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Antibiotic Resistance of Agricultural and Foodborne *Salmonella* Isolates in Canada: 1986-1989

JEAN-YVES D'AOUST*, A. M. SEWELL, E. DALEY, and P. GRECO

Food Directorate, Health Protection Branch, Health and Welfare Canada, Tunney's Pasture, Ottawa, Ontario, Canada K1A 0L2

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ABSTRACT

A total of 689 *Salmonella* cultures isolated during 1986-1989 from Canadian agricultural products and from imported fish, shellfish, and reptiles were examined for resistance to a test panel of 11 antibiotics. The incidence of antibiotic resistance in strains from all sources seemingly increased during the study period, whereas the occurrence of resistance within individual sample categories fluctuated annually. Although poultry figured as a major reservoir of resistant salmonellae (53.4%), red meats and fish/shellfish also yielded substantial numbers of resistant strains. The range of streptomycin (27.1 to 48.7%) and tetracycline (24.3 to 37.8%) resistance among poultry and red meat isolates, and identification of meat isolates carrying chloramphenicol (0.4 to 9.1%) and ampicillin (3.4 to 11.4%) resistance codons was disquieting. Most of the multiply-resistant (≥ 2 antibiotics) strains belonged to somatic serogroups B and C, with poultry occurring as the principal reservoir of multiresistant phenotypes. Of the 27 resistance patterns encountered in this study, all but two contained a resistance determinant for streptomycin and/or tetracycline. These findings underscore a disturbing level of antibiotic resistant *Salmonella* in the food chain, and the need to reassess the alleged benefits of subtherapeutically medicated feeds in current animal husbandry practices.

The widespread occurrence of *Salmonella* spp. in the natural environment coupled with the intense husbandry practices applied to the meat animal industry undoubtedly have contributed to the prevalence of salmonellae in the food chain and to their notoriety as the leading etiological agent in human foodborne diseases (*8,12*). Concerted efforts to control the incidence and spread of these bacterial species on rearing farms and within meat processing operations have met with limited success, as evidenced by the continuing high levels of *Salmonella* in retail meat samples, notably poultry (*8,38*). The administration of subtherapeutic doses of antibiotics to meat animals for prophylaxis or to enhance the rate of feed conversion is practiced worldwide (*18,38*). Such doses of antibacterials are lower than that required for the clinical management of severe infections in farm animals but sufficiently high to repress the growth of sensitive intestinal microflora. This agricultural practice introduces selective pressures that potentiate the emergence and distribution of resistant salmonellae in meats and other food products (*3,8,12,17*). Foods harboring resistant strains present an increased level of human health risk because their systemic spread in the human host could lead to serious complications or to a fatal outcome (*9,19*). Recent findings that human infections with drug-resistant bacteria double the risks of severe disease, hospitalization, and death compared to that attributed to drug-susceptible strains place the issue of antibiotic-resistant *Salmonella* in proper perspective (*16*).

The present study examines the occurrence of antibiotic resistant *Salmonella* spp. in raw and processed foods, animal feeds, and other samples obtained from domestic and imported sources.

MATERIALS AND METHODS

Foods and food isolates

Salmonella cultures were obtained as a result of survey or regulatory activities conducted between 1986-1989 by federal and provincial government agencies in Canada. Although strains isolated between 1986-1988 had been requested, a total of 57 cultures isolated in 1989 were received from collaborators and included in the study. All foods except fish/shellfish and spices originated from Canadian sources (Table 1). The majority of infected reptiles were imported from the United States.

Antibiotic susceptibility testing

The antibiotic resistance profiles of 689 strains of *Salmonella* were determined according to the NCCLS disk diffusion procedure described in the National Committee for Clinical Laboratory Standards (*25*). Bacterial cultures were stored at room temperature in tubes of semisolid agar containing (per liter): meat extract (5 g); peptone (10 g); NaCl (3 g); $Na_2HPO_4 \cdot 12H_2O$ (2 g); agar (10 g); pH 7.4. The *Salmonella* inocula for Mueller-Hinton test plates were prepared by inoculating growth from the stored semisolid agar tubes into separate tubes of nutrient broth (9 ml) and incubating the bacterial suspensions for 16-18 h at 35°C. A loopful of each culture was then streaked on individual plates of MacConkey agar. Following incubation of plates for 16-18 h at 35°C, four to five well-isolated and morphologically similar colonies from each MacConkey plate were combined into a single tube of tryptic soy broth (5 ml) and incubated for 4 h at 35°C. To adjust cell density, one Pasteur pipette drop of the 4-h culture was diluted into 5 ml of fresh tryptic soy broth. The latter manipula-

