

# Use of Antibiotics and Roxarsone in Broiler Chickens in the USA: Analysis for the Years 1995 to 2000

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**ABSTRACT** In 1995, an antibiotic (ANT) was used in starter, grower, and withdrawal (WD) feeds by 94.3, 98.2, and 75.1% of broiler production units, but by 2000, ANT use had declined to 64.8, 66.9, and 48.1% respectively. Roxarsone (ROX) was used in the starter and grower feeds by 69.8 and 73.9% of production units. Bacitracin (BAC) was used more frequently than other antibiotics in the starter and grower feed. Virginiamycin (VIR) was used most frequently in the WD feed. Most units (69.4%) reported use of two different antibiotics. The use of programs comprising two ANT decreased, whereas programs with a single ANT increased during the period of study. A combination of ionophore (ION) + ROX + ANT was employed most frequently in the starter and grower feeds, whereas an ANT alone was used most frequently

in the WD ration. The use of ION + ROX + ANT declined from 1995 to 2000, but use of ION + ROX increased. There were no significant differences in calorie conversion whether plants used ION + ROX + ANT, ION + ROX, or ION + ANT. The number of days to rear birds to 2.27 kg was significantly greater for production units using ION + ROX. Mortality was lower for units that used ION + ROX + ANT and ION + ROX than for those that used ION + ANT. Production units that used ION + ANT were more likely to rear birds to a weight greater than 2.5 kg than to 2.0 to 2.5 kg. Units in the South and Central states were more likely to use an ION + ROX than those in the Northeast and Atlantic states, whereas for ION + ROX + ANT the reverse was the case. The cost of medicating with ION + ROX + ANT decreased from 1995 to 1998.

(Key words: broiler production unit, ionophore, antibiotic, roxarsone)

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## INTRODUCTION

Antibiotics (ANT) are included in the feed of broilers to increase the rate of weight gain and improve efficiency of feed use (Miller Publishing Co., 2000). Some ANT [bacitracin (BAC) methylene disalicylate, virginiamycin (VIR), and lincomycin (LIN)] may also aid in the prevention of necrotic enteritis, a bacterial infection caused by *Clostridium spp.* The arsenical drug roxarsone (ROX) is used to improve weight gain, feed utilization and pigmentation, and when used in conjunction with ionophores (ION; narasin or salinomycin), may also aid in the control of coccidiosis caused by strains of *Eimeria tenella* that are refractory to these drugs (Miller Publishing Co., 2000; Skinner et al., 1997).

Antibiotics and ROX are widely used by the broiler industry in the United States, but quantitative information concerning the types of drug program in which they

are employed is not available. An extensive database (representing more than 90% of the broiler industry) compiles information on a monthly basis from individual broiler units and is used to assess many aspects of poultry production.<sup>2</sup> The feed medication usage tables of this database have been employed to assess use of anticoccidial drugs by the broiler industry (Chapman, 2001). In this study, quantitative aspects of the use of ANT and ROX during the last 6 yr were determined, and the types of drug program in which they were employed examined, to observe whether there was any correlation with performance characteristics of the birds.

## MATERIALS AND METHODS

A database developed by Agri Stats. Inc.<sup>2</sup> provides accurate, frequent information on a monthly basis from individual poultry plants throughout the United States. A poultry plant is defined as a production unit (PU) that in most cases represents a broiler complex comprising a

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**Abbreviation Key:** ANT = antibiotic; BAC = bacitracin; BAM = bambamycins; CHE = chemical; ION = ionophore; LIN = lincomycin; PU = production unit; ROX = roxarsone; TYL = tylosin; VIR = virginiamycin; WD = withdrawal.

group of farms, in a common geographical area, that is served by a single feed mill. For January 1995, information from 76 PU was available, but by October 2000 information from 162 PU was recorded. Data for five feeds [prestarter, starter, grower, first, and final withdrawal (WD)] were reported but only those for starter, grower, and final WD were used in this study.

Results were analyzed for January, April, July, and October from 1995 to 2000. The number of PU that used ANT, ROX, or anticoccidial drug in the feed was determined. Antibiotics included two types of BAC, bacitracin methylene disalicylate and zinc bacitracin; bambermycins (BAM), LIN, tylosin (TYL), and VIR. Anticoccidial drugs were classified as ION or chemicals (CHE). Ionophores included lasalocid, monensin, narasin, salinomycin, and semduramicin. The principal CHE used during this study were nicarbazin and zoalene. Maxiban® (a mixture of nicarbazin and narasin) was also used.

For each month, the number of PU using ROX, individual antibiotics (BAC, BAM, LIN, TYL, and VIR); drug combinations (ION + ROX + ANT, ION + ROX, ION + ANT, CHE + ROX + ANT, CHE + ROX, or CHE + ANT); or ION, CHE, or ANT separately was determined and expressed as a percentage of the total number that reported for that month. The number of PU using one, two, or three ANT in the starter, grower, and WD feed was determined and expressed as a percentage of the total number that used an ANT. The number of PU using different concentrations of ROX (11, 20, 25, 37, and 50 ppm) and BAC (27.5 and 55 ppm) in the starter and grower feed and VIR (11, 16.5 and 22 ppm), LIN (2.2 and 4.4 ppm), or TYL (11 and 16.5 ppm) in the WD feed was expressed as a percentage of the total number using that drug.

