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Use of antimicrobials in swine feeds in the United States

Catherine E. Dewey, DVM, PhD; Barbara D. Cox, MS; Barbara E. Straw, DVM, PhD; Eric J. Bush, DVM, MS; Scott Hurd, DVM, PhD

Summary

Objective: To describe the use of in-feed antimicrobials by stage of production in the United States swine industry.

Methods: National Swine Survey data from 712 farms were collected by the National Animal Health Monitoring System (NAHMS) between 1989 and 1991. Specifically, producers were asked to record over one 7-day interval the number of feeds they used, the phases of production to which those feeds were fed, and which antimicrobials had been added to the feeds. Producers were also asked whether the antimicrobials were used continuously or to treat a specific problem.

Results: Of the 712 farms, 84 (12%) did not use any antimicrobials in feeds. Across all participating farms, 39.5% of feeds contained no antimicrobial. Forty-one percent of the feeds included one or more individual antimicrobials and 19% included combinations of antimicrobials. Creep, starter, and first-stage grower pigs were more likely to be fed antimicrobials than second-stage growers, finishers, or adult swine (P=.02). Most (92.2%) antimicrobials were fed on a continuous basis. The age groups most likely to be fed antimicrobials to treat specific problems were nursery, grower, and finisher pigs. The most commonly used antimicrobials, listed in order of frequency were: tetracyclines, carbadox, bacitracin, tylosin, apramycin, and lincomycin. Carbadox, apramycin, and lincomycin were typically added to creep and starter feeds. Bacitracin and tylosin were most often used in feeds for grower and finisher pigs. Tetracyclines were fed to all ages of pigs but were included more frequently in feeds for immature swine than for mature swine.

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Producers use antimicrobial feed additives either to improve growth rate or to prevent, control, or treat health problems in their pigs.[1,2] When used to treat specific diseases, antimicrobials are either fed for 2–6 weeks or are used in a pulse medication format. However, to enhance the growth of pigs, antimicrobials are used for extended periods of time, often for the entire stage of production. Farms with chronic disease problems will feed antimicrobials during one production phase for extended periods of time to prevent clinical signs of a specific disease. Lincomycin, for example, is labeled for use continuously at 20 g per ton for growth promotion, continuously at 40 g per ton to prevent swine dysentery, for 3 weeks at 100 g per ton to treat clinical swine dysentery, or for 3 weeks at 200 g per ton to treat mycoplasma pneumonia.[3] Although producers are widely assumed to use antimicrobials in some swine feeds, the frequency of use and the production phases during which antimicrobials are most commonly administered is unknown.

The general public is becoming increasingly concerned that antimicrobials fed to swine will result in antibiotic-resistant pathogens and drug residues. Similar studies have been conducted in the dairy[5] and beef[6] industries in the United States and in the Canadian swine industry.[1] We encourage producers and veterinarians to use antimicrobial feed additives in a responsible manner.[5,7–9]

Antimicrobials added to swine feeds should be continually monitored and re-evaluated on a farm-by-farm basis to determine whether

- the product is still effective against the organism of concern,
- the benefits of the product compensate for the cost of the product, and
- antibiotic resistance has developed, leading to reduced efficiency.[2,4]

The purposes of this study were to identify which antimicrobials are commonly used in United States swine feeds, to determine whether there is a difference in antimicrobial use by production phase, and to describe producers' reasons for including the antibiotics or sulfonamides in swine feeds.

Materials and methods

Source of the data

Swine producers voluntarily participated in the United States Department of Agriculture: Animal and Plant Health Inspection Systems: National Animal Health Monitoring System (USDA:APHIS:NAHMS) National Swine Survey after their herds were randomly selected using the multiple-frame sampling technique of the National Agricultural

CED: Department of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada N1G 2W1, Email: cdewey@ovcnet.uoguelph.ca; BES: Michigan State University; EJB, SH: USDA APHIS; BDC:University of Nebraska

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Table 1

Type and prevalence of antimicrobials fed to each production phase during a 1-week observation period

Production phase	Total pigs	Total feeds	Feeds with no antimicrobials	Feeds with continuous antimicrobials	Feeds with treatment antimicrobials
Creep	24,550	542	24%[a]	74%[a]	2%[a]
Starter	134,692	1001	19%[b]	77%[a]	4%[bd]
Grower 1	158,865	778	27%[a]	67%[b]	6%[bc]
Grower 2	238,297	738	35%[c]	59%[c]	6%[c]
Finisher	196,690	607	38%[c]	55%[c]	7%[c]
Lactation	11,172	740	55%[d]	44%[d]	3%[ad]
Gestation	106,461	849	77%[e]	20%[e]	3%[ad]
Boar	5762	588	79%[e]	17%[e]	3%[ad]
Cull	4575	213	75%[e]	21%[e]	3%[abc]
Other	NA	67	55%[d]	44%[cd]	0%[abc]
Total	881,064	6123	45%	51%	4%

a–e Different superscripts indicate a different within-column prevalence of antimicrobial use, $P<.02$
Lactation, Boar, Cull, and Other phases do not total 100% owing to rounding errors.