TABLE 1. Salmonella *serogroups in foods and other samples: 1986-1989.*

Serogroup	No. of test cultures										
	Poultry[a]	Pork[b]	Other meats[c]	Fish/ shellfish[d]	Animal feeds	Egg products[e]	Milk products[f]	Spices[g]	Reptiles[h]	Others[i]	Total
B	102	43	5	19	39	4	1	4			217
C	111	18	8	31	87	3	2	1	1	2	264
D	6	2	4	4	4		1			1	22
E	14	6	1	30	49		2	3			105
F		1		3							4
G	3		2	1	4				10	1	21
H				1							1
I	1			8							9
K			1								1
M							1				1
N				2				4			6
O					2						2
P				1							1
R				1	13						14
U				5							5
W				1							1
X				1							1
Z				2					1		3
61			1						1		2
65				5							5
Rough	1										1
Untypeable				3							3
Total	238	70	22	118	198	7	7	12	13	4	689

[a] Raw chicken (213), turkey (19), and other poultry (6).
[b] Retail meat cuts (45), sausages (13), minced (2), and organ meats (10).
[c] Raw beef (20), lamb (1), and goat (1).
[d] Imported mollusks (54), crustaceans (70), fish (11), and froglegs (10).
[e] Pasta (3), dried albumen (2), and egg yolk mix (2).
[f] Skim milk powder (2), cheese (4), and milk chocolate (1).
[g] Black pepper (9), turmeric (2), and basil (1).
[h] Pet turtle water (8), other pet reptiles (5).
[i] Tea (1), food supplement (2), and peanut butter (1).

tion represents an in-lab modification of the NCCLS-recommended $BaSO_4$ turbidity standardization. The diluted bacterial suspension was uniformly inoculated onto the surface of dry Mueller-Hinton agar plates using an impregnated swab. The surface inoculum was allowed to dry before a set of 11 antimicrobial disks were dispensed onto the agar surface using a semiautomated dispenser (Difco Laboratories, Detroit, MI). The antibiotic test panel consisted of the following: agents: ampicillin (A), 10 μg; cefotaxime (Cefo), 30 μg; chloramphenicol (C), 30 μg; gentamicin (G), 10 μg; kanamycin (K), 30 μg; polymyxin B (Poly), 300 units; streptomycin (S), 10 μg; trimethoprim 1.25 μg and sulfamethoxazole 23.75 μg (SXT); tetracycline (T), 30 μg; sulfisoxazole (Su), 300 μg; cephalothin (Cep), 30 μg. Mueller-Hinton plates were then incubated for 16-18 h at 35°C. The zone of growth inhibition was reported as the diameter of the zone surrounding individual antimicrobial disks in which bacterial growth was absent. Test strains were scored as sensitive, intermediate, or resistant according to the NCCLS interpretive standards (*25*).

RESULTS AND DISCUSSION

Most of the 689 *Salmonella* strains examined in this study were isolated from raw meat and animal feed samples collected within the Canadian agricultural sector, whereas most fish and shellfish were imported from Asiatic and from South and Central American countries (Table 1). The prevalence of serovars belonging to the somatic serogroups B, C, and E in our study reiterates their importance in the global food chain, and recalls their prominent association with human salmonellosis (*8,20*). Although the antibiotic resistance of strains from all sources increased from 29.1 to 50.9% between 1986-1989 (Table 2), the occurrence of resistant strains from individual sources fluctuated annually, except for an apparent temporal increase in resistance among fish and shellfish isolates. A study of longer duration might have delineated more definitive trends. The resistance of poultry isolates to one or more antimicrobials remained high from year to year, and generally exceeded that encountered in *Salmonella* strains isolated from other sources (Table 2). Levels of resistance in other raw meats, fish, and shellfish were nevertheless appreciable, ranging from 28.8 to 50.0%. Incomplete information on the source of isolates preempted consideration of a relationship between the presence of medicating ingredients in feeds and prevalence of resistant strains. The nine resistant strains

TABLE 2. *Antibiotic resistance of* Salmonella *by source and year of isolation.*