For each PU using the same drug combination (ION + ROX + ANT, ION + ROX, or ION + ANT) in the starter and grower feed, the calorie conversion (a measure of feed efficiency), number of days to grow a flock to 2.27 kg, and percentage mortality (number of birds settled divided by number of birds placed) were analyzed for January, April, July, and October 1998 to 2000. Methods for calculating these performance variables are given in the live production monthly definition manual.<sup>2</sup> PU reporting from January 1998 to October 2000 were categorized according to whether birds were reared to a final BW less than 2.0 kg, from 2.0 to 2.5 kg, or greater than 2.5 kg. They were also categorized by region within the United States. The percentages using ION + ROX + ANT, ION + ROX, or ION + ANT were then calculated to establish whether there was any correlation between final weight or region and type of program. Data for five regions were available (Region 20: Delaware, Maryland, North Carolina, Virginia, Pennsylvania, and West Virginia; Region 30: Georgia, South Carolina, Tennessee, and Florida; Region 40: Alabama and Mississippi; Region 50: Arkansas, Texas, and Missouri; Region 60: Ohio, Wisconsin, Kentucky, Minnesota, and Indiana).

Sixteen PU that had used ION + ROX + ANT, ION + ROX, and ION + ANT in the starter and grower feeds

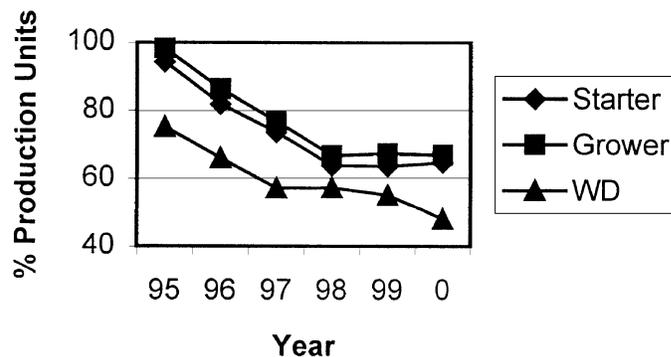


FIGURE 1. The number of production units using an antibiotic in the starter, grower, and withdrawal (WD) feeds was expressed as a percentage of the total number reporting for that month. Results for each year were combined, and means were calculated.

were randomly selected, and the mean cost of medication for each feed was (US\$ per ton) determined. Data for January, April, July, and October 1995 to 2000 were combined, and means were calculated.

Performance characteristics (calorie conversion, days to 2.27 kg, and percentage mortality) were analyzed using the general linear models (GLM) procedure of the SAS Institute (1988) to examine differences due to drug combination. Means were separated using probabilities generated by the LSMEANS option of this procedure. Chi-squared analysis was used to determine if the percentage of PU in each final body weight category differed due to type of program and if the percentage using each drug combination differed by region. Trends over time for percentage of PU using each ANT and drug combination for starter, grower, and WD feeds were examined using the regression (REG) procedure of SAS (1988). Linear and quadratic equations were examined. Year was coded from 1 to 6 in these equations with 1 corresponding to 1995, 2 to 1996, etc.

## RESULTS

### Use of ANT and ROX

During 1995, ANT was used in the starter, grower, and WD feed by 94.3, 98.2, and 75.1% of PU, but by 2000 total ANT use had declined to 64.8, 66.9, and 48.1% respectively. There was a decrease in overall ANT use from 1995 to 2000 (Figure 1). For starter and grower, this decrease was quadratic, whereas for WD feed, the percentage using ANT decreased linearly by about 4.8% per year (Table 1). There was no difference in ANT use at different times of the year (Figure 2). ROX was used in the starter and grower feed by 69.8 and 73.9% of PU, respectively, but was not used in the WD feed. There were no significant differences in the use of ROX during the period of study or at different times of the year (data not presented).

The percentage of PU that reported use of individual antibiotics (BAC, BAM, VIR, LIN, and TYL) is presented in Figures 3, 4, and 5. BAC was used more frequently than other antibiotics in the starter and grower feeds

TABLE 1. Equations for the percentage of production units reporting use of various antibiotics and antibiotic combinations in broiler feeds from 1995 to 2000<sup>1</sup>

