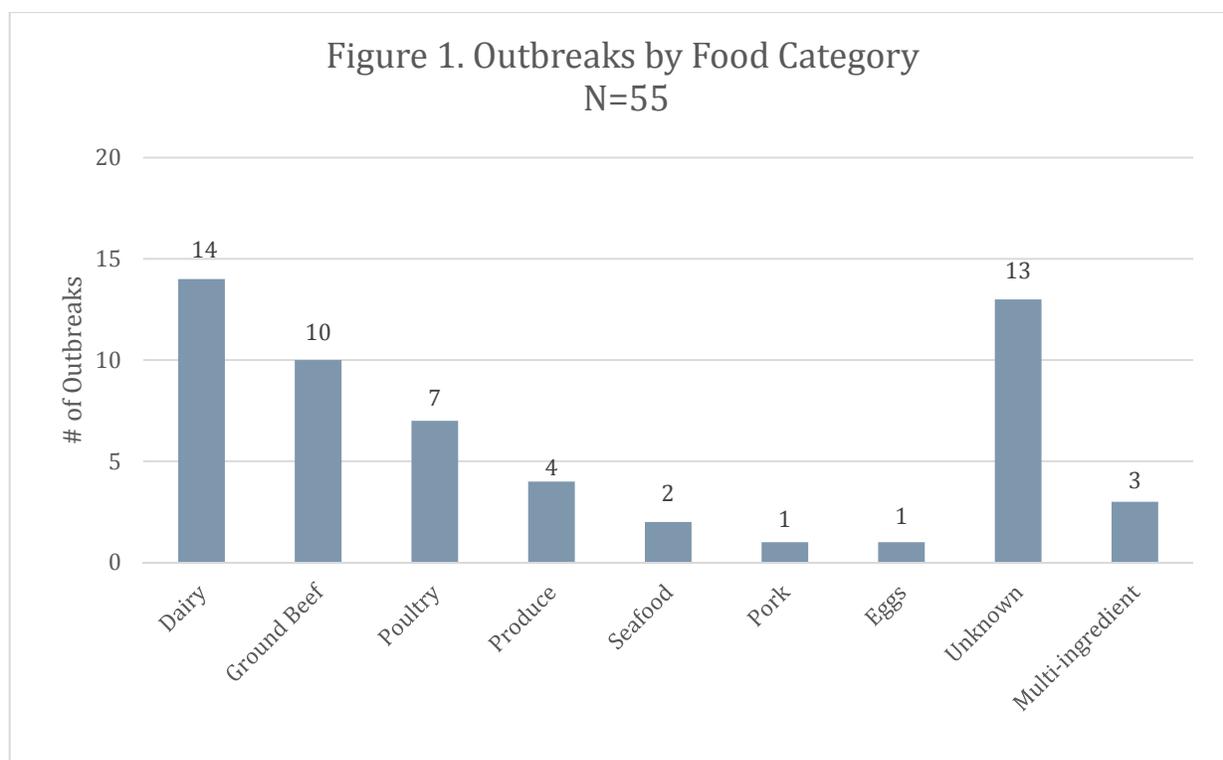
Limiting use in animals to preserve cephalosporin effectiveness in humans

Two populations that are most at risk of foodborne illness are children and immune-compromised individuals. Ceftriaxone or cefotaxime are third-generation cephalosporins and are often the treatment of choice for severely complicated pediatric salmonellosis. Concerns about the pervasiveness of plasmids that confer resistance to first-, second-, and third-generation cephalosporins led FDA in January 2012 to announce that it would ban the extra-label use of certain cephalosporin antibiotics in major species of food-producing animals. That ban took effect on April 5, 2012.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

Findings

While antibiotic-resistant outbreaks have been catalogued since the 1970s, the majority have (34, 58%) occurred since 2000. Dairy products accounted for a quarter of the outbreaks (14 outbreaks, 25%). Contaminated ground beef was also a common cause (10 outbreaks, 18%). Contaminated poultry products caused seven outbreaks, produce items caused four, and seafood accounted for two. One outbreak each was linked to pork and eggs. Multi-ingredient foods caused three outbreaks, and no specific food vehicle was determined for thirteen of the outbreaks, though characteristics of the outbreaks indicated that they were food related (Figure 1).

