Effects of water-based antimicrobials on growth performance of weanling pigs

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Summary

Objective: To compare growth performance of nursery pigs provided antimicrobials through the feed or water.

Materials and methods: Two experiments were performed using weaned pigs in a randomized complete block design. Experiment One treatments included nonmedicated feed and water; feed containing neomycin sulfate and oxytetracycline (neo-oxy); water containing neomycin sulfate; water containing oxytetracycline; and water containing both neomycin sulfate and oxytetracycline. Experiment Two treatments included nonmedicated feed and water; feed containing neo-oxy; water containing neomycin sulfate at 38.0, 75.5, and 113.5 mg per L; feed containing neomycin sulfate at 157 and 314 mg per kg; and both feed and water containing neo-oxy. Pigs were weighed and feed intake was measured to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency, and water disappearance was measured.

Results: In pigs provided diets containing neo-oxy and pigs provided neomycin sulfate in the water or feed, ADG and ADFI were greater ($P < .048$) than in pigs provided nonmedicated water and feed. Productivity of pigs provided neomycin sulfate did not differ from that of pigs provided neomycin sulfate plus oxytetracycline. However, productivity in Experiment One was better when pigs were treated in feed rather than in water because of a lower than expected dosage delivered in the water.

Implications: Under the conditions in this study, growth performance is better when neomycin sulfate is administered either in the feed or drinking water than when no antimicrobial is provided, with a similar response to both methods of delivery.

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Resumen - Efectos de los antimicrobianos en agua de bebida en el desempeño del crecimiento de cerdos destetados

Objetivo: Comparar el desempeño de crecimiento de cerdos en el destete provistos con antimicrobianos a través del alimento o del agua.

Materiales y métodos: Se realizaron dos experimentos utilizando cerdos destetados en un diseño de bloque completo al azar. Los tratamientos del Experimento Uno incluyeron agua y alimento no medicado; alimento que contenía sulfato de neomicina y oxitetraciclina (neo-oxi); agua que contenía sulfato de neomicina; agua que contenía oxitetraciclina; y agua que contenía ambos sulfato de neomicina y oxitetraciclina. Los tratamientos del Experimento Dos incluyeron agua y alimento no medicado; alimento que contenía neo-oxi; agua que contenía sulfato de neomicina a 38.0, 75.5, y 113.5 mg por L; alimento que contenía sulfato de neomicina a 157 y 314 mg por kg; y ambos, alimento y agua que contenían neo-oxi. Se pesaron los cerdos y se midió el consumo de alimento para determinar la ganancia diaria promedio (ADG por sus siglas en inglés), el consumo de alimento diario promedio (ADFI pos sus siglas en inglés), y la eficiencia del alimento, y se midió la desaparición de agua.

Resultados: En los cerdos provistos con las dietas que contenían neo-oxi y en los cerdos provistos con sulfato de neomicina en agua o alimento, la ADG, y el ADFI fueron mayores ($P < .048$) que en los cerdos provistos con alimento y agua no medicados. La productividad de los cerdos provistos con sulfato de neomicina no difirió de la de los cerdos provistos con sulfato de neomicina más oxitetraciclina. Sin embargo, la productividad en el Experimento Uno fue mejor cuando los cerdos se trataron en alimento en vez del agua debido a una administración menor de la dosis esperada el agua.

Implicaciones: Bajo las condiciones de este estudio, el desempeño del crecimiento es mejor cuando se administra sulfato de neomicina ya sea en el alimento o en el agua de bebida que cuando no se provee ningún antimicrobiano, con una respuesta similar a los dos métodos de administración.

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Résumé - Effets d'antimicrobiens administrés dans l'eau sur les performances de croissance de porcelets au sevrage

Objectif: Comparer les performances de croissance de porcelets en pouponnière recevant des antimicrobiens dans la nourriture ou dans l'eau.