Drug	Figure	Feed	Equation <sup>2</sup>	Type	R <sup>2</sup>	PP
ANT	1	ST	111.668 - 18.6648 yr + 1.801 yr <sup>2</sup>	Q	0.86	< 0.001
ANT	1	GR	115.832 - 18.798 yr + 1.775 yr <sup>2</sup>	Q	0.86	< 0.001
ANT	1	WD	76.530 - 4.784 yr	L	0.77	< 0.001
BAC	3	ST	90.560 - 7.674 yr	L	0.84	< 0.001
BAC	4	GR	75.812 - 6.295 yr	L	0.81	< 0.001
VIR	3	ST	5.512 - 2.592 yr + 0.383 yr <sup>2</sup>	Q	0.21	< 0.09
VIR	5	WD	44.400 - 3.681 yr	L	0.49	< 0.001
One ANT	6	All	7.155 + 4.174 yr	L	0.40	< 0.001
Two ANT	6	All	79.605 - 2.776 yr	L	0.33	< 0.004
Three ANT	6	All	13.600 - 1.493 yr	L	0.41	< 0.001
I + R + A	7	ST	50.272 - 3.119 yr	L	0.29	< 0.01
I + R + A	8	GR	77.628 - 5.549 yr	L	0.52	< 0.001
I + R	7	ST	-12.588 + 12.425 yr - 0.953 yr <sup>2</sup>	Q	0.87	< 0.001
I + R	8	GR	-10.00 + 11.294 yr - 0.896 yr <sup>2</sup>	Q	0.83	< 0.001
A	7	ST	13.870 - 7.358 yr + 0.941 yr <sup>2</sup>	Q	0.45	< 0.001
A	8	GR	4.540 - 2.691 yr + 0.421 yr <sup>2</sup>	Q	0.43	< 0.01
A	9	WD	74.742 - 4.911 yr	L	0.79	< 0.001
I	7	ST	0.918 + 0.894 yr	L	0.17	< 0.05
I	8	GR	-4.355 + 5.318 yr - 0.583 yr <sup>2</sup>	Q	0.39	< 0.01
C + R + A	10	ST	21.373 - 2.326 yr	L	0.27	< 0.01
BAC 55/27.5	11	ST/GR	11.035 + 4.258* yr	L	0.57	< 0.001
BAC 27.5/27.5	11	ST/GR	25.307 - 2.658* yr	L	0.19	< 0.05
BAC 27.5/55	11	ST/GR	13.563 - 5.113* yr + 0.484* yr <sup>2</sup>	Q	0.77	< 0.001

<sup>1</sup>ANT = antibiotic; BAC = bacitracin; VIR = virginiamycin; I = ionophore; R = roxarsone; A = antibiotic; C = chemical; ST = starter feed; GR = grower feed; WD = withdrawal feed.

<sup>2</sup>Linear (L) and quadratic (Q) equations for the percentage of plants using various drugs in broiler feeds from 1995 to 2000.

(Figures 3 and 4), whereas VIR was used more frequently in the WD feed (Figure 5). BAM and LIN were principally used in the grower and WD feeds. TYL was occasionally used in the WD ration (Figure 5). Use of BAC decreased linearly by about 7.7% per year in starter feed and by about 6.3% in grower feed, but use did not change in WD feed (Table 1). Use of VIR tended to decrease quadratically in starter feeds, did not change in grower feeds, and decreased linearly by about 3.7% per year in WD feed (Table 1).

### Drug Programs

The percentage of PU that reported use of one or more ANT, expressed as a percentage of the total number that

used an ANT, is presented in Table 2. A single ANT (principally BAC) was used by 21.9% of PU, whereas programs using two ANT (principally BAC, VIR and BAC, BAM) or three ANT were used by 69.4 and 8.1% of PU, respectively. One PU even used four different drugs (BAC, BAM, VIR, LIN) in the starter, grower, and first and final WD feeds. Other combinations of drugs (frequency < 0.5%) have been reported (Table 2). There was a linear increase in the use of a single ANT from 1995 to 2000, whereas the use of two or three ANT showed a linear decrease (Figure 6; Table 1).

### Drug Combinations

The percentage of PU using ION, ANT, or various drug combinations (ION + ROX, ION + ANT, and ION + ROX

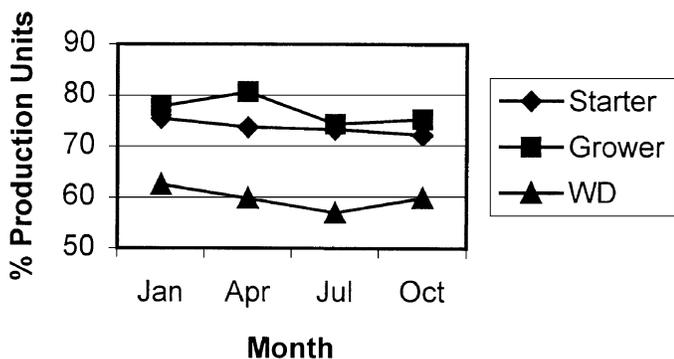


FIGURE 2. For January, April, July, and October, the number of production units using an antibiotic in the starter, grower, and withdrawal (WD) feeds was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

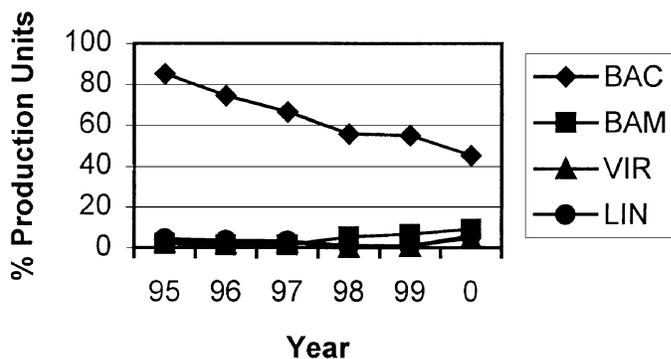


FIGURE 3. The number of production units using bacitracin (BAC), bambamerycins (BAM), virginiamycin (VIR), and lincomycin (LIN) in the starter feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