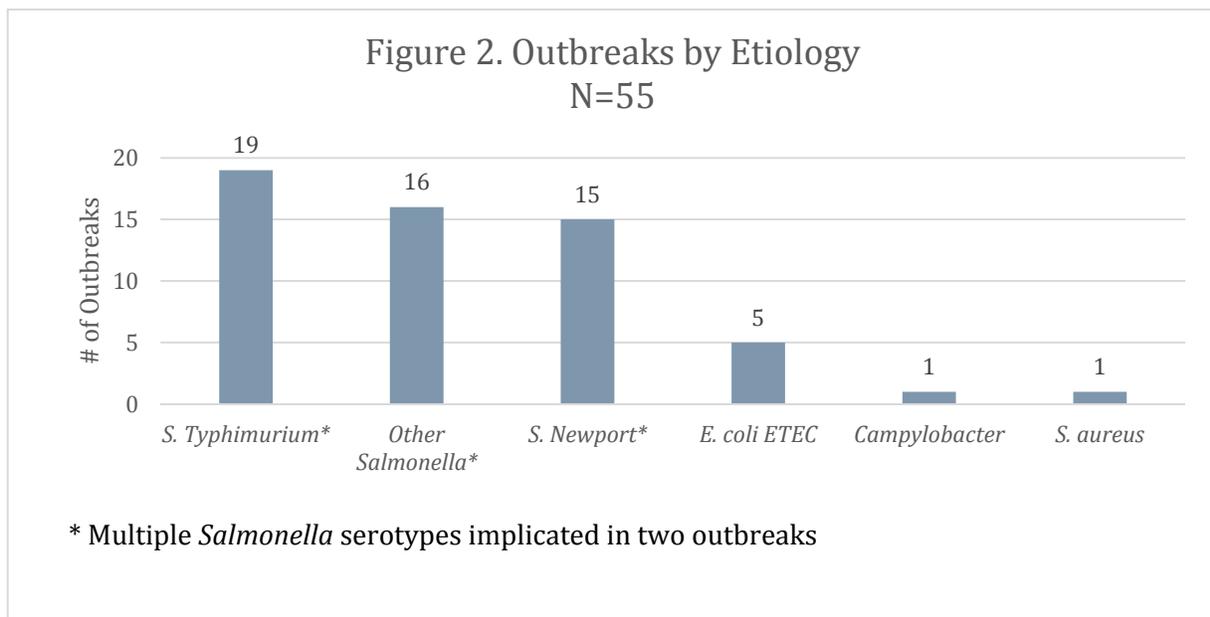


The 55 reported outbreaks sickened 20,601 individuals, of whom 3,166 required hospitalization and 27 died. Two-thirds (67%) of the deaths were due to a huge milk-associated outbreak in 1985 that killed 18 and sickened 16,659 people. That outbreak was also responsible for 88% (2,777) of all reported hospitalizations.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

The most common cause of outbreaks was *Salmonella* spp., identified in 48 of the 55 outbreaks (see Figure 2). *Salmonella* Typhimurium was the most frequently identified serotype, associated with 19 outbreaks (35% of total outbreaks). *S. Typhimurium*-associated outbreaks caused 17,979 illnesses and included the large milk-associated outbreak in 1985. The second most frequently identified serotype was *Salmonella* Newport, implicated in 15 outbreaks with 872 linked cases. Additional *Salmonella* serotypes were implicated in sixteen outbreaks, and two outbreaks were caused by multiple *Salmonella* serotypes. Of those sixteen, *Salmonella* Heidelberg accounted for four outbreaks, and *Salmonella* Hadar was implicated in two outbreaks. By etiology, the median number of outbreaks is 10.

