FOODBORNE PATHOGENS AND DISEASE
Volume 9, Number 3, 2012

DOI: 10.1089/fpd.2011.0983

Original Article

Use Estimates of In-Feed Antimicrobials in Swine Production in the United States

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Abstract

When considering the development of antimicrobial resistance in food animals, comparing gross use estimates of different antimicrobials is of little value due to differences in potencies, duration of activity, relative effect on target and commensal bacteria, and mechanisms of resistance. However, it may be valuable to understand quantities of different antimicrobials used in different ages of swine and for what applications. Therefore, the objective of this project was to construct an estimate of antimicrobial use through the feed in swine production in the United States. Estimates were based on data from the National Animal Health Monitoring System (NAHMS) Swine 2006 Study and from a 2009 survey of swine-exclusive practitioners. Inputs consisted of number of pigs in a production phase, feed intake per day, dose of the antimicrobial in the feed, and duration of administration. Calculations were performed for a total of 102 combinations of antimicrobials ($n=17$), production phases ($n=2$), and reasons for use ($n=3$). Calculations were first conducted on farm-level data, and then extrapolated to the U.S. swine population. Among the nursery phase estimates, chlortetracycline had the largest estimate of use, followed by oxytetracycline and tilmicosin. In the grower/finisher phase, chlortetracycline also had the largest use estimate, followed by tylosin and oxytetracycline. As an annual industry estimate for all phases, chlortetracycline had the highest estimated use at 533,973 kg. The second and third highest estimates were tylosin and oxytetracycline with estimated annual uses of 165,803 kg and 154,956 kg, respectively. The estimates presented here were constructed to accurately reflect available data related to production practices, and to provide an example of a scientific approach to estimating use of compounds in production animals.

Introduction

Recent emphasis on antimicrobial use in livestock by legislative bodies, regulatory agencies, and the press has been fueled by estimates of antimicrobial use in food animals and in people. When considering the development of antimicrobial resistance in food animals, comparing gross use estimates of different antimicrobials is of little value due to differences in potencies, duration of activity, relative effect on target and commensal bacteria, and mechanisms of resistance. However, estimates may be valuable in understanding quantities of specific antimicrobials used in different ages of swine and for what applications. Other estimates related to the United States either do not contain specific information as to individual drugs and use categories (FDA, 2009) or are based on aggregated numbers as opposed to starting with farm level information (UCS, 2001). The objective of this project was to utilize data collected in two surveys to estimate antimicrobial use through the feed in swine production.

Methods

Input data obtained from the NAHMS Swine 2006 Study included the number of farms, number of pigs on the farms, reason for use, and the duration of this use. These data were combined with data collected from a survey of swine-exclusive veterinary practitioners detailing dose and age of grower/finisher pigs when receiving antimicrobials in feed.

Definitions

Production phase. The nursery phase of production starts when pigs are weaned and placed in a nursery. The pigs are later moved to another facility and enter the grower/finisher

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phase, where they continue to grow and then are finished for slaughter.

Production cycle. The production cycle consists of one cycle, or "turn" from weaning to slaughter, including both the nursery and grower/finisher phases.

Group. A group of pigs consists of the pigs entering and leaving the production phase at the same time.

NAHMS Swine 2006 Study

The survey methodology for this study has been previously described (USDA, 2006b). Briefly, questionnaire data were obtained on operations with 100 or more hogs in the top 17 swine States. These 17 states accounted for 93.6% of the U.S. swine inventory for operations with more than 100 hogs, and 94.2% of U.S. operations with more than 100 hogs.

A stratified random sample of 5,006 operations with 100 or more swine on June 1, 2006 was selected from the National Agricultural Statistics Service (NASS) list frame. Stratified sampling was based on state and herd size. A total of 2,230 producers completed the NASS general swine farm questionnaire administered by NASS enumerators between July 17 and September 15, 2006. NASS enumerators asked respondents permission for Veterinary Medical Officers (VMOs) to contact the producer and discuss additional periods of data collection. In the first of two farm visits, the Initial Veterinary Services Visit Questionnaire was administered between September 5, 2006 and March 15, 2007 to 514 producers. Antimicrobial use data from the 514 producers were extrapolated to represent the population of almost 57 million swine in inventory on approximately 24,398 production sites.