Statistics Service.[10,11] A detailed description of the sample population and selection process has been previously described.[10,11] Although the study lasted 1 year, individual producers were monitored for only 3 months and feed data were collected for only 1 week. Hence, the data included in the survey represent one time point for each producer.

Producers completed a feed data sheet for each diet used on the farm.[12] Data sheets included information on the amount of the diet fed to each group of animals. The producer recorded either the brand name or the generic equivalents of antimicrobials added to the ration.

Feed diaries were kept for each feed used on the farm for 7 consecutive days.[12] Producers recorded the production phase, the lb of feed used, the specific ration fed to those pigs, and whether the purpose of the antimicrobial was continuous use or to treat a specific problem. The production phases were taxonomized as follows:

- nursing piglets fed creep feed,
- nursery pigs (weaned to 39 lb) fed starter ration,
- grower 1 (40–99 lb),
- grower 2 (100–179 lb),
- finishing pigs (180+ lb),
- lactating sows,
- gestating sows and gilts,
- boars, and
- breeding herd culls.[12]

Producers recorded the total number of pigs on the farm by production phase. Detailed descriptions of the producer questionnaires and the diary cards have been previously described.[12]

The antimicrobial use was measured as its inclusion in feed offered to one production phase. If the same antimicrobial was fed during two production phases on the same farm, it was listed as two uses. The use of antimicrobials was also described in terms of numbers of animals fed per production phase.

Statistical analysis

The rates of antimicrobial use among different production phases and reasons for use were compared using a Cochran-Mantel-Haenszel χ^2 test.[13] Descriptive statistics and statistical tests were performed using the Statistical Analysis System for Personal Computers (PC/SAS).[14]

Results

A total of 1661 producers agreed to participate in the USDA-APHIS NAHMS National Swine Survey; however, only 712 producers completed the entire survey.[10,11] Of these, 12% of the farms did not use antimicrobials in any feeds. A total of 6123 different feeds were reported to be in use on the 712 farms included in the survey. Some feeds were fed to pigs in more than one production phase. Of the total of 6123 feeds, 45% did not contain an antimicrobial (Table 1), 35% included one antimicrobial, and 20% contained more than one antimicrobial.

Antimicrobials were more frequently used on a continuous basis (51%) than for treatment purposes (4%) (Table 1). Older animals were less likely to be fed antimicrobials than young animals. Antimicrobials were most prevalent in creep and starter feeds, followed by first-stage growers, then second-stage growers and finishers, then lactation, and finally other adult animals (P=.02) (Table 1). The use of feeds with antimicrobials was lower in adult animals (21%–45% of feeds) than in either finisher pigs (62%) or young growing animals (65%–81%) (P =.02) (Table 1).

Of the feeds with multiple antimicrobials, 74.4% contained registered combinations (Tables 2 and 3). The most common combination products were:

- chlortetracycline/sulfathiazole/penicillin (fed to 7% [61,716] of

Table 2

Combinations of antimicrobials fed to immature swine during a 1-week observation period

		Creep		Starter		Grower 1	Grower 2		Finisher	
Combination	Use	%	#	%	#	%	%	#	%	#
chlortetracycline/ sulfathiazole/ penicillin	C	4	2819	8	24,536	6	13	36,999	0.6	1385
	T	0.3	420	0.9	760	0.9	5	1529	0.5	97
tylosin/ sulfamethazine	C	1	416	1	4133	2	6	11,366	0.3	105
	T	0	-	0.2	1902	0	1	414	0.2	32
chlortetracycline/ sulfamethazine/ penicillin	C	6	6239	6	23,674	4	13	26,898	0.3	179
	T	0	-	0.2	222	0.1	3	256	0.3	250
furazolidone/ oxytetracycline/ arsanilic acid	C	8	5918	8	28,631	5	12	29,018	0.8	1069
	T	1	47	0.6	3293	0.5	1	3680	0	-
oxytetracycline/ neomycin	C	5	4811	4	16,477	1.5	6	6601	1	1656
	T	0	-	0.2	1402	0.2	1	832	0.3	350
penicillin/ streptomycin	C	0	-	0.3	1011	0.6	3	3063	0.5	610
	T	0	-	0	-	0.1	1	1300	0.2	300
carbadox/ pyrantel tartrate	C	0	-	0.4	64	0	0	-	0	-
	T	0	-	0.1	95	0	0	-	0	-
furazolidone/ oxytetracycline	C	0	-	0	-	0	0	-	0	-
	T	0.2	28	0.1	195	0	0	-	0	-