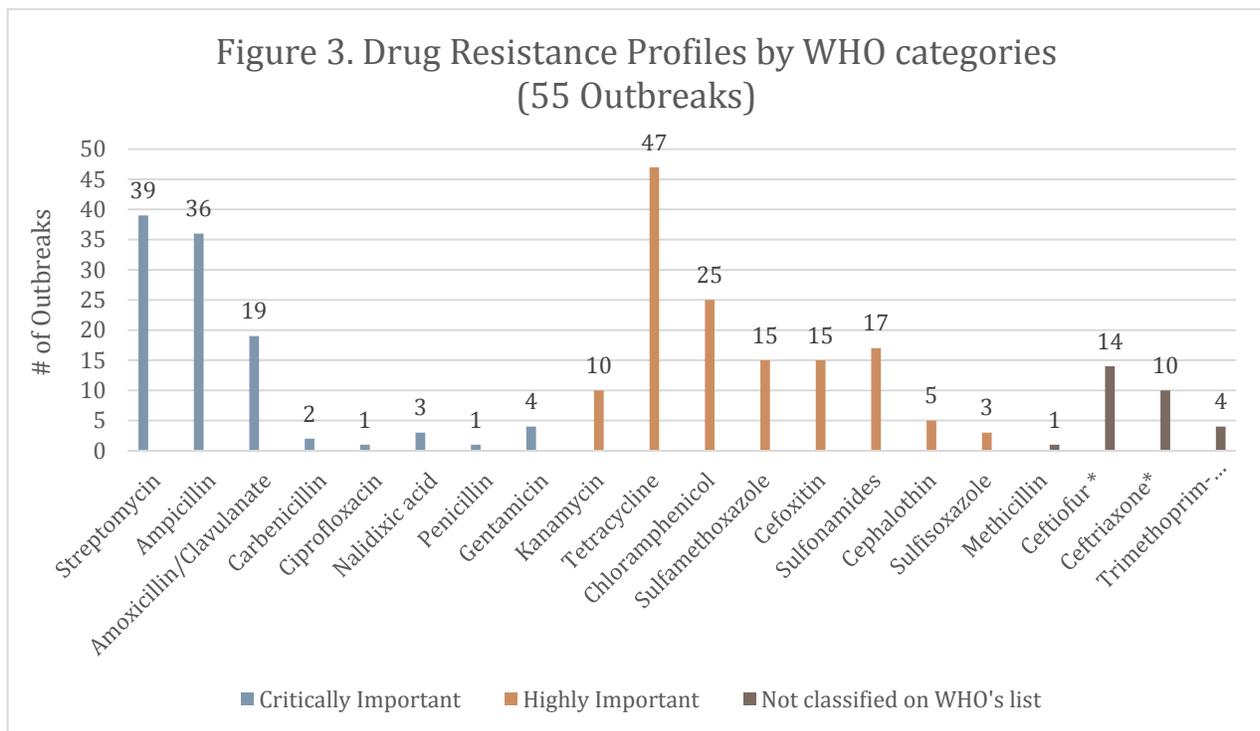
Among other resistant pathogens that caused outbreaks, enterotoxigenic *Escherichia coli* (ETEC) caused five outbreaks, with 446 illnesses. *Campylobacter jejuni* and *Staphylococcus aureus* were each implicated in one outbreak.



Drug-resistance patterns show that the majority of outbreaks (39 of 55, 70%) were resistant to at least one antibiotic, streptomycin (Figure 3). Streptomycin is an aminoglycoside classified by the World Health Organization (WHO) as “critically important” and by the Food and Drug Administration (FDA) (Guidance for Industry 152) as “highly important” for treatment in human medicine. (See page 11 for further