Source[b]	1986		1987		1988		1989		Total	
	Tested	% resistant[a]	Tested	% resistant[a]	Tested	% resistant[a]	Tested	% resistant[a]	Tested	% resistant[a]
Poultry	45	60.0	154	48.7	15	80.0	24	54.2	238	53.4
Pork	6	16.7	60	36.7	3	0.0	1	100.0	70	34.3
Other meats	2	50.0	18	44.4	NT[c]	NT	2	100.0	22	50.0
Fish/shellfish	8	12.5	NT	NT	93	29.0	17	35.3	118	28.8
Animal feeds	55	9.1	121	7.4	21	23.8	1	0.0	198	10.0
Egg products	4	0.0	3	0.0	NT	NT	NT	NT	7	0.0
Milk products	1	100.0	4	0.0	NT	NT	2	100.0	7	42.9
Spices	11	18.2	1	0.0	NT	NT	NT	NT	12	16.7
Reptiles	1	0.0	1	100.0	2	100.0	9	44.4	13	53.9
Others	1	100.0	NT	NT	2	0.0	1	100.0	4	50.0
Total	134	29.1	362	31.8	136	33.8	57	50.9	689	33.2

[a] Strains resistant to one or more antibiotics.

[b] Refer to footnotes of Table 1.

[c] No strains were tested.

from reptiles originated from imported pet turtles and their environment (*10*); isolates from imported lizards were susceptible to all test antibacterials. The three milk products that each yielded one resistant strain consisted of skim milk powder, cheese, and milk chocolate (Table 2). It is equally noteworthy that 260 strains obtained mainly from poultry, red meats, shellfish, and animal feeds exhibited intermediate levels of resistance to three or fewer antibiotics (data not shown). The intense husbandry practices used in the poultry industry and the widespread use of medicated feeds in broiler and layer operations facilitate the horizontal transmission of salmonellae within flocks and encourage the shedding of resistant strains in the poultry environment (*26,30,38*). This veterinary problem recognizes no geographical boundaries and has been reported in many countries (*7,12,29,36*). Similarly, widespread use of medicated feeds in bovine and porcine husbandry likely contributed to the establishment and spread of resistant bacterial populations within livestock herds and derived meat products (*18,32,37* and Table 2). The propensity for intra- and intergeneric conjugative transfer of resistance (R) plasmids that may also bear virulence determinants further exacerbates prospects for the effective control of this global zoonosis (*2,18,24,26,27*).

The resistance of salmonellae to individual antibacterial agents was revealing (Table 3). Summary data for isolates from all sources showed substantial resistance to S (27.7%), T (19.4%), and Su (10.0%). Resistance to these antibiotics in poultry, pork, and other meat isolates was considerably higher and varied from 11.3 to 48.7% (Table 3). These findings were not totally unexpected given the extensive use of antibacterials in animal husbandry. If a subtherapeutic dose relates to the presence of < 200 g of antibacterial agent per ton of medicated feed (*18*), current Canadian regulations permit the use of feeds containing subtherapeutic levels of chlortetracycline and oxytetracycline in bovine, porcine, chicken, turkey and ovine rearing operations, penicillin and streptomycin in porcine, chicken and turkey husbandry, and sulfamethazine on porcine farms (*1*). Statistics on the manufacture of antibiotics in the United States indicate that tetracycline and penicillin accounted for 42% of the 14.5 x 10^6 kg of antibiotics produced in that country in 1983. The U.S. Food and Drug Administration further estimated that 55-60% of the total tetracycline and penicillin produced was mixed into animal feeds at subtherapeutic levels (*3,18*). In this context, the recommendation of the Swann Committee (*5,33*) that tetracycline and penicillin, which are used in human medicine, be excluded from animal feeds remains valid and was recently reiterated by the World Health Organization (*38*). Application of such a restrictive measure in The Netherlands reportedly yielded tangible benefits. A multiyear survey of *Salmonella* drug resistance in humans and in farm animals showed that prohibiting the use of T-medicated feeds for growth enhancement engendered a marked decrease in T-resistant salmonellae in humans and in porcine populations (*35*). It is noteworthy that therapeutic levels of antibiotics in feeds can also select for resistant strains (*21*).