Veterinary practitioner data

Thirty members of the American Association of Swine Veterinarians (AASV) were identified to participate in an antimicrobial use survey; 27 agreed to participate. The swine practitioners were selected from multiple states in rough proportion to the allocation of swine producers randomly selected in the NAHMS Swine 2006 Study. Along with their practice partners, these veterinarians provided veterinary services to a total of 48,791,569 market hogs at the time of the survey. This equates to 81% of the June 2009 NASS estimate of 60,292,000 market hogs in inventory.

The survey was designed to capture feed grade antimicrobial use from weaning to market and had similarities to the NAHMS Swine 2006 Study in wording of questions. Responses were broken down by size of production site. In contrast to the NAHMS Swine 2006 Study, these questions were in relation to general practices for three size categories, and were not in specific reference to individual production units within their practice. Each veterinarian categorized feed grade antimicrobial use during the production phase by reason, dose, days included in the feed, and starting age. An internal validation test resulted in one survey being excluded, resulting in 26 surveys being used to impute missing data in the NAHMS Swine 2006 Study. Data from both surveys were entered by NAHMS staff using SAS software for data entry, validation, editing, and subsequent analysis (SAS, 2008).

Computational model

The model for these estimates is based on the computational model used in the Union of Concerned Scientists (UCS) "Hogging It!" report (UCS, 2001). The equation for determining total kilograms of use for an antimicrobial-reason combination was the same as for the UCS report; however, the calculations reported here are based on farm-level data rather than utilizing national-level estimates as in the UCS report.

$$\text{Use} = N \times F \times T \times D$$

where: N = Number of animals in a group for the given phase
F = Estimated feed consumed per day
T = Duration in days that pigs received antimicrobial in feed in the phase
D = Dose of antimicrobials in feed

This equation was applied to a total of 102 combinations of the following parameters:

- Seventeen antimicrobial or antimicrobial combination products
- Three reasons for use (growth promotion, disease prevention, and disease therapy based on producer intent)
- Two production phases (nursery and grower/finisher)

Antimicrobials used

Seventeen antimicrobial or antimicrobial combination products included in the NAHMS 2006 Swine Study and the AASV veterinary practitioner survey represent all feed-grade antimicrobials approved and marketed for use in swine production in the United States as listed in Tables 1 and 2. The survey respondent was asked to supply usage data for each of the antimicrobial or antimicrobial combination products. The feed additives were listed alphabetically in the survey to minimize bias.

Number of animals in a group (N)

The NAHMS Swine 2006 Study captured, at the farm level, the number of animals that entered a phase between December 1, 2005 and May 31, 2006, the average age of pigs entering and leaving each phase, and the number of pigs that died during the 6-month period (USDA, 2006a).

The 6-month pig entry numbers were converted to the number of pigs in individual groups because feed consumption, timing, and duration of antimicrobial use was expressed in days during a defined portion of the cycle. First, the number of groups that entered the production phase during the 6-month period was calculated by dividing the number of days in the phase (age leaving minus age entering) by 181 days and rounding up to the nearest integer. We assumed mortalities occurred half way through the phase, group size was constant, and there was no downtime between groups. Therefore, the number of pigs in a group was calculated as follows: (Number of pigs entering during the 6-month period) – [0.5 × mortalities]) / (Number of groups).

For example, pigs entering the nursery phase at 19.3 days of age and leaving at 65.1 days of age had a nursery phase duration of 45.8 days. Dividing 181 days by 45.8 days equals 3.95, and rounding up yields an estimate of four nursery groups that sequentially entered the nursery phase during the 6-month period. If 4,800 pigs entered the nursery phase during this 6-month period at a site and 160 died, then the

Table 1. Equation Inputs for Estimating Swine Antimicrobial In-Feed Use in the U.S. Nursery Phase for One Group