C= continuous use; T=treatment use
%= percent of feeds; #= number of pigs

Table 3

Combinations of antimicrobials fed to mature swine during a 1-week observation period

		Lactation		Gestation		Boar		Cull	
Combination	Use	%	#	%	#	%	#	%	#
chlortetracycline/ sulfathiazole/ penicillin	C	2	505	0.7	1126	0.5	50	0	-
	T	0.5	12	0.4	154	0.5	8	0	-
tylosin/ sulfamethazine	C	0.3	87	0.1	433	0	-	0	-
	T	0	-	0	-	0	-	0	-
chlortetracycline/ sulfamethazine/ penicillin	C	2	275	0.6	1104	0.5	24	0.9	17
	T	0.1	3	0.1	17	0.2	1	0.5	3
furazolidone/ oxytetracycline/ arsanilic acid	C	6	817	2	1949	0.9	53	0.5*	0
	T	0.4	47	0.5	772	0.2	2	0.5*	0
oxytetracycline/ neomycin	C	7	1043	2	2825	0.5	22	1	13
	T	0.4	6	0.2	359	0.3	27	0	-
penicillin/ streptomycin	C	0.4	40	0.2	146	0	-	0	-
	T	0.1	78	0	-	0	-	0	-
furazolidone/ oxytetracycline	C	0.7	78	0.2	193	0	-	0	-
	T	0	-	0	-	0	-	0	-

C= continuous use; T=treatment use
%= percent of feeds; #= number of pigs
* One farm regularly uses this combination in this stage but had no pigs at this stage when the inventory was taken

pigs);

- chlortetracycline/sulfamethazine/penicillin (fed to 6.7% [59,162] pigs); and
- furazolidone/oxytetracycline/arsanilic acid (fed to 8.5% [75,296] pigs).

The most commonly used antimicrobials were tetracyclines, carbadox, bacitracin, tylosin, apramycin, and lincomycin (Tables 2–4).

The distribution of antimicrobials differed by production phase ($P<.05$) (Table 4). Carbadox, apramycin, and lincomycin were typically added to creep and starter feeds (4%–20% of feeds contained these antimicrobials). Bacitracin and tylosin were used in 8%–22% of feeds for grower and finisher pigs. Tetracyclines were fed to all

Table 4

Percent of feeds containing specific antimicrobials by production phase in 712 swine units

Stage	Tetracycline	Carbadox	Bacitracin	Apramycin	Tylosin	Lincomycin
Creep	32 [a]	18 [a]	0 [a]	20 [a]	2 [ac]	4 [a]
Starter	38 [a]	23 [b]	0.5 [b]	11 [b]	3 [a]	6 [a]
Grower 1	64 [b]	0.9 [c]	8 [c]	0.5 [c]	9 [b]	2 [b]
Grower 2	35 [c]	7 [d]	20 [d]	0.1 [c]	10 [b]	1 [b]
Finisher	30 [c]	0 [ef]	22 [d]	0.2 [c]	10 [b]	1 [bd]
Lactation	33 [c]	0.7 [d]	2	0.1 [c]	1 [cd]	0.1 [c]
Gestation	18 [d]	0.3 [df]	0.8	0.2 [c]	0.7 [d]	0.1 [c]
Boar	16 [d]	0.2 [df]	1	0.3 [c]	0.9 [cd]	0.2 [cd]
Cull	4 [d]	0 [df]	16 [bc]	0 [c]	4 [cd]	2 [bc]

a–f Different superscripts indicate a different within-column feed additive inclusion rate, $P<.02$

Table 5

Number of pigs fed specific antimicrobials on a continuous basis in 712 production units