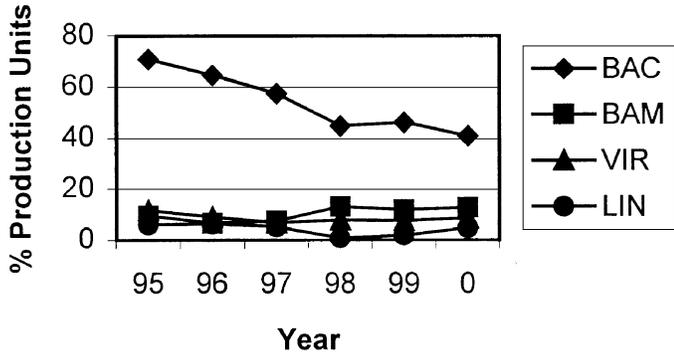


FIGURE 4. The number of production units using bacitracin (BAC), bambermycins (BAM), virginiamycin (VIR), and lincomycin (LIN) in the grower feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

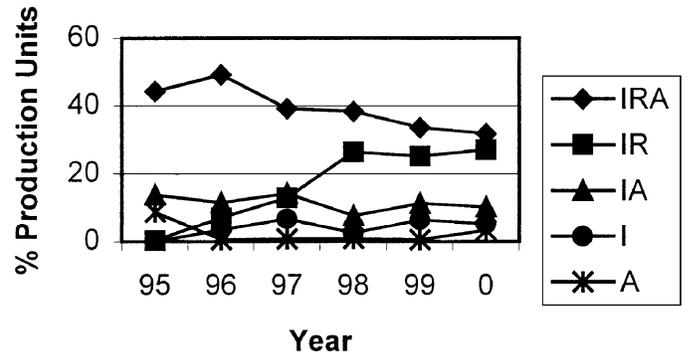


FIGURE 7. The number of production units using an ionophore (I), antibiotic (A), or I combined with roxarsone (IR) or with A (IA) in the starter feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

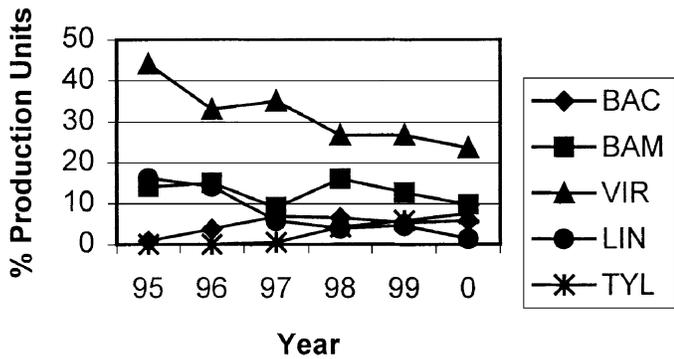


FIGURE 5. The number of production units using bacitracin (BAC), bambermycins (BAM), virginiamycin (VIR), lincomycin (LIN), and tylosin (TYL) in the withdrawal feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

+ ANT) is presented in Figures 7, 8, and 9. A combination of ION + ROX + ANT was most frequently used in the starter and grower feed (Figures 7 and 8), whereas an ANT alone was used most frequently in the WD (Figure 9). There was a decrease in the use of an ION + ROX + ANT during the period of this study, but the use of an ION + ROX combination increased. Use of ION + ROX + ANT decreased linearly by about 3.1% per year in starter feeds and by about 5.5% a year in grower feeds (Table 1). Use of the ION + ROX combination increased quadratically for starter and grower feeds (Table 1). Use of ANT alone decreased quadratically in starter and grower feeds and decreased linearly by about 4.9% per year in WD feed. There was no change in the use of the ION + ANT combination; however, use of an ION alone increased linearly in starter feeds and quadratically in grower feeds (Table 1).

The percentage of PU using a CHE, CHE + ROX + ANT, CHE + ROX, or CHE + ANT is presented in Figure 10. CHE were principally used in the starter feed with ROX

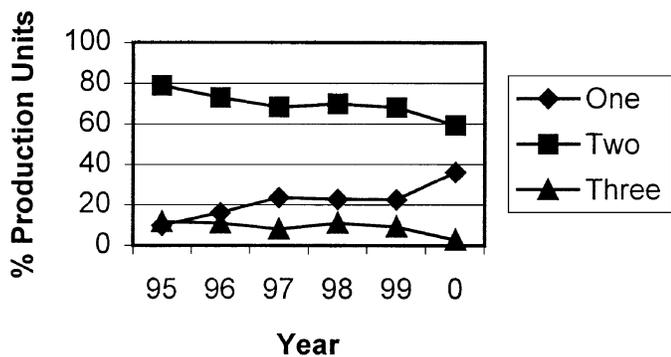


FIGURE 6. The number of production units using one, two, or three antibiotics (ANT) was expressed as a percentage of the total number using an antibiotic for that month. Results for each month for the 6-yr period were combined, and means were calculated.