	Growth Promotion			*Prevention*			*Therapy*		
Drug	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]
Arsanilic acid	—	—	—	—	—	—	—	—	—
Bacitracin	30	26.5	624,651	250[a]	16.9	124,165	—	—	—
Bacitracin zinc	—	—	—	—	—	—	—	—	—
Bambermycins	—	—	—	—	—	—	—	—	—
Carbadox	25	27.5	796,914	50	30.4	1,587,164	50	23.5	1,319,020
Chlortetracycline	250	41.2	1,473,705	400	30.2	1,374,304	400	18.2	1,891,278
CTC/Sulfathiazole/Pen	250	42.2	95,103	250	32.7	490,561	250	10.1	379,900
CTC/Sulfamethazine/Pen	250[c]	32.0	101,669	250	24.3	401,737	250	15.2	106,769
Lincomycin	20[c]	16.1	152,755	100	15.2	333,197	100	24.1	646,562
Neomycin/Oxytetracyline	50[c]	27.3	661,935	150	16.2	88,135	150	23.3	486,912
Oxytetracycline	50[c]	31.0	33,374	450	38.6	214,648	450	16.0	892,744
Roxarsone	34[c]	17.0	78,021	181[c]	14.0	11,924	—	—	—
Tiamulin	35	29.5	174,688	35	27.9	1,024,468	35	27.5	974,660
Tilmicosin	363[c]	54.0	32,293	181	34.6	476,468	363[c]	28.3	639,259
Tylosin	40	33.6	228,737	40	28.2	319,047	100	16.5	706,993
Tylosin/Sulfamethazine	100[c]	28.3	16,479	100[c]	17.4	55,712	100[c]	—	124,090
Virginiamycin	10[c]	42.0	39,700	—	—	—	—	—	—

— No dose value imputed because the antimicrobial was not used by any producers in NAHMS Swine 2006 study (for the given reason).
[a]Weighted national estimate based on NAHMS Swine 20006 data on number of days antimicrobial was included in feed, by reason.
[b]Estimate of pigs receiving that antimicrobial and reason combination in one production cycle.
[c]No dose value from AASV vet survey so the FDA maximum label dose was used.

average number per group would be calculated as (4,800 − [0.5*160])/4, yielding an average group size of 1180 pigs. The same procedure was repeated to calculate the number of animals in the grower/finisher phase.

Estimated feed consumed per day (F)

The basis for feed consumption estimates was the KSU Swine Nutrition Guide (DeRouchey *et al.*, 2007). A constant feed consumption value of 1.5 lbs/pig per day was used for the nursery phase. For the grower/finisher phase, feed consumption was calculated using a linear model based on a starting feed intake of 2.5 lbs/pig per day at an entry age of 65 days and culminating at 7.0 lbs/pig per day at the end of the finishing period at 180 days of age (ADFI = 0.0368 + .039*[days of age]). The feed intake was calculated for each specific antimicrobial-use combination in the grower/finisher phase. The pig age used was the mid-point between the median starting age an antimicrobial was included in the feed and when it was removed from the feed. In some instances, the AASV veterinary practitioner survey indicated that the same antimicrobial-reason combination was started at different ages. In those cases, the oldest starting age was used in the calculation of the median starting age for a given antimicrobial-reason. Adding the duration of use to the starting age gave the pig age when a given antimicrobial was removed from the feed.

Duration that pigs received antimicrobials in feed (T)

Duration of use for each antimicrobial, reason, and production phase combination was taken directly from the reported days in feed from NAHMS Swine 2006 Study sites.

Dose of antimicrobials in feed (D)

When possible, the median dose calculated from the veterinary practitioner survey by reason and production phase was used in the model. The maximum label dose was imputed into the model when fewer than three respondents used the antimicrobial in the feed for a given reason. In cases where a drug had regimens labeled for different categories, the classification was based on intent of use as described in the NAHMS Swine 2006 survey, and the corresponding label regimen was applied.

In the case of tilmicosin, which has a dose range to be prescribed by the veterinarian through a veterinary feed directive, the proportion of selected doses indicated in the veterinary practitioner survey was applied in the equation. For other antimicrobials, if no dose or range of doses was available from the swine veterinary practitioner survey, then the maximum label dose was used in the model. Total doses used for combination products were allocated to the different antimicrobials according to their proportion in the product.