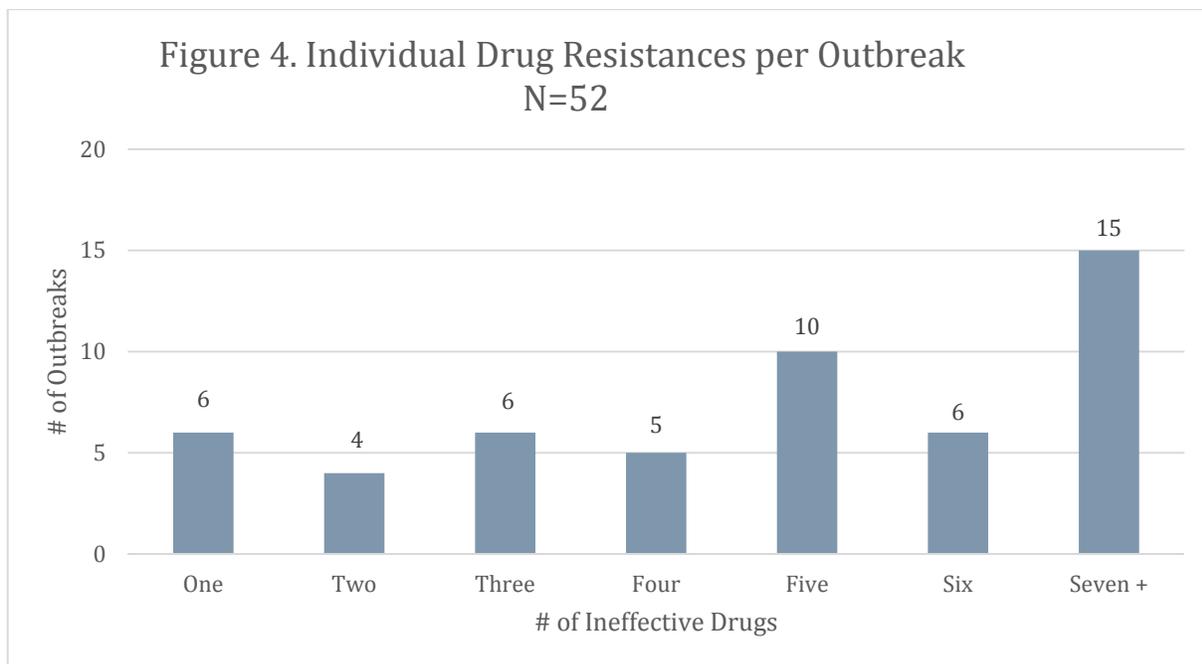
ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

discussion of the WHO and FDA categories.) Resistance to tetracycline, a commonly used antibiotic in food animal production, deemed to be highly important in human medicine by the FDA and the WHO, was detected in 47 of 55 outbreaks (85%). Cephalosporin antibiotic-resistance occurred in 28 outbreaks, and resistance to cephamycin, an antibiotic similar to cephalosporin, occurred in 15 outbreaks.



Thirty-one (56%) outbreaks involved a pathogen with multi-drug resistance to five or more antibiotics (Figure 4). Either reporting of antibiotic-resistant outbreaks is improving, or there could be an appreciable increase in outbreaks resulting from resistant bacteria, as two-thirds of those outbreaks occurred in the last two decades. An outbreak associated with eggs in 1973 had an unknown antibiotic-resistance profile, as did two outbreaks from raw milk, one in 1979, and the other in 1980. Thus, the total number of outbreaks with resistance profiles is 52, not 55.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS



Meat and poultry products were identified in 18 outbreaks: 10 in ground beef, 7 in poultry, and 1 in pork. Ground beef contaminated with *Salmonella* Newport caused seven outbreaks, and the other three were *Salmonella* Typhimurium-associated. Six of the poultry outbreaks were linked to *Salmonella* spp. contamination, and one was associated with *E. coli* O27:H7. Meat and poultry outbreaks caused 1,639 cases of illness, with 191 hospitalizations, and eight deaths.

There were 14 outbreaks associated with dairy: 8 were associated with milk products, and 6 were associated with cheeses. In 11 of the 14 outbreaks (79%), the implicated food item was described as being raw / unpasteurized milk or cheese. Pasteurized milk caused three outbreaks, including the large outbreak in 1985. All of the dairy-associated outbreaks identified *Salmonella* spp. as the etiologic agent – ten associated with *S. Typhimurium*, three with *S. Newport* (including one also linked to *S. Meleagridis*), and one with *S. Dublin*. Overall, dairy outbreaks were responsible for 17,257 illnesses, 2,871 hospitalizations, and 19 deaths.