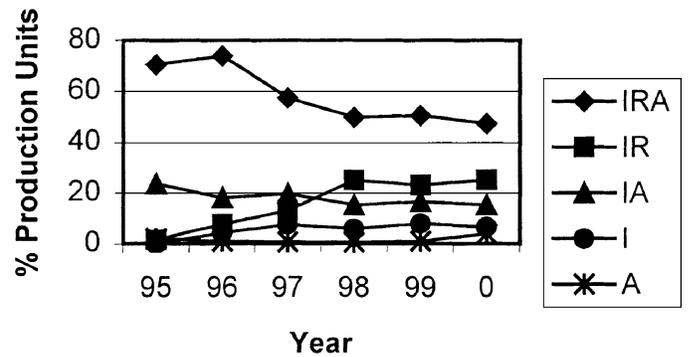


FIGURE 8. The number of production units using an ionophore (I), antibiotic (A), or I combination with roxarsone (IR) or with A (IA) in the grower feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

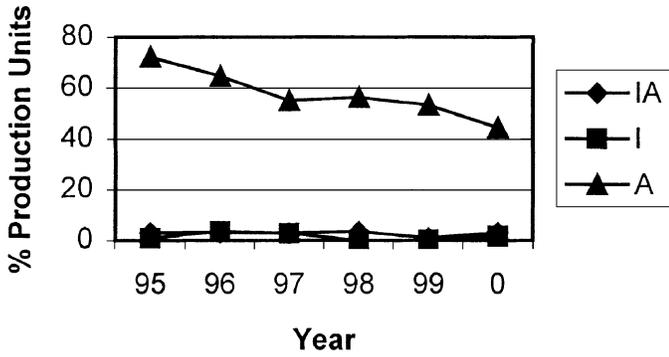


FIGURE 9. The number of production units using an ionophore (I), antibiotic (A), or I and A (IA) in the withdrawal feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

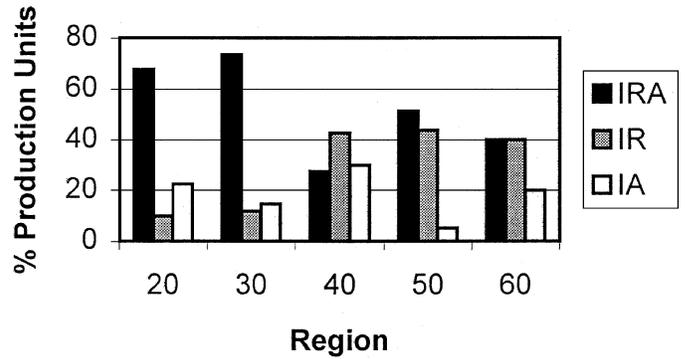


FIGURE 12. Production units that had utilized ionophore (I) + roxarsone (R) + antibiotic (A), I + R, or I + A in the starter and grower feeds were selected according to regions of the United States (Region 20: Delaware, Maryland, North Carolina, Virginia, Pennsylvania, and West Virginia; Region 30: Georgia, South Carolina, Tennessee, and Florida; Region 40: Alabama, and Mississippi; Region 50: Arkansas, Texas, and Missouri; Region 60: Ohio, Wisconsin, Kentucky, Minnesota, and Indiana). The number of production units was expressed as a percentage of the total number using that combination of drugs. Results for January, April, July, and October were combined, and means were calculated.

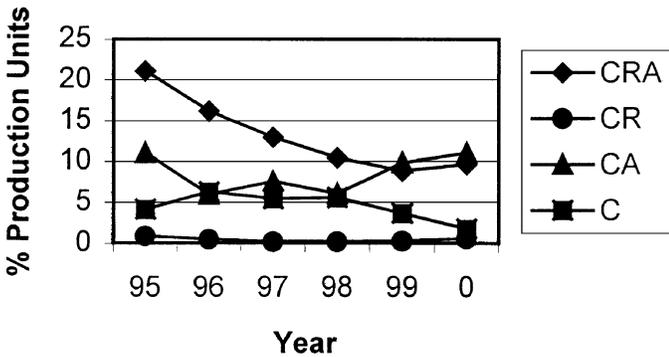


FIGURE 10. The number of production units using a chemical (C), or C combination with roxarsone (CR) or with an antibiotic (CA) in the starter feed was expressed as a percentage of the total number reporting for that month. Results for each month for the 6-yr period were combined, and means were calculated.

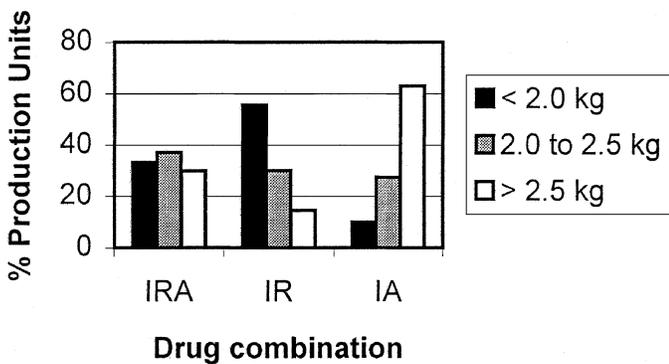


FIGURE 11. Production units that had utilized ionophore (I) + roxarsone (R) + antibiotic (A), I + R, or I + A in the starter and grower feeds were selected according to whether the final weight reported for the birds was less than 2.0 kg, between 2.0 and 2.5 kg, or greater than 2.5 kg. The number of production units was expressed as a percentage of the total number using that combination of drugs. Results for January, April, July, and October were combined, and means were calculated.

+ ANT or ANT. There was a linear decrease in the use of a CHE + ROX + ANT during the period of this study.