Feed additive	Creep	Starter	Grower	Finisher	Lactation	Gestation	Boar	Cull
amprolium	-	-	-	-	21	-	-	-
apramycin	20,776	36,495	1093	302	120	705	44	-
arsanilic acid	0	444	1129	0	-	804	38	-
bacitracin	-	669	144,722	30,708	345	837	33	69
bambermycin	-	-	220	100	-	-	-	-
carbadox	16,931	76,650	119,136	-	109	271	5	-
chlortetracyline	4948	34,077	127,856	21,434	3060	15,430	722	107
decoquinate	-	-	-	-	131	311	-	-
furazolidone	620	2659	1885	188	1399	1782	33	-
hygromycin B	-	-	1832	-	-	-	-	-
lincomycin	2513	53,040	3992	1854	14	30	2	20
monensin	-	-	-	-	30	-	-	-
neomycin	2142	3409	8801	72	189	1,504	4	-
oxytetracycline	2099	8839	15,982	1512	178	825	8	-
penicillin	57	1042	3610	310	114	130	14	-
pyrantel pamoate	-	135	-	-	-	-	-	-
pyrantel tartrate	677	3750	5917	-	62	42	3	-
roxarsone	-	-	-	-	-	424	21	-
sulfamethazine	-	979	895	-	106	-	-	-
tetracycline	809	5083	18,499	27,673	217	605	43	7
tiamulin	1150	2160	3515	711	-	-	-	-
tylosin	221	3135	57,255	12,599	57	612	26	4
virginiamycin	-	-	14,467	5879	166	-	-	-

production phases but the prevalence of feeds containing tetracyclines was higher for immature swine than for mature swine.

Sulfonamides were used in 7.7% of feeds and fed to 3819 animals (Tables 2, 5, and 6). Two percent of finisher diets, fed to 2048 animals, contained sulfonamide products. Sulfonamides were also fed to 988 lactating sows. These numbers represented 1% of the finisher pigs and 9% of the lactating sows in our study.

Discussion

The results of this study pertain specifically to this sample of farms. Although a random sample of farms was selected, the results may be biased because the participants were volunteers and only 43% of the cooperators completed the study. Because the data were collected at one point in time, the frequency of antimicrobial use may be underestimated; only antimicrobials used during one 7-day period were recorded.

Table 6

Number of pigs fed specific antimicrobials to treat specific problems in 712 production units

Feed additive	Creep	Starter	Grower	Finisher	Lactation	Gestation	Boar	Cull
apramycin	797	1112	-	-	-	-	-	-
bacitracin	-	-	3689	3337	-	-	-	-
bambermycin	-	67	-	-	-	-	-	-
carbadox	-	1070	5751	-	-	-	-	-
chlortetracyline	-	2784	33,319	8278	192	2303	149	69
furazolidone	-	216	466	-	63	-	-	-
lincomycin	610	1100	780	-	-	-	-	-
neomycin	-	315	556	-	-	-	-	-
oxytetracycline	-	-	-	60	40	-	-	-
penicillin	-	-	-	-	-	492	30	2
tetracycline	-	400	940	50	-	-	-	-
tiamulin	-	-	932	693	-	-	-	-
tylosin	-	-	3137	730	20	249	9	-
virginiamycin	-	-	650	300	-	-	-	-

Our finding that feeds containing antimicrobials were frequently included in the feed of younger animals is consistent with that of a survey of Ontario swine farms, which found that 94% of starter feeds contained antimicrobials.[1] The relationship between antimicrobial use and the age of the animal is to be expected, because the greatest antimicrobially induced improvement in growth will be seen in the young animal during the starter and first-stage grower phase and is less pronounced during the finisher stage.[2,15]

Unlike our study, in which producers were asked to indicate whether antimicrobial use was continuous or to treat a specific problem, the Ontario study asked producers to categorize their reasons for including antimicrobials in grower feeds as follows:

- promoting growth (37%),
- preventing disease (36%),
- controlling disease (30%), and
- treating disease (36%).[1]

The classification of continuous versus treatment use of antimicrobials in our survey may have resulted in some subjective evaluation by the producer. These terms are not necessarily exclusive because producers could use antimicrobials on a continuous basis to fight a specific disease. However, we feel the distinction is important because it shows that a high percentage of feeds contained antimicrobials on a continuous basis.

Antimicrobials may be added to swine feeds at therapeutic levels for 2–6 weeks to treat or prevent specific diseases. Some producers with chronic disease problems in their herds may choose to use antimicrobials for extended periods of time in one production phase to prevent clinical signs of a specific disease.[1] The cost efficiency of an antimicrobial and the clinical diseases on a given swine unit should influence the decision to use antibiotics in the feed.

Perhaps of most interest is the type of antimicrobial used in swine feeds. Because producers probably rotate the use of antimicrobials in swine feeds,[1] the distribution we found of antimicrobials used by producers may vary over time. The distribution of antimicrobials is driven by the recommended use of the feed additive, the age restrictions imposed on antimicrobial use, and the withdrawal times.