Matériels et méthodes: Des porcelets sevrés ont été utilisés pour réaliser deux expériences selon un plan en blocs aléatoires. Dans l'Expérience 1, les groupes de traitement incluaient: nourriture et eau non-médicamentées; nourriture contenant du sulfate de néomycine et oxytétracycline (néo-oxy); eau contenant du sulfate de néomycine; eau contenant de l'oxytétracycline; et eau contenant sulfate de néomycine et oxytétracycline. Dans l'Expérience 2, les groupes de traitement incluaient: eau et nourriture non-médicamentées; nourriture contenant du neo-oxy; de l'eau contenant du sulfate de néomycine à des concentrations de 38.0, 75.5 et 113.5 mg par L; de la nourriture contenant du sulfate de néomycine à des concentrations de 157 et 314 mg par kg; et de l'eau et de la nourriture contenant du néo-oxy. Les porcs ont été pesés et leur consommation de nourriture mesurée afin de déterminer le gain quotidien moyen (ADG), la consommation journalière moyenne (ADFI), et l'efficacité alimentaire, et on a mesuré également la disparition de l'eau.

Résultats: Chez les porcs recevant une diète contenant de la néo-oxy et les porcs recevant du sulfate de néomycine dans l'eau ou la nourriture, l'ADG et l'ADFI étaient plus élevés ($P < .048$) que chez les porcs recevant l'eau ou la nourriture non-médicamentée. La productivité des porcs recevant du sulfate de néomycine n'a pas différé de celle des porcs recevant du sulfate de néomycine et de l'oxytétracycline. Toutefois, dans l'Expérience 1 la productivité était meilleure lorsque les porcs étaient traités dans la nourriture plutôt que dans l'eau étant donné qu'une quantité moindre que celle attendue est obtenue lors de l'administration par l'eau.

Implications: Dans les conditions expérimentales de cette étude, les performances de croissance sont meilleures lorsque du sulfate de néomycine est administré soit dans la nourriture ou dans l'eau de boisson comparativement à aucune administration d'antimicrobien et ce quelque soit la méthode d'administration.

The use of in-feed antimicrobials in swine diets has long been recognized as a method to improve growth performance and health.[1] Because of increased public awareness and concern regarding in-feed antimicrobial use, however, regulatory agencies around the world have begun to limit the inclusion of antimicrobials in feed.[2] Use is being limited because of potential development of bacterial resistance to antimicrobials that could be used in humans. As a result, many producers and feed manufacturing facilities have considered limiting the use of antimicrobials in swine feeds.

Research indicates that in multi-site swine systems, there is little or no growth response when antimicrobials are fed to finishing pigs, whereas nursery pig growth rate improves when antimicrobials are fed.[3] Because feed consumed by nursery pigs represents approximately 10% of the total feed consumed from weaning to market, limiting use of in-feed antimicrobials to the nursery phase could substantially reduce antimicrobial usage. Unfortunately, research evaluating in-feed antimicrobial alternatives for nursery pigs (eg, yeast, bacteria, organic acids, enzymes, and oligosaccharide products) has failed to indicate that these additives can provide the same growth performance as in-feed antimicrobials.[4,5] Therefore, eliminating in-feed antimicrobial usage during the nursery phase has been avoided because of the biological and economic improvements at risk.

Instead of changing the type of growth-promoting additive for nursery pigs, possibilities exist in simply changing the mode of delivery to allow elimination of antimicrobials from the feed mill. Thus, growth responses could be maintained, while feed mills would benefit from manufacturing simpler diets and from reduced concerns about cross-contamination with nonmedicated feed and contamination of feed for other species with antimicrobial residues.

Water-based antimicrobials previously have been used only for prevention or therapeutic treatment of bacterial disease. We are unaware of any research data that quantifies the production benefits of antimicrobials continuously administered through the water. Therefore, our objective was to compare the growth performance responses of nursery pigs provided antimicrobials through the feed or water.

Materials and methods

Animals and housing

The experimental procedures used in these studies were approved by the Kansas State University Institutional Animal Care and Use Committee. The experiment consisted of two trials conducted at Kansas State University. In Experiment One, a total of 350 weaned pigs (PIC L337 × C22 genotype, both genders), initially weighing 5.9 ± 0.9 kg, were housed five per pen in 70 pens with 0.46 m^2 space per pig. In Experiment Two, a total of 360 pigs (PIC L337 × C22 genotype, both genders), initially weighing 6.4 ± 1.0 kg, were housed five per pen in 72 pens with 0.46 m^2 space per pig. Pigs in both experiments were allowed 3 days adjustment upon arrival at the facility before being weighed and allotted to experimental treatments.