The probability of having a certain medication differed ( $\chi^2 = 151.73$ ;  $P < 0.001$ ) if birds were reared to different weights (Figure 11). PU that utilized ION + ANT were more likely to rear birds to a final weight of greater than 2.5 kg than to a final weight of 2.0 to 2.5 kg or to less than 2.0 kg, whereas for those that used ION + ROX, the converse was the case. An ION + ROX + ANT combination was used to a similar extent, irrespective of final bird weight.

The probability of having a certain combination of drugs differed ( $\chi^2 = 31.65$ ;  $P < 0.001$ ) in different regions (Figure 12). Regions 20 and 30 were more likely to employ an ION + ROX + ANT than regions 40, 50 and 60, whereas an ION + ROX was more likely to be used in Regions 40, 50, and 60 than in Regions 20 and 30.

### Drug Concentration

BAC was used at 55 ppm in the starter and grower feeds by 73.7 and 57.2% of PU respectively (Table 3). A

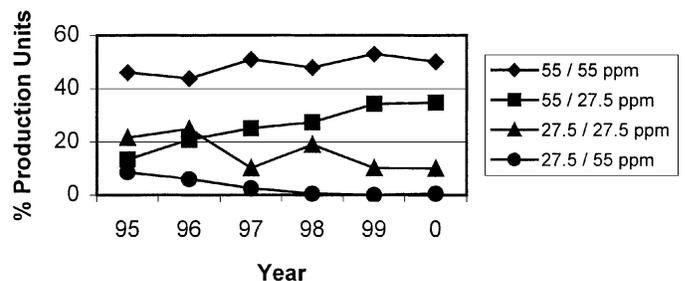


FIGURE 13. The number of production units using bacitracin (BAC) in the starter and grower feeds at 50 or 25 ppm (50/50 or 25/25), respectively; 50 ppm followed by 25 ppm (50/25); or 25 ppm followed by 50 ppm (25/50) was expressed as a percentage of the total number using BAC for that month. Results for each month, for the 6-yr period, were combined, and means were calculated.

TABLE 2. The percentage of production units (PU) reporting use of one, two, or three antibiotics<sup>1</sup>

		Program type			
One antibiotic		Two antibiotics		Three antibiotics	
Antibiotic	% PU	Antibiotics	% PU	Antibiotics	% PU
BAC	13.7	BAC, VIR	37.8	BAC, BAM, VIR	5.0
BAM	3.0	BAC, BAM	16.0	BAC, BAM, LIN	1.8
LIN	3.1	BAC, LIN	9.3	FLA, VIR, LIN	0.7
VIR	2.0	BAC, TYL	3.1	BAC, VIR, LIN	0.6
—	—	VIR, BAM	2.5	—	—

<sup>1</sup>Each observation is the number of PU that reported using one, two, or three antibiotics in the starter, grower, or withdrawal feed, expressed as a percentage of the total number that used an antibiotic. Results for January, April, July, and October 1995 to 2000 were combined. BAC = bacitracin; BAM = bambamycin; LIN = lincomycin; VIR = virginiamycin; TYL = tylosin. Other drug programs (frequency < 0.5% of plants) included: TYL; VIR, LIN; VIR, TYL; BAM, LIN; BAM, TYL; BAC, BAM, TYL; BAC, TYL, LIN; and BAM, VIR, TYL.

lower concentration (27.5 ppm) was used in these feeds by 26.3 and 42.8% of PU. BAC was used at 55 ppm in starter and grower feeds and at 27.5 ppm in both feeds by 48.6 and 16.0% of PU, respectively (Table 3). Some PU (28.0%) used 55 ppm in the starter, followed by 27.5 ppm in the grower, but a few (3.1%) used 55 ppm in the grower feed and 27.5 ppm in the starter feed. The percentage of PU using a lower concentration of BAC (27.5 ppm) in the grower feed than in the starter feed increased linearly during the period of the study, whereas the percentage using 27.5 ppm in both feeds, or a higher concentration (55 ppm) in the grower, showed a linear or quadratic decline, respectively (Figure 13; Table 1).

Of the PU that used ROX, similar concentrations were used in the starter and grower feeds (Table 4). Most PU used ROX at 50 ppm, but some used lower concentrations. VIR was used at 11, 16.5, and 22 ppm in the WD feed (72.0, 18.6, and 9.4% of PU, respectively, that used this ANT). LIN was used at 2.2 and 4.4 ppm (by 74.7 and 25.3% of PU) and TYL at 11 or 16.5 ppm (57.1 and 42.9% of PU) in the WD feed.

**Performance Characteristics**

The calorie conversion, days to 2.27 kg, and percentage mortality reported by PU given a combination of ION + ROX + ANT, ION + ROX, or ION + ANT in starter and grower feeds from 1998 to 2000 are given in Table 5. There were no differences in calorie conversion. The number of days to rear birds to 2.27 kg was greater ( $P < 0.01$ ) for

PU using ION + ROX than those using ION + ROX + ANT or ION + ANT. PU using ION + ROX reported a lower mortality ( $P < 0.01$ ) than PU using an ION + ROX + ANT, whereas PU using an ION + ANT had higher mortalities than the latter (Table 5).