TABLE 3. *Antibiotic resistance of* Salmonella *by source: 1986-1989.*

Source[a]	No. strains tested	% antibiotic resistance[b]										
		A[c]	Cefo	C	G	K	Poly	S	SXT	T	Su	Cep
Poultry	238	3.4	0.0	0.4	5.0	13.9	0.0	48.7	0.0	37.8	11.3	0.4
Pork	70	11.4	0.0	4.3	0.0	7.1	0.0	27.1	0.0	24.3	15.7	1.4
Other meats	22	9.1	0.0	9.1	9.1	4.6	0.0	31.8	0.0	27.3	31.8	0.0
Fish/shellfish	118	1.7	0.0	4.2	0.0	3.4	0.0	19.5	0.8	5.9	12.7	0.0
Animal feeds	198	0.0	0.0	0.5	0.0	0.5	0.0	6.6	0.0	3.5	1.0	0.5
Reptiles	13	0.0	0.0	0.0	46.2	7.7	0.0	53.8	0.0	53.8	53.8	0.0
Others[d]	30	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	3.3	0.0
Total	689	2.9	0.0	1.7	2.9	6.5	0.0	27.7	0.1	19.4	10.0	0.4

[a] Refer to footnotes of Table 1.

[b] Percent ratio of resistant strains to total number of strains tested from each source.

[c] A = ampicillin; Cefo = cefotaxime; C = chloramphenicol; G = gentamicin; K = kanamycin; Poly = polymyxin B; S = streptomycin; SXT = trimethoprim sulfamethoxazole; T = tetracycline; Su = sulfisoxazole; Cep = cephalothin.

[d] Includes egg and milk products, spices, and "others" described in Table 1.

The range of C- (4.3 to 9.1%) and A- (9.1 to 11.4%) resistant *Salmonella* in porcine and in other meats (Table 3) is disquieting because these antibacterial agents together with SXT are widely used for the treatment of human systemic salmonellosis (*9*). The lower incidence of A and C resistance among poultry, fish, and shellfish isolates remains substantial given the large number of test cultures examined from these sources (Table 3). Although of uncertain origin, introduction of resistant salmonellae in imported fish and shellfish products conceivably arose from the use of human wastewater in aquaculture industries of third world countries (*39*), and from postharvest contamination of products processed under poor sanitary conditions. The rearing of fish and lobster in oxytetracycline-treated ponds in the United States and other countries, and use of sulfa drugs in various fish-rearing operations, will likely accentuate current problems of antibiotic resistant microflora in foods (*13,28*). It follows that consumption of lightly cooked beef, fish, or shellfish contaminated with resistant *Salmonella* strains would increase the inherent level of risk to unsuspecting consumers. A serious and even fatal outcome could result if such resistant pathogens spread systemically in a patient that had been treated initially with an antibiotic to which the invasive *Salmonella* lacked susceptibility (*14,22,34*). National reports of parallel increases in human typhoidal and nontyphoidal strains variously resistant to A, C, and SXT plausibly underline a consequence of resistance codons circulating in the environment and in the food chain (*6*).

Although strains isolated from animal feeds were generally susceptible to the antibiotics tested, modest levels of resistance to S (6.6%) and T (3.5%) were encountered (Table 3). An earlier study had also reported low numbers of S- and T-resistant salmonellae from feeds manufactured in Canada (*11*). Rendering plant processing of contaminated meats derived from animals reared on medicated feeds, together with multiple opportunities for in-plant cross-contamination of finished products (*38*), likely contributed to the observed levels of contamination. Eight of the 13 reptilian isolates (Table 3) originated from a study of pet turtles imported from Louisiana (*10*). Their resistance to gentamicin undoubtedly underscores the impact of regular on-farm disinfection of fertile turtle eggs with gentamicin sulfate and its selection of resistant strains. The strains that were resistant to Su originated from an urban survey of turtle water in pet shops.

The prevalence of antibiotic resistance within the principal somatic serogroups was similar except for group E where only 18.1% of the isolates were resistant to one or more antibacterial drugs (Table 4). Resistance to S and T was particularly prominent among members of somatic groups B, C and G, whereas higher susceptibility to S was encountered in groups D and E. *Salmonella poona* isolated from pet turtle environment accounted for most G- and T-resistant strains within serogroup G.