Pigs were housed in an environmentally controlled nursery facility with totally slatted-floor pens (1.52 m × 1.52 m). Environmental temperature was maintained at 29.5°C for the first week on test and then lowered by 1.7C° at the beginning of each subsequent week. Each pen contained one stainless steel four-hole self-feeder and a single nipple drinker (Experiment One) or bowl drinker (Experiment Two) to provide ad libitum access to feed and water. The basal diets were corn-soybean meal-based, fed in a meal form and in two phases from study day 0 to 14 for phase 1 in both experiments and from study day 15 to 28 (Experiment One) or 24 (Experiment Two) for phase 2. The phase 1 diet was formulated to 1.55% lysine and contained 3.75% fish meal with 15% dried whey in Experiment One and 10% dried whey in Experiment Two. The phase 2 diet was formulated to 1.45% lysine with no specialty protein sources.

Water-based medication was administered through peristaltic pumps (SelectDoser; Genesis Instruments, Elmwood, Wisconsin). This type of pump is powered by electricity and siphons a concentrated, premixed stock solution through a tube, metering the medication into the existing water supply. Concentrated stock solutions were made on alternate days throughout the experiment and were metered into the existing water line at a ratio of 1:100 to achieve the desired dosage of antimicrobial in the water. Each pump was checked prior to Experiment One by measuring an amount of water delivered and ensuring that it contained the appropriate amount of stock solution.

Experimental design

Experiment One. All pigs were randomly assigned to five dietary or drinking-water treatments in a randomized complete block design with pig weight as the blocking factor. Two adjacent pens supplied by the same water line served as one experimental unit, with five pigs per pen and seven experimental units (14 pens) per treatment. Pigs received dietary and water treatments for 28 days. The five treatments included a negative control (no antimicrobial in the feed or water), a positive control (neomycin sulfate and oxytetracycline in the feed and no medication in the water), and three treatments providing either neomycin or oxytetracycline or both in the water but no in-feed antimicrobials (Table 1). Pigs that received water-based antimicrobials were fed the negative control diet.

The combination of neomycin sulfate and oxytetracycline (neo-oxy) in the positive control diet was administered as labeled for control of bacterial enteritis. Neomycin sulfate and oxytetracycline were administered in the drinking water in an extra-label manner in an effort to achieve the expected dosages provided by these drugs in the positive control diet. Each concentrated stock solution consisted of 4 L of water and either 50.0 mL of neomycin sulfate solution, 181.4 g of oxytetracycline powder, or a combination of 50.0 mL neomycin sulfate solution and 181.4 g oxytetracycline powder.

Experiment Two. All pigs were randomly assigned to eight dietary or drinking-water treatments in a randomized complete block design with pig weight as the blocking factor. Each pen contained a bowl drinker to allow the use of pen as the experimental unit. There were five pigs per pen and nine experimental units (pens) per treatment. Pigs received dietary and water treatments for 24 days. The eight treatments included a negative control (no antimicrobials in the feed or water), a positive control (neomycin sulfate and oxytetracycline in the feed and no medication in the water), three treatments providing varying doses of neomycin sulfate in the water, two treatments providing varying doses of neomycin sulfate in the feed, and one treatment providing neomycin sulfate in the water and neo-oxy in the feed (Table 1). Pigs that received water-based antimicrobials were fed the negative control diet.

Table 1: Experimental treatments used to compare the growth performance responses of nursery pigs provided antimicrobials through the feed or drinking water

Study group*	In-water medication		In-feed medication	
	Antimicrobial	Concentration (mg/L)	Antimicrobial	Concentration (mg/kg)
Experiment One				
1 (negative control)	None	NA	None	NA
2 (positive control)	None	NA	Neomycin sulfate†	154
			Oxytetracycline†	154
3	Neomycin sulfate‡	25.0	None	NA
4	Oxytetracycline§	25.0	None	NA
5	Neomycin sulfate‡	25.0	None	NA
	Oxytetracycline§	25.0		
Experiment Two				
1 (negative control)	None	NA	None	NA
2 (positive control)	None	NA	Neomycin sulfate†	154
			Oxytetracycline†	154
3	Neomycin sulfate‡	38.0	None	NA
4	Neomycin sulfate‡	75.5	None	NA
5	Neomycin sulfate‡	113.5	None	NA
6	None	NA	Neomycin sulfate¶	157
7	None	NA	Neomycin sulfate¶	314
8	Neomycin sulfate‡	75.5	Neomycin sulfate†	154
			Oxytetracycline†	154