Estimation of total use per year

The total weight of each antimicrobial was calculated for each production phase at each production site based on the reported use characteristics of that particular site. It was assumed that the antimicrobial use pattern on a site applied to 100% of the pigs in the production phase. Based on these values, national estimates were generated by production phase. National estimates for the number of days in the nursery and grower/finisher production phases were used to calculate the length of a production cycle. Age inputs, as a weighted mean of all site sizes, were 19.3 days of age for

TABLE 2. EQUATION INPUTS FOR ESTIMATING SWINE ANTIMICROBIAL IN-FEED USE IN THE U.S. GROWER/FINISHER PHASE FOR ONE GROUP

	Growth promotion				*Prevention*				*Therapy*			
Drug	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]	*Mean feed intake*	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]	*Mean feed intake*	*Dose (g/ton)*	*Average days/cycle*[a]	N[b]	*Mean feed intake*
Arsanilic acid	—	—	—		90	60.0	290,313	5.95	—	—	—	
Bacitracin	30	82.4	5,346,314	4.63	250[c]	31.2	273,740	5.39	250[c]	30.7	566,945	4.73
Bacitracin zinc	50[c]	77.4	171,506	6.29	—	—	—		—	—	—	
Bambermycins	4	111.0	152,519	6.95	—	—	—		—	—	—	
Carbadox	25[c]	21.8	2,186,292	2.93	25	29.2	1,342,193	3.55	50	64.5	559,256	4.24
Chlortetracycline	100	75.5	2,835,774	4.18	400	38.5	3,528,379	3.42	400[c]	26.3	4,921,096	4.41
CTC/Sulfathiazole/Pen	250[c]	60.0	3,900	5.95	250[c]	29.7	417,091	5.36	250[c]	11.0	413,051	4.99
CTC/Sulfamethazine/Pen	250[c]	56.0	52,097	5.87	250[c]	26.1	108,845	5.29	250[c]	7.0	236,559	4.91
Lincomycin	20[c]	12.9	260,261	3.50	40	21.3	1,226,696	3.67	100	25.4	1,226,023	3.89
Neomycin/Oxytetracycline	50[c]	31.9	620,789	5.40	150	13.9	697,785	2.97	150[c]	21.1	1,578,379	5.19
Oxytetracycline	50[c]	70.4	147,033	6.04	400	71.4	134,519	6.06	400	44.4	446,409	5.53
Roxarsone	34[c]	50.0	59,688	3.37	—	—	—	—	181[c]	56.0	111,817	3.48
Tiamulin	35	42.0	241,371	5.60	35	40.2	1,033,993	3.88	35	23.9	1,161,165	2.86
Tilmicosin	—	—	—	—	363[c]	34.0	984,956	3.37	363[c]	17.6	394,398	5.03
Tylosin	20	68.6	3,151,853	4.63	40	48.9	3,370,520	4.83	100	37.7	4,231,465	3.93
Tylosin/Sulfamethazine	100[c]	29.0	168,772	5.34	100[c]	4.3	49,025	4.86	100[c]	32.5	389,256	6.09
Virginiamycin	10	88.3	3,487,944	6.15	100[c]	65.1	1,116,765	4.84	100[c]	30.0	27,235	5.36

— No dose value imputed because the antimicrobial was not used by any producers in NAHMS Swine 2006 study (for the given reason).
[a]Weighted national estimate based on NAHMS Swine 20006 data on number of days antimicrobial was included in feed, by reason.
[b]Estimate of pigs receiving that antimicrobial and reason combination in one production cycle.
[c]No dose value from AASV vet survey so the FDA maximum label dose was used.

entering the nursery, 65.1 days of age for entering grow/finish, and 179.7 days for leaving the grower/finisher unit and going to market. Subtracting the nursery phase entry age from the market age gave an estimate of 160.4 days for a production cycle. This number was then divided into 365 days to calculate the number of production cycles completed per year, assuming no gap between groups of pigs. The rounded result is 2.25 production cycles per year. Extrapolation to yearly usage was accomplished by multiplying the sum of the final drug use estimates for nursery and grower/finisher phases by 2.25.