**Cost of Medication**

Cost of providing ION + ROX + ANT decreased quadratically from 1995 to 2000 (Figure 14) in the starter feed ( $8.273 - 1.063 \text{ year} + 0.099 \text{ year}^2$ ;  $R^2 = 0.83$ ;  $P < 0.001$ ) and grower feed ( $8.811 - 1.423 \text{ yr} + 0.141 \text{ year}^2$ ;  $R^2 = 0.88$ ;  $P < 0.001$ ). The cost of including ION + ROX + ANT in the feed was greater than providing ION + ROX or ION + ANT in the ration (Table 6). An ION + ANT combination was more expensive than an ION + ROX combination. ROX cost less than ION or ANT.

**DISCUSSION**

Growth-promoting ANT have been routinely included in poultry rations for 50 yr (NRC, 1999), but little information is available on the manner in which they are used by the poultry industry. In view of restrictions imposed on the use of certain ANT by the European Union, quantitative information regarding the types of drug program in which these agents are used is timely. The availability

TABLE 3. The percentage of production units (PU) that used 55 or 27.5 ppm bacitracin in the starter and grower feeds<sup>1</sup>

Concentration (ppm)	% PU		
	Starter	Grower	Starter and grower
55	73.7 ± 3.1	57.2 ± 2.0	48.6 ± 1.4
27.5	26.3 ± 3.1	42.8 ± 2.0	16.0 ± 2.7

<sup>1</sup>Each observation is the percentage of units that reported using 55 or 27.5 ppm of bacitracin in the starter, grower, or starter and grower feeds expressed as a percentage of the total number that used bacitracin. Results for January, April, July, and October 1995 to 2000 were combined, and means ± SE were calculated.

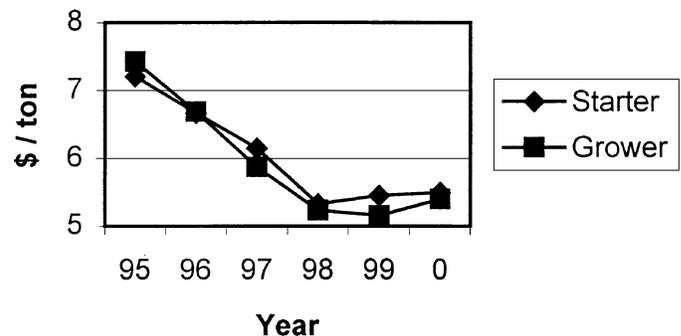


FIGURE 14. The cost of medication with an ionophore + roxarsone + antibiotic in starter and grower feeds. Results for each month for the 6-yr period were combined, and means were calculated.

TABLE 4. The percentage of production units that used roxarsone in the starter and grower feeds<sup>1</sup>

Feed	Concentration (ppm)				
	50	37	25	20	11
	Plants (%)				
Starter	69.4 ± 3.3	8.8 ± 0.5	11.1 ± 1.1	1.1 ± 0.2	7.2 ± 2.3
Grower	67.1 ± 2.6	10.9 ± 1.5	11.2 ± 1.2	1.1 ± 0.4	6.6 ± 1.9

<sup>1</sup>Each observation is the percentage of production units that reported using different concentrations of roxarsone in the starter and grower feed, expressed as a percentage of the total number that used roxarsone. Results for January, April, July, and October 1995 to 2000 were combined, and means ± SE were calculated.

of a comprehensive, detailed database that provides extensive information on many aspects of poultry production makes such an analysis possible.

Data have been examined for the years 1995 to 2000 to determine the extent to which ANT and ROX are used by the broiler industry in the United States. In addition to an anticoccidial agent (most often an ION), an ANT and ROX were frequently employed, particularly in the starter and grower feeds. Antibiotics and ROX were also utilized in the first WD feed, but ROX was not used (and is not approved for use) in the final WD ration. The most popular programs involved the use of BAC in the starter and grower feeds and VIR in the WD feed. Most production units used the same concentration of BAC (55 ppm) in the starter and grower feeds. There was an increase in the percentage using 27.5 ppm in the grower following 55 ppm in the starter and a decrease in the percentage using 55 ppm in the grower, during the period of the study. As more feed is consumed during the grower phase, this decrease in percentage may reflect a desire to decrease the cost of medication by using a lower concentration of drug in the feed. Apart from perceived efficacy as a growth promoter, factors that affect the choice of ANT include cost and approvals for use with other agents. For example, a limitation on the use of VIR in starter and grower feeds is that this drug is approved for use with salinomycin (the most frequently used anticoccidial) and ROX at 5.5 ppm but not at higher concentrations. TYL is not approved for use with salinomycin or ROX.

In some cases, the same ANT was used in different feeds, but usually two and sometimes three ANT are

used. In view of the possible reduction in efficacy that may occur if the same ANT is used repeatedly, it might be desirable to use different ANT to reduce the probability of selecting resistant strains. There have been no recent studies, however, to indicate whether growth is improved if two or more ANT are used in a single flock. BAC and ROX were used most frequently at their maximum approved use concentrations (55 and 50 ppm, respectively) presumably because it is believed that this use will result in maximum efficacy. VIR, LIN, and TYL were most frequently used at less than their maximum approved levels (11, 2.2, and 11 ppm, respectively).

There was a significant decline in the total use of ANT (BAC in the starter and grower feeds and VIR in the WD feed). One explanation for the reduction in ANT usage is that, despite the decrease in cost of medication with ION + ROX + ANT, considerable savings can still result by removal of these agents from the feed. These cost savings must be balanced against perceived reductions in growth-promoting effects and the increased risk of intestinal diseases such as necrotic enteritis. Antibiotics and ROX are used to increase the rate of weight gain and to improve use of feed. ROX, however, costs less than ANT, and therefore, greater cost savings may be achieved by removing an ANT rather than ROX from poultry diets.