* In Experiment One, each treatment group included seven pairs of pens, with five pigs per pen. Each pair of pens was supplied by a single water line that supplied one nipple drinker per pen. In Experiment Two, each treatment group included nine pens, with five pigs per pen. Each pen contained one bowl drinker.

† Neo/Oxy 10/10; Penfield Animal Health, Omaha, Nebraska.

‡ Agri Laboratories, Ltd, St Joseph, Missouri.

§ Pfizer Animal Health, New York, New York.

¶ Penfield Animal Health, Omaha, Nebraska

NA = not applicable

As in Experiment One, the neo-oxy in the positive control diet was used as labeled for control of bacterial enteritis. Neomycin sulfate was administered in the water (treatments 3, 4, and 5) and in the feed (treatments 6 and 7) in an extra-label manner in order to characterize the response to delivery method and ensure that it was not due to differences in dosage. For administration of neomycin sulfate in treatments 3, 4, and 5, each concentrated stock solution consisted of 4 L of water and either 76, 151, or 227 mL of neomycin sulfate solution.

Response criteria

Pigs and feeders were weighed at Days 0, 7, 14, 21, and 28 during Experiment One and at Days 0, 7, 14, and 24 during Experiment Two to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (gain-to-feed ratio, G:F). An electronic scale with an accuracy of 0.1 kg was used to weigh the pigs and feed. Water disappearance also was measured daily.

Economic analysis

Calculations of feed and antimicrobial costs (FAC) per kg gain and margin over feed and antimicrobial costs (MOF) were based on the feed and antimicrobials consumed over the experimental periods (all currency in $US). Feed costs (FC) were $0.23 per kg for nonmedicated feed and $0.24 per kg for feed containing neo-oxy. Antimicrobial costs (AC) used were $19.28 per L for water-soluble neomycin sulfate solution (200,000 mg neomycin sulfate per L), $0.03 per g for water-soluble oxytetracycline powder (55.1 mg oxytetracycline HCl per g), $14.33 per kg for in-feed neomycin sulfate (220.0 g neomycin sulfate per kg), and $1.39 per kg for in-feed neo-oxy (22.0 g neomycin sulfate, 22.0 g oxytetracycline HCl per kg). FAC were calculated by using the equation FAC = [(FC × overall feed intake per pig) + (AC × antimicrobial concentration in water × overall water disappearance per pig)] ÷ overall gain. Margin over feed and antimicrobial costs was based on market value of $0.94 per kg live weight and calculated by using the equation MOF = (overall gain × $0.94) – FAC per pig.

Statistical analysis

Data from all experiments were analyzed by using an analysis of variance model for a randomized complete block design with treatment as the fixed effect and block as the random effect.[6] The experimental units for analysis of variance were pairs of pens in Experiment One and individual pens in Experiment Two. Data were analyzed by using the Proc Mixed procedure of SAS version 8.1 (SAS Institute, Cary, North Carolina). Preplanned contrasts were used to determine the effects of water-based medication, in-feed medication, or the combination treatment compared with the controls. Linear and quadratic polynomial contrasts were also used in Experiment Two to determine the effects of increasing dosages of water-based or feed-based medication.

Results

Pigs in both experiments experienced transient loose stool during the adjustment period and for the first week of the experiments. For the remainder of both studies, there was no clinical evidence of enteric disease. There was no clinical evidence of respiratory disease during the duration of either experiment.

Experiment One

For the overall treatment period (Days 0 to 28), ADG and ADFI were greater in treatment groups provided water medication than in the negative control group (Table 2). However, ADG and ADFI were greater in the positive control group than in groups provided water medication (Table 2). In addition, ADG and ADFI were greater ($P < .05$) in groups provided water containing neomycin sulfate or neo-oxy than in the negative control group. Average daily gain and ADFI were numerically greater in the group provided water containing oxytetracycline than in the negative controls, and numerically less than in the groups on the other two water medication treatments (Table 2). Average daily gain and ADFI were greater in the positive control group than in all other groups ($P < .05$). There were no differences in growth performance or feed efficiency among the three water-based treatments.