Results

Model inputs calculated by antimicrobial–reason combinations for nursery and grower finisher applications are reported in Tables 1 and 2, respectively. Blank cells indicate that no use was reported in the NAHMS Swine 2006 Study for this antimicrobial-reason combination in that production phase. Fourteen and 17 of the 17 possible antimicrobial products were reported as used in the nursery and grower/finisher phases, respectively. The average days/phase for each product is a weighted mean based on the NAHMS Swine 2006 data.

Tables 3 and 4 report the use estimates for nursery and grower/finisher phases, respectively. These estimates are for a single production cycle across all U.S. swine production sites. The "Any Reason" column is the sum of use estimates for all reasons for that phase. Among the nursery phase estimates (Table 3), chlortetracycline had the largest production cycle estimate of use at 32,741 kg from all product combinations. Oxytetracycline had the second highest estimate at 8,426 kg from all products, followed by tilmicosin at 6,696 kg.

Chlortetracycline also had the highest estimated production cycle use in the grower/finisher phase at 204,580 kg from all products. The second and third highest use estimates for the grower/finisher phase were for tylosin and oxytetracycline, at 72,119 and 60,444 kg, respectively.

The combined nursery and grower/finisher overall yearly use estimates are reported in Table 5. The antimicrobials are reported by categories as defined in Appendix A of the Food and Drug Administration Center for Veterinary Medicine (FDA/CVM) Guidance Document 152 (FDA/CVM, 2010) There are no antimicrobials labeled for feed use in swine which are designated as "important" in the document, so this designation is not included in the table. The total kilogram estimate for the antimicrobials not listed in Appendix A of Guidance 152 comprises 15.2% of the total use estimate. By not being listed in this Appendix, the FDA did not classify these antimicrobials as being important, highly important, or critically important for human therapy. Antimicrobials classified as highly important in Appendix A of Guidance 152 comprised 66.0% of the total use estimate for 2006, and those classified as critically important were responsible for 18.2% of the total estimate.

Table 3. National Estimate of Total Kilograms of In-Feed Antimicrobials Used for One Swine Nursery Group Production Cycle Across All U.S. Sites Reported by Antimicrobial and Reason

Antimicrobial	*Growth promotion*	*Prevention*	*Therapy*	*Any reason*
Arsanilic acid	0	0	0	0
Bacitracin	225	319	0	544
Bacitracin zinc	0	0	0	0
Bambermycins	0	0	0	0
Carbadox	348	1,423	1,006	2,778
Chlortetracycline (CTC)				
as CTC alone	6,642	13,138	9,398	29,179
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	349	1,464	356	2,169
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	359	930	103	1,393
Lincomycin	37	357	962	1,356
Neomycin				
as Neomycin/Oxytetracycline	492	80	529	1,100
Oxytetracycline (OTC)				
as OTC alone	66	2,796	4,464	7,326
as Neomycin/Oxytetracycline	492	80	529	1,100
Penicillin				
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	175	732	178	1,085
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	179	465	52	696
Roxarsone	34	23	0	56
Sulfamethazine				
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	359	930	103	1,393
as Tylosin/Sulfamethazine	20	36	97	153
Sulfathiazole				
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	349	1,464	356	2,169
Tiamulin	70	824	576	1,470
Tilmicosin	475	2,547	3,674	6,696
Tylosin				
as Tylosin alone	325	253	937	1,515
as Tylosin/Sulfamethazine	20	36	97	153
Virginiamycin	13	0	0	13

Table 4. National Estimate of Total Kilograms of In-Feed Antimicrobials Used for One Swine Grower/Finisher Group Production Cycle Across All U.S. Sites Reported by Antimicrobial and Reason