Public awareness of antimicrobial use in livestock feed is increasing due to concerns over antibiotic-resistant pathogens and drug residues. One hypothesis is that there is an exchange of plasmids from antibiotic resistant bacteria in swine to human pathogens, making the human pathogens antibiotic resistant.[16–19] Although case studies have linked human outbreaks of salmonellosis to antibiotic use in cattle,[20] there is no scientific evidence that antibiotic use in animal feeds is associated with antibiotic resistance in human pathogens.[17,21] Antibiotic resistance patterns are not lower in vegetarians than in nonvegetarians,[21] and there is no association between the antibiotic resistance patterns in people working in poultry plants and the antibiotic resistance patterns of the poultry.[19] In fact, antibiotic therapy administered to people is directly related to antibiotic-resistant bacteria in those people.[19,21] Therefore, we conclude that continuous use of antimicrobials in swine does not pose a human health risk. However, our finding that 25% of feeds contained more than one antimicrobial agent suggests that resistant bacteria will develop within those swine units.

Restricting the use of antimicrobials in feeds will increase the morbidity and mortality rates,[22] increase the cost of pork production, and decrease feed efficiency.[18] Because of the benefits of using antimicrobials in pork production, veterinarians must work with producers to use these products in an educated manner. The decision to include antimicrobials in swine feeds must include an evaluation of the risk of residues in pork. Veterinarians and producers must be cognizant of drug withdrawal times for market animals.[7] The United States Department of Agriculture Food Safety and Inspection Service (USDA:FSIS) tests market animals for violative tissue residues for specific antibiotics and

sulfonamides.[23,24] In 1993, antimicrobials in the feed accounted for 18% of the violations in all species. In that same year, 276 market hogs, four sows, and seven boars were identified with residues.[24,25] Antibiotics were found in 0.15% of carcasses, and sulfonamides were found in 0.8% of carcasses.[26] The primary causes of residues were failure to adhere to withdrawal times and failure to keep proper identification and treatment records. While the total number of violations has decreased annually since 1990, we must aim to have no violations.

It is notable that residues were found in 11 adult animals.[24] Although these numbers are small, we must be aware of withdrawal times for breeding animals. Often sows are sold immediately after weaning their litters; hence, they are the most likely adult animal to become part of the food chain.[22] Farms that keep sows for a while after weaning prior to culling rarely have a specific cull-sow feed. Only four farms included in our survey used a specific feed for culled sows. Adult swine require antimicrobials in the feed to treat or control disease. Although antibiotics have been used to improve reproductive performance, this practice is not cost effective.

Sulfonamides are of particular concern because animals fed even very low concentrations (2 ppm) within 15 days of market will have violative tissue residues.[17,25] Also, these compounds adhere to feed mills, so there can be a carry over to the next feed produced. One positive finding in this study is that only 7.7% of the feeds contained sulfonamides; unfortunately, they were fed to 1% of the finisher pigs in the study.

The use of carbadox in starter feeds reported in this survey was similar to the findings of the Ontario survey, where 34% of starter feeds contained this antimicrobial.[1] In Ontario, 19% of the grower-finisher feeds contained tylosin and 8% contained tetracyclines.[1]

Antimicrobial use has changed over time. The Pork Quality Assurance (PQA) program was established by the National Pork Producers Council (NPPC) to educate producers about the most appropriate way to use antimicrobial feed additives to avoid residues.[7,22] The program recommends:

- an annual review of all feed additive use by the producer and the veterinarian,
- education of all personnel working with the pigs regarding the appropriate use of each feed additive and steps to take to avoid residues,
- use of proper feed mixing protocols, and
- keeping records of which animals were treated.

The data for this study were collected from 1989 to 1991, when the PQA program was beginning. By the end of 1991, there were only 193 pork producers certified at Level III of the PQA program.[27] At the end of 1994, there were 11,562 producers certified at Level III. The frequency of labeled use of feed additives in the United States swine industry will probably increase because of the educational efforts of the veterinarians and producers through the PQA program.[28] However, a second survey will be needed to confirm this trend.

Implications

- Use of antimicrobials in the United States swine industry is widespread.
- Antimicrobials are most commonly used in young growing swine where there is the most benefit in added growth potential and also the smallest risk of residues.
- The most commonly used antibiotics are tetracyclines, carbadox, and bacitracin.
- Most antimicrobials are used on a continuous basis, so there is a need to continually reassess the cost effectiveness of the products being used.

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