Multiple resistance ($\geq$ 2 antibiotics) was highest in *Salmonella* strains belonging to somatic groups B and C (Table 5). Resistance (28.6%) to four antibiotics within members of serogroup G arose mainly from *S. poona* isolated from pet turtle water and from roast beef samples (data not shown). Further examination of these susceptibility data by source (Table 6) confirmed the importance of poultry as a reservoir of multiply-resistant salmonellae. Such strains were not identified in spices, egg and milk products, and occurred in low numbers in fish/shellfish and in animal feeds. Of the five isolates exhibiting resistance to six antibiotics, one strain of *Salmonella indiana* was recovered from chicken gizzards, three strains of *Salmonella*

TABLE 4. *Antibiotic resistance of* Salmonella *by serogroup: 1986-1989.*

Sero-group	No. strains tested	% antibiotic resistance[a]											Total[c]
		A[b]	Cefo	C	G	K	Poly	S	SXT	T	Su	Cep	
B	217	5.5	0.0	2.3	2.8	7.4	0.0	31.3	0.5	23.0	16.1	0.9	40.1
C	264	1.9	0.0	1.1	1.9	10.2	0.0	29.6	0.0	25.4	3.8	0.0	31.4
D	22	4.6	0.0	9.1	0.0	0.0	0.0	18.2	0.0	9.1	18.2	0.0	36.4
E	105	1.9	0.0	0.9	0.9	0.9	0.0	15.2	0.0	5.7	2.9	0.9	18.1
G	21	0.0	0.0	4.8	33.3	4.8	0.0	47.6	0.0	33.3	33.3	0.0	47.6
Others[d]	60	0.0	0.0	0.0	1.7	0.0	0.0	25.0	0.0	3.3	16.7	0.0	36.6
Total	689	2.9	0.0	1.7	2.9	6.5	0.0	27.7	0.1	19.4	10.0	0.4	33.2

[a] Percent ratio of resistant strains to total number of strains tested from each serogroup.
[b] Refer to Table 3 for key to abbreviations.
[c] Percent ratio of strains resistant to one or more antibiotics.
[d] Remaining serogroups listed in Table 1.

TABLE 5. *Multiple antibiotic resistance of* Salmonella *by serogroup: 1986-1989.*

Serogroup	No. strains tested	% strains with resistances[a]						
		0	1	2	3	4	5	6
B	217	59.9	19.4	6.0	7.4	1.8	3.7	1.8
C	264	68.6	4.9	14.4	9.1	2.3	0.4	0.4
D	22	63.6	27.3	0.0	4.6	4.6	0.0	0.0
E	105	81.9	12.4	1.0	2.9	1.0	1.0	0.0
G	21	52.4	0.0	14.3	0.0	28.6	4.8	0.0
Others[b]	60	63.3	31.7	1.7	1.7	1.7	0.0	0.0
Total	689	66.8	13.9	7.7	6.5	2.8	1.6	0.7

[a] Percent ratio of resistant strains to total number of strains tested from each serogroup.
[b] Remaining serogroups listed in Table 1.

typhimurium from pork (*2*) and bovine (*1*) meat, and one strain of *Salmonella infantis* from pork meat (data not shown). Although 27 resistance patterns were encountered in this study, only those found in ≥ 5 test strains are reported (Table 7). It is interesting to note that all but two of the 27 patterns contained a resistance determinant for S and/or T; resistance to these two agents were linked in 15 patterns (data not shown). Single resistance to S occurred with the highest frequency (9.4%) followed by ST (6.2%) and KST (3.0%). Such prominence of S and T resistance patterns in poultry and in red meats reiterates the potential impact of subtherapeutically medicated feeds on the selection of resistant microflora in animal husbandry (*1,8,18*). It has already been intimated that emergence of multiply-resistant salmonellae can be the product of conjugative transfer of R-plasmids between bacterial species, and that agricultural use of subtherapeutic doses of a single antibiotic could select for bacterial strains harboring plasmids with multiple resistance codons (*9*). Stated differently, use of a single antibiotic could select for a multiple-resistant strain.

Several episodes of animal-to-human spread of infection have shown that the emergence and prevalence of multiply-resistant salmonellae in meat animals can seriously compromise public health. A recent estimate that the pool of antibiotic resistance genes in the United States is tenfold greater in animal than in human microflora further heightens the level of public health concern (*18*). For example, receipt of bovine calves infected with multiply-resistant *Salmonella heidelberg* on a dairy farm in Connecticut led to the infection of the farmer and his pregnant daughter. Hospital delivery by the infected daughter precipitated a nursery outbreak of *S. heidelberg* resistant to C, T, and sulfamethoxazole (*23*). A similar nursery outbreak