Antimicrobial	*Growth promotion*	*Prevention*	*Therapy*	*Any reason*
Arsanilic acid	0	4,664	0	4,664
Bacitracin	32,113	4,584	11,073	47,770
Bacitracin zinc	2,153	0	0	2,153
Bambermycins	241	0	0	241
Carbadox	1,335	1,869	4,737	7,942
Chlortetracycline (CTC)				
as CTC alone	30,394	78,451	87,323	196,167
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	70	5,057	1,326	6,452
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	857	698	407	1,961
Lincomycin	122	1,530	8,302	9,953
Neomycin				
as Neomycin/Oxytetracycline	1,316	1,090	6,757	9,164
Oxytetracycline (OTC)				
as Oxytet alone	1,096	11,293	38,891	51,280
as Neomycin/Oxytetracycline	1,316	1,090	6,757	9,164
Penicillin				
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	35	2,529	663	3,226
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	428	349	203	980
Roxarsone	171	0	1,980	2,151
Sulfamethazine				
as Chlortetracycline/Sulfamethazine/Penicillin G (ASP)	857	698	407	1,961
as Tylosin/Sulfamethazine	3,313	30	1,538	4,881
Sulfathiazole				
as Chlortetracycline/Sulfathiazole/Penicillin G (CSP)	70	5,057	1,326	6,452
Tiamulin	993	2,185	1,011	4,189
Tilmicosin	0	18,300	6,453	24,753
Tylosin				
as Tylosin alone	11,071	16,588	39,579	67,238
as Tylosin/Sulfamethazine	3,313	30	1,538	4,881
Virginiamycin	11,591	24,381	219	36,191

Discussion

The NAHMS Swine 2006 study and the AASV veterinary practitioner surveys are cross-sectional surveys. Preventive or therapeutic uses reported in this publication should not be construed as "routine" since the justification for different uses will change over time according to disease pressure. The NAHMS Swine 2006 Study captured antimicrobial use data for a 181-day period. It was assumed that the antimicrobial use patterns are the same for all production groups on a site during the 6-month period. It was also assumed that these use patterns applied to the entire year for estimating the total kilogram of each antimicrobial used in a year.

Estimates provided by producers in the NAHMS Swine 2006 Study are not presented here as being precise measurements of reason for use, but rather as reported intent by the producer which is subject to misclassification and recall bias. This is illustrated by the classification of tilmicosin by some respondents as being used for growth promotion or for treatment. Tilmicosin may only be used in a veterinary-client-patient relationship where a veterinarian provides a Veterinary Feed Directive to authorize the use of the drug. It is labeled "For the control of swine respiratory disease associated with *Actinobacillus pleuropneumoniae* and *Pasteurella multocida*" (Pulmotil 90 Label, 1996). In order for extralabel use to occur, a veterinarian would have to consciously make a decision to provide a legal document authorizing an illegal use. Therefore, it is most likely that the responses indicating the use of tilmicosin for growth promotion or treatment are in error. The misclassification of the use of tilmicosin for growth promotion is the only example of growth promotion misclassification found in the responses. Discrepancies between reported use and label indications were noted for five antimicrobials in Table 1 and for four antimicrobials in Table 2. The proportion of nine out of 10 use misclassifications being between prevention or therapy applications suggests that the producers possibly made a large distinction between growth promotant and disease-related uses, with less clearly defined distinction between the primary reason for disease use being related to prevention or therapy. Preventive uses, indicating labels for prevention and control as used in this estimate, are classified as therapeutic uses by the American Veterinary Medical Association (AVMA, 2011). The Food and Drug Administration Center for Veterinary Medicine "considers uses that are associated with the treatment, control, or prevention for specific diseases, including administration through food and water, to be uses that are necessary for assuring the health of food-producing animals" (FDA, 2010).

The NAHMS Swine 2006 study required producers to report antimicrobial use for the primary reason that an antimicrobial was used and not for all reasons used. This could result in some loss of data regarding amount of feed grade antimicrobial used.