The use of ROX did not change during the period of the study. A possible reason is that ROX, in addition to its action as a growth promoter, is used to assist in control of coccidiosis. Ionophores are used in most flocks to control this disease, but there are many reports that these drugs are not as efficacious as when first introduced (e.g., Chapman and Shirley, 1989; Jeffers, 1989; Chapman and Hacker, 1994). ROX may help control certain species (*E.*

TABLE 5. Performance characteristics reported by production units using different combinations of ionophores (I), antibiotics (A), or roxarsone (R) from 1998 to 2000<sup>1</sup>

Variable	Drug combination		
	IRA	IR	IA
Calorie conversion	2,892 ± 7.6	2,889 ± 8.2	2,889 ± 15.9
Days to 2.27 kg	48.1 ± 0.1 <sup>b</sup>	49.4 ± 0.1 <sup>a</sup>	48.1 ± 0.21 <sup>b</sup>
Mortality (%)	5.02 ± 0.08 <sup>b</sup>	3.95 ± 0.09 <sup>c</sup>	6.29 ± 0.17 <sup>a</sup>

<sup>a-c</sup>Values within the same row with no common superscript differ significantly ( $P < 0.01$ ).

<sup>1</sup>The mean calorie conversion, number of days to 2.27 kg, and percentage mortality reported by 16 production units that had utilized IRA, IR, or IA in the starter and grower feed were calculated. Results for January, April, July, and October 1998 to 2000 were combined, and means were calculated.

TABLE 6. Costs of medicating starter and grower feeds with different combinations of ionophores (I), antibiotics (A), or roxarsone (R)<sup>1</sup>

Feed type	Program type					
	IRA	IR	IA	I	R	A
	Cost of medication (\$/ton)					
Starter	5.42	3.26	4.26	2.09	1.16	2.17
Grower	5.26	3.57	4.07	2.37	1.19	1.70

<sup>1</sup>Each observation is the cost of medication reported by 16 production units that had utilized IRA, IR, or IA in the starter or grower feed. Results for January, April, July, and October 1995 to 2000 were combined. The theoretical cost of medicating with I, R, or A alone was then calculated as follows: R = IRA - IA; A = IRA - IR; I = IRA - R - A.

*tenella*) that may be resistant to ION (McDougald et al., 1992).

An ION + ANT combination was more likely to be employed by PU rearing heavy birds (to more than 2.5 kg), whereas an ION + ROX combination was more likely to be employed by those rearing lighter birds (to less than 2.0 kg). Inclusion of ROX in the feed of smaller birds may reflect a desire to ensure satisfactory control of coccidiosis. Although the disease occurs in birds of all ages, less time is available for recovery after infection in birds raised for a shorter period.

Another possible reason for the decline in ANT use is that producers believe these drugs no longer give the growth-promoting benefits observed in the past. In this study, no differences in calorie conversion were observed whether birds were given an ION + ROX + ANT, ION + ROX, or ION + ANT. In controlled trials, supplementation of anticoccidial drugs with ROX and ANT, separately or together, can result in improved body weight gains and feed utilization (Waldroup et al., 1987, 1986a,b). It is difficult, however, to consistently demonstrate these effects (Dilworth and Day, 1985). For example, no change in BW gain or feed utilization was found in broilers given various ANT compared with controls, although processing characteristics, such as dressing percentage and parts yield, were improved (Izat et al., 1990). The precise mechanisms by which antibiotics promote growth when included in the feed are not known, but it is thought that their effect is directed against harmful microorganisms that depress growth (Fuller et al., 1984).

Many factors are known that influence responses to ANT supplementation, including age of the animal, duration of ANT usage, type of ration, nutritional adequacy of the diet, environmental conditions, and management (Hays, 1969; Rosen, 1984). Improvements in live weight gain and feed conversion from use of a growth promoter have been estimated as ranging from 3 to 6% (Armstrong, 1986), but measurable responses vary greatly in magnitude and may be difficult to detect without analysis of many trial results at different times and from various environments (Rosen, 1984).

Regional differences were evident in the use of different drug combinations. An ION + ROX + ANT was used more frequently in the Northeast and Atlantic states (Regions 20 and 30) than in the Central states and the South (Regions 40, 50, and 60). An ION + ROX was used more frequently in the latter areas of the country. Regional differences probably reflect different philosophies concerning the use of drugs by broiler producers whose production units are located in those areas.

Differences in performance were evident for units using different drug combinations. There were no significant differences in calorie conversion, but the number of days to rear birds to 2.27 kg was significantly lower for units that used an ION + ROX + ANT or ION + ANT combination than those that used an ION + ROX. This result suggests a possible advantage in using an ANT, because exclusion from the ration may increase the time required to rear birds to a specific weight and, therefore, increase

the cost of production. Differences in mortality were also evident reflecting the size to which birds were reared. Thus PU that used ION + ROX were more likely to rear smaller birds, and these PU reported the lowest mortality, whereas units using ION + ANT were more likely to rear larger birds and had the highest mortalities.

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