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 were deadly before antibiotics became available are now readily treatable. 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 that antibiotics are used, the more bacteria will develop resistance. In recent years, scientists have begun to understand at the molecular level the sophisticated mechanisms that enable 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 (Levy et al., 1976; Smith et al., 1999). 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 resistant pathogens include more serious infections and increased frequency of treatment failures. Patients may experience prolonged

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.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

duration of illness, increased frequency of bloodstream infections, greater likelihood of hospitalization, and increased mortality (Angulo et al., 2004).

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 document the problem of antibiotic-resistant foodborne pathogens, but any 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. The main obstacle for researchers working to identify solutions to antimicrobial resistance is a lack of data – especially data on drug use. More robust data is needed on the types and quantities of antibiotics sold for use in food-producing animals, the species in which they are used, when they are administered, the purpose of their use (disease treatment, disease prevention, or growth promotion), and the method used to administer them. Denmark, for example, collects data on antibiotic use from drug companies, veterinary pharmacies, feed mills, private companies, and veterinarians. Reporting includes species-specific drug administration data, the age at which animals are given drugs, the diseases being treated, and dosage. Such data have allowed Danish researchers to determine how changes in the use of antibiotics in animals affect the emergence of antibiotic-resistant bacteria (DANMAP, 2011). Information like those is not collected in the United States.

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 one bacterium resistant can even be shared by different species through horizontal gene transfer. Widespread use of antibiotics in agriculture increases the likelihood that they will become 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 from a human health perspective was devised for use by governments and other

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

stakeholders when they develop risk-management strategies concerning the use of antimicrobials in food animals.

The WHO divides antimicrobials into three categories based on their overall importance to human health: critically important, highly important, and important (WHO, 2011).

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 just one of those criteria are ranked as highly important, while antimicrobials that meet neither criterion are ranked as important.

In 2003, the FDA also ranked antimicrobial drugs according to their importance in human medicine (FDA, 2003). The FDA rankings are divided into “critically important”, “highly important” and “important”. 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 (FDA 2003, WHO 2011).

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 into lower costs for producers. Many animal producers believe the use of antibiotics for growth promotion also prevents disease (GAO, 2011).

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

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

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.

Beginning in 2008, 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, FDA, 2013). Three years of data show that the aggregate quantity of antibiotics being sold for use in food-producing animal species increased from 28.81 to 29.86 million pounds from 2009 to 2011. Combined totals of drug distribution in human medicine data changed little over that time period from approximately 7.31 to 7.25 million pounds. The data reported to FDA is not broken down by species, route of administration, or purpose of use. Thus, antibiotics sold for use in food animals constitute about 80% of all antibiotics distributed in the United States. Of those antibiotics sold in 2011 (excluding not independently reported or "other" antibiotics and Ionophores), approximately three quarters used in animal agriculture are identical or similar to those used in human medicine (Table 1).

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

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

The use of critically important antimicrobials, such as aminoglycosides, cephalosporins, and macrolides, appears to have decreased from 2009 to 2011 based on distribution and sales data (both animal and human). On the other hand, the use in animals of penicillins, a class that includes critically important antibiotics, appears to have increased from 2009 to 2011. There was also a significant increase in sales and distribution of the highly important class of antibiotics, tetracyclines, in food-producing animals.