Table 5. National Estimate of Total Kilograms of Swine In-Feed Antimicrobials for All Production Cycles in a Year by Antimicrobial and Reason

	Antimicrobial	*Growth promotion*	*Prevention*	*Therapy*	*Any reason 'yearly basis'*
Antimicrobials **not listed** in FDA/CVM Guidance 152 Appendix A	Arsanilic acid	0	10,494	0	10,494
	Bacitracin	72,760	11,032	24,914	108,707
	Bacitracin zinc	4,844	0	0	4,844
	Bambermycins	543	0	0	543
	Carbadox	3,787	7,409	12,923	24,119
	Roxarsone	461	51	4,456	4,967
	Sulfamethazine[a]				
	as Chlortetracycline/Sulfamethazine/ Penicillin G (ASP)	2,735	3,663	1,148	7,546
	as Tylosin/Sulfamethazine	7,500	149	3,460	11,109
	Sulfathiazole[a]				
	as Chlortetracycline/Sulfathiazole/ Penicillin G (CSP)	942	14,673	3,784	19,398
	Tiamulin	2,393	6,770	3,571	12,734
Antimicrobials or classes **listed as Highly Important** in Guidance 152 Appendix A	Chlortetracycline[b]				
	as Chlortetracycline alone	83,331	206,076	217,622	507,029
	as Chlortetracycline/Sulfathiazole/ Penicillin G (CSP)	942	14,673	3,784	19,398
	as Chlortetracycline/Sulfamethazine/ Penicillin G (ASP)	2,735	3,663	1,148	7,546
	Lincomycin[c]	356	4,246	20,844	25,446
	Neomycin				
	as Neomycin/Oxytetracycline	4,068	2,632	16,394	23,094
	Oxytetracycline[b]				
	as Oxytetracycline alone	2,615	31,699	97,547	131,862
	as Neomycin/Oxytetracycline	4,068	2,632	16,394	23,094
	Penicillin				
	as Chlortetracycline/Sulfathiazole/ Penicillin G (CSP)	471	7,336	1,892	9,699
	as Chlortetracycline/Sulfamethazine/ Penicillin G (ASP)	1,367	1,832	574	3,773
	Virginiamycin[d]	26,108	54,858	493	81,459
Antimicrobials or classes **listed as Critically Important** in Guidance 152	Tilmicosin[e]	1,068	46,906	22,786	70,761
	Tylosin[e]				
	as Tylosin alone	25,641	37,893	91,160	154,694
	as Tylosin/Sulfamethazine	7,500	149	3,460	11,109

[a]Only potentiated sulfonamides are listed in Guidance 152, Appendix A.
[b]The tetracycline class representative in Guidance 152, Appendix A is tetracycline.
[c]The lincosamide class representative listed in Guidance 152, Appendix A is clindamycin.
[d]The streptogramin class representative in Guidance 152, Appendix A is dalfopristin/quinupristin.
[e]The macrolide class representatives listed in Guidance 152, Appendix A are erythromycin, azithromycin, and clarithromycin.
Antimicrobials are grouped according to classification or lack of classification in Appendix A of FDA/CVM guidance 152.

To evaluate the accuracy of the estimates reported here, three companies were approached with the use estimate related to their swine-only feed antimicrobial included in this study. The companies were assured that their specific response would not be paired with their antimicrobial in the publication. Company 1 indicated that the estimate reported here is within ±5% of their actual 2006 sales. Company 2 indicated that the estimate in this report comprised approximately 40% of their actual 2006 sales. Company 3 reported that the estimate in this report was a "reasonable approximation" of their 2006 sales. These responses demonstrate the variability encountered in estimating national antimicrobial use from farm level data. However, these responses also demonstrate that the methods that generated inputs for this model provide reasonable estimates within the context of this variation.

Conclusion

This report of the estimated in-feed antimicrobial use in U.S. swine production (Table 5) presents the overall estimates for each antimicrobial according to classification, or lack of classification, in Appendix A of FDA/CVM Guidance 152. These use categories were determined in relation to importance for human therapeutics and have no correlation with the potential for release of resistant pathogens from swine production or exposure of humans to these pathogens should they be released.

The estimates presented here were constructed to accurately reflect available data related to production practices through the use of farm level usage data, and to provide an example of a scientific approach to estimating use of compounds in production animals.

The authors present these estimates for the purpose of informing discussions related to specific antimicrobial uses in swine. Any use estimate should be used with great caution as a basis for policy formation or legislative actions.

Acknowledgments

We wish to acknowledge support for meeting expenses by the AASV, and also the valuable input of Drs. Steve Dritz, Charles Haley, Hans Rotto, Gene Ver Steeg, and John Waddell.

Disclosure Statement

No competing financial interests exist.

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