TABLE 6. *Multiple antibiotic resistance of* Salmonella *by source: 1986-1989.*

Source[a]	No. strains tested	% strains with resistances[b]						
		0	1	2	3	4	5	6
Poultry	238	46.6	14.7	18.5	13.9	3.8	2.1	0.4
Pork	70	65.7	14.3	4.3	7.1	0.0	4.3	4.3
Other meats	22	50.0	22.7	4.6	9.1	9.1	0.0	4.6
Fish/shellfish	118	71.2	21.2	1.7	1.7	2.5	1.7	0.0
Animal feeds	198	90.4	7.1	1.5	1.0	0.0	0.0	0.0
Egg products	7	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Milk products	7	57.1	42.8	0.0	0.0	0.0	0.0	0.0
Spices	12	83.3	16.7	0.0	0.0	0.0	0.0	0.0
Reptiles	13	46.2	0.0	0.0	7.7	38.5	7.7	0.0
Others	4	50.0	50.0	0.0	0.0	0.0	0.0	0.0
Total	689	66.8	13.9	7.7	6.5	2.8	1.6	0.7

[a] Refer to footnotes of Table 1.

[b] Percent ratio of resistant strains to total number of strains tested from each source.

TABLE 7. *Prevalent antibiotic resistance patterns of* Salmonella *by source: 1986-1989.*[a]

Resistance patterns	No. resistant strains	% number of strains[b]							
		Poultry (238)[d]	Pork (70)	Other meats (22)	Fish/shellfish (118)	Animal feeds (198)	Reptiles (13)	Others[c] (30)	Total (689)
S	65	10.5	7.1	13.6	14.4	4.6	0.0	20.0	9.4
T	16	3.8	4.3	0.0	0.0	2.0	0.0	0.0	2.3
Su	15	0.8	2.9	9.1	6.8	0.0	0.0	3.3	2.2
S-T	43	16.4	4.3	0.0	0.0	0.5	0.0	0.0	6.2
S-Su	6	1.7	0.0	0.0	0.8	0.5	0.0	0.0	0.9
K-S-T	21	8.4	0.0	0.0	0.0	0.5	0.0	0.0	3.0
S-T-Su	13	2.9	4.3	0.0	0.8	0.5	7.7	0.0	1.9
A-S-T	6	1.3	2.9	4.5	0.0	0.0	0.0	0.0	0.9
G-S-T-Su	8	0.4	0.0	9.1	0.0	0.0	38.5	0.0	1.2
G-K-S-Su	6	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.9
A-K-S-T-Su	5	1.3	2.9	0.0	0.0	0.0	0.0	0.0	0.7
Total	204	50.0	28.6	36.4	22.9	8.6	46.2	23.3	29.6

[a] Resistance patterns found in ≥5 test strains; the 16 uncommon patterns of 25 resistant strains were not tabulated.

[b] Percent ratio of resistant strains to total number of test strains from each source.

[c] Refer to Table 3 (footnote d).

[d] Total number of test strains from source.

of *S. typhimurium* resistant to six antibiotics (ACKST and sulfadiazine) occurred in a Canadian hospital following on-farm consumption of contaminated raw milk by a pregnant farmer's wife (*4*). A similarly resistant strain of *S. typhimurium* was retrospectively identified as the etiological agent in a prolonged outbreak associated with the consumption of raw milk in Arizona (*34*). In two extensive epidemiological studies, the transmission of multiply-resistant *Salmonella newport* from infected meat animals to humans in California (*31*) and in Midwestern States (*15*) duly underscored the public health hazards associated with the use of antimicrobials and medicated feeds on farms.

The high prevalence of resistant *Salmonella* (and other bacterial pathogens) in raw meat products (Table 3), the propensity for bacterial pathogens to acquire multiple resistance in the natural environment (Table 7), the demonstrated animal-to-human spread of resistant strains (*4,15,31,34*), and the potentially serious and even fatal consequences of human systemic infections with multiply-resistant *Salmonella* (*16,17*), question the wisdom of widespread use of subtherapeutic regimens of antibiotics in animal husbandry. Growing evidence for the ability of a single antimicrobial agent to select for multiply-resistant strains, and to activate bacterial defense mechanisms to a state of multiple antibiotic resistance is disquieting (*8,18*). The potential coupling of resistance and virulence determinants within a single plasmid could engender devastating repercussions on the clinical course of human salmonellosis (*18*). The alleged prophylactic and growth promoting benefits of subtherapeutic doses of antibiotics in feeds should be reassessed on the strength of existing and new experimental data. Furthermore, the efficacy of drugs used in the clinical management of human disease should not be compromised through addition to medicated feeds (*33*). Continued agricultural use of medicated feeds and their application in the rapidly developing aquacultural fish and shellfish industries (*13,28*) can only foster a greater dissemination of virulent and resistant bacterial pathogens in the natural environment and in the human food chain.

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