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)	2011 Animal Annual Totals(LBS)	WHO Status
Aminoglycosides	748,862	442,675	473,762	Critically / highly
Cephalosporins	91,113	54,207	58,667	Critically / highly
Ionophores	8,246,671	8,424,167	9,090,230	Not ranked
Lincosamides	255,377	340,952	419,101	Important
Macrolides	1,900,352	1,219,661	1,284,933	Critically
Penicillins	1,345,953	1,920,112	1,940,427	Critically / highly
Sulfas	1,141,715	1,116,020	817,959	Highly
Tetracyclines	10,167,481	12,328,521	12,439,744	Highly
Other (Not Independently Reported (NIR))**	4,910,501	3,345,398	3,330,241	
Total	28,808,024	29,191,712	29,855,066	
	2009 Human Annual Total (LBS)	2010 Human Annual Total (LBS)	2011 Human Annual Total (LBS)	WHO Status
Aminoglycosides	20,682	15,413	14,297	Critically / highly
Cephalosporins	1,101,465	1,107,957	1,095,499	Critically / highly
Ionophores	0	0	0	Not ranked
Lincosamides	153,744	152,637	157,531	Important
Macrolides	388,626	362,239	361,620	Critically
Penicillins	3,217,027	3,174,502	3,219,677	Critically / highly
Sulfas	1,039,352	1,057,081	1,061,887	Highly
Tetracyclines	289,108	284,800	250,957	Highly
Other (Not Independently Reported (NIR))**	1,102,567	1,074,121	1,089,921	
Total	7,312,570	7,228,750	7,251,390	

* 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.

ANTIBIOTIC RESISTANCE IN FOODBORNE PATHOGENS

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Appendix. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
1973	ME	S. Typhimurium	Eggs	32	NR	NR	unknown		
1975	MD, FL, CO	S. Newport	Ground beef	27	NR	NR	streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1977	KY	S. Typhimurium	Raw milk	3	NR	NR	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	S. Dublin	Raw milk	39	NR	NR	unknown		
1980	MT	S. Typhimurium	Raw milk		NR	NR	unknown		
1983	AZ	S. Typhimurium	Raw milk	12	NR	1	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1983	MN, SD, NE, IA	S. Newport	Ground beef	18	11	1	ampicillin	penicillin	critically important
							carbenicillin	penicillin	critically important
							tetracycline	tetracycline	highly important
1984	OR	S. Typhimurium	Salad bar	715	45	0	tetracycline	tetracycline	highly important
							streptomycin	aminoglycosides	critically important
1985	CA	S. Newport	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	S. Typhimurium	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	S. Havana	Chicken	73	36	1	tetracycline	tetracycline	highly important
1994	WI	E. coli O153:H45 (ETEC)	Unknown, banquet food	205	NR	NR	ampicillin	penicillin	critically important
							tetracycline	tetracycline	highly important
							sulfisoxazole	sulfonamides	highly important
							streptomycin	aminoglycosides	critically important
1995	AZ	S. Stanley	Alfalfa sprouts	19	5	NR	kanamycin	aminoglycosides	highly important
							tetracycline	tetracycline	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
1996	NE	S. Typhimurium DT104	Unknown, chocolate milk suspected	19	0	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	WA	S. Typhimurium 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

Appendix. Antibiotic-Resistant Foodborne Outbreaks

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	NR	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	CA	S. Typhimurium var Copenhagen DT104b	Mexican-style cheese (raw milk)	31	14	NR	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1997	MD	S. Heidelberg	Pork	706	NR	2	kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							tetracycline	tetracycline	highly important
1997	VT	S. Typhimurium	Raw milk	9	1	NR	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
1998	NY	S. l 4,[5],12:-	Unknown, dinner reception multiple foods suspected	86	31	0	ampicillin	penicillin	critically important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
1998	KS	<i>Campylobacter jejuni</i>	Unknown, gravy, potato, pineapple	128	2	0	ciprofloxacin	fluoroquinolone	critically important
							tetracycline	tetracycline	highly important
2000	TN	<i>Staphylococcus aureus</i> (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)	27	12	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	<i>E. coli</i> O169:H41/ST (ETEC)	Quesadilla, fajitas, nacho chips, beans	21	0	0	tetracycline	tetracycline	highly important

Appendix. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
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
							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> O169:H49 (ETEC)	Catfish, coleslaw	41	2	0	tetracycline	tetracycline	highly important
2003	9 states	<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	*
							amoxicillin/clavulanate	penicillin	critically important
2004	CA	S. Newport	Pasteurized milk	100	5	0	ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
							amoxicillin/clavulanate	penicillin	critically important
2004	IL	S. Newport	Unknown	2	NR	NR	ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
							amoxicillin/clavulanate	penicillin	critically important
2004	MN	S. Agona	Sandwich, turkey	24	6	0	sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2004	NY	S. Istanbul	Chicken	42	14	0	tetracycline	tetracycline	highly important
2005	MN	S. Heidelberg	Chicken	4	1	0	gentamicin	aminoglycosides	critically important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important

Appendix. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
2005	TN	S. Heidelberg	Unknown	19	2	0	gentamicin	aminoglycosides	critically important
							nalidixic acid	quinolone	critically important
							streptomycin	aminoglycosides	critically important
							tetracycline	tetracycline	highly important
2005	IN, MI, MO, OH	S. Braenderup	Tomato	84	8	0	ampicillin	penicillin	critically important
							gentamicin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2005	CO	S. Typhimurium S. Newport	Unknown	100	1	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2005	CO	S. Typhimurium	Sushi	25	0	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							trimethoprim-sulfamethoxazole	sulfonamides	*
							tetracycline	tetracycline	highly important
2006	AR	S. l 4,[5],12:i-	Unknown	14	4	0	nalidixic acid	quinolone	critically important
2006	PA	S. Typhimurium	Queso fresco, unpasteurized; raw milk	20	2	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2006	UT	S. Typhimurium	Root vegetable	3	NR	NR	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
							tetracycline	tetracycline	highly important
2006	PA	S. Schwarzengrund	Unknown	6	0	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
2006	CA	S. Newport	Multiple foods	24	NR	NR	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
tetracycline	tetracycline	highly important							

Appendix. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
2006	IL	S. Newport	Unknown	9	3	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	highly important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
tetracycline	tetracycline	highly important							
2006	IL	S. Newport S. Meleagridis	Mexican-style cheese (cotija), (raw milk)	96	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
2006	TN	S. Hadar	Unknown	9	1	0	streptomycin	aminoglycosides	critically important
							tetracycline	tetracycline	highly important
2007	CA, AZ, ID, NV	S. Newport	Ground beef	43	15	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							cefoxitin	cephamycin	highly important
							ceftiofur	cephalosporin (3G)	*
							ceftriaxone	cephalosporin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfonamide*	sulfonamides	highly important
tetracycline	tetracycline	highly important							
2007	MN	S. Newport	Unknown	11	0	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
streptomycin	aminoglycosides	critically important							
2009	7 states	S. Typhimurium DT104	Ground beef	14	6	0	ampicillin	penicillin	critically important
							chloramphenicol	amphenicol	highly important
							streptomycin	aminoglycosides	critically important
							sulfamethoxazole	sulfonamides	highly important
2009	14 states	S. Newport	Ground beef	68	4	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							

Appendix. Antibiotic-Resistant Foodborne Outbreaks

Year	Location	Bacteria	Food/Source	Cases	Hosp	Death	Resistances	Drug Family	WHO Status
2009	AZ	S. Newport	Ground beef	2	NR	NR	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							
2011	10 states	S. Hadar	Ground turkey (Jennie-O ground turkey burgers)	12	3	0	ampicillin	penicillin penicillin	critically important
							amoxicillin/clavulanate	cephalosporin	critically important
							cephalothin	tetracycline	highly important
							tetracycline		highly important
2011	34 states	S. Heidelberg	Ground turkey (Cargill)	136	37	1	ampicillin	penicillin	critically important
							streptomycin	aminoglycosides	critically important
							tetracycline	tetracycline	highly important
							gentamicin	aminoglycosides	critically important
2011	7 states	S. Typhimurium	Ground beef	20	8	0	amoxicillin/clavulanate	penicillin	critically important
							ampicillin	penicillin	critically important
							ceftriaxone	cephalosporin	critically important
							cefoxitin	cephamycin	highly important
							kanamycin	aminoglycosides	highly important
							streptomycin	aminoglycosides	critically important
							sulfisoxazole	sulfonamides	highly important
							tetracycline	tetracycline	highly important
				<i>NR = Not Reported</i>		<i>* Not on WHO's list of antimicrobials used in human medicine</i>			
		Source: Center for Science in the Public Interest							
Totals				20601	3166	27			