In pigs provided water-based antimicrobials or neo-oxy in the feed (positive control), MOF was greater ($P < .01$) than in the negative control group (Table 2). There was no difference in MOF for the positive control group and the group provided neomycin sulfate in the water (Table 2). FAC and MOF were greater for the positive control group than for the groups provided oxytetracycline or neo-oxy in the water (Table 2). Water disappearance averaged 30.1% of BW during the overall treatment period (Table 3); however, a numerical increase in water disappearance was observed with the addition of antimicrobials to the drinking water supply.

Experiment Two

For the overall treatment period (Days 0 to 24), ADG ($P < .05$) and ADFI ($P < .05$) were greater in the positive control group and in groups provided neomycin sulfate in the water or in the feed than in the negative control group (Tables 4 and 5). In groups provided neomycin sulfate in the water or feed, G:F tended to be greater ($P < .10$) than in the negative control group. In groups provided the combination of the positive control diet and neomycin sulfate in the water at 75.5 mg per L, ADFI was greater ($P < .05$) and ADG tended to be greater ($P < .10$) than in groups provided the positive-control diet with nonmedicated water or groups provided the negative-control diet with neomycin sulfate in the water at 75 mg per L. As the dosage of neomycin sulfate in the water or feed increased across treatment groups, ADG ($P < .05$) and ADFI ($P < .05$) increased linearly, with most of the response at the lowest dosage. There were no differences in growth performance between pigs provided neomycin sulfate in the water and in the feed.

The MOF for groups provided neomycin sulfate or neo-oxy in the feed or neomycin sulfate at 38.0 mg per L of water was greater ($P < .05$) than for the negative control group. In addition, MOF was greater in groups provided neomycin sulfate in the feed than in groups provided neomycin sulfate in the water ($P < .01$).

Water disappearance in Experiment Two was lower than in Experiment One. In this experiment, in which bowl drinkers were provided, water disappearance was relatively similar throughout the trial with an overall average (Days 0 to 24 after weaning) of 23.9% of BW per pig (Table 6).

Discussion

When antimicrobials were added to the feed, ADG and ADFI were higher in both experiments, as in previous research.[3,4] In Experiment One, growth performance

Table 2: Growth performance measures (least squares means) in early-weaned nursery pigs provided water-based medication during Days 0 to 28 of Experiment One, costs of feed and treatment, and margin over costs*

Variable	Negative control†	Positive control†	Water medication‡ Neo	Water medication‡ Oxy	Water medication‡ Neo-oxy	*P* for preplanned contrasts: Treatment	*P*: Water medication versus Negative control	*P*: Water medication versus Positive control	SE
ADG (g)	436[a]	492[b]	464[c]	453[ac]	463[c]	< .01	< .01	< .01	10.02
ADFI (g)	598[a]	670[b]	633[c]	614[ac]	629[c]	< .01	.02	< .01	12.90
G:F	0.73	0.74	0.73	0.74	0.74	.79	.29	.96	0.010
FAC ($)§	0.11[a]	0.12[b]	0.10[a]	0.10[a]	0.10[a]	< .01	.73	< .01	0.002
MOF ($)¶	8.37[a]	9.28[b]	8.93[bc]	8.80[c]	8.88[c]	< .01	< .01	.02	0.199

* A total of 350 weanling pigs, initially 5.9 ± 0.9 kg and 21 ± 3 days of age (PIC L337 × C22), were housed five per pen, with 14 pens per treatment. Each mean consists of seven experimental units (pairs of pens, each pair served by one water line).

† Negative control: no antimicrobials in feed or water; positive control, feed containing 154 mg/kg neomycin sulfate and 154 mg/kg oxytetracycline HCl and nonmedicated water.

‡ Neo: neomycin sulfate, 25.0 mg/L of water; Oxy: oxytetracycline HCl, 25.0 mg/L of water; Neo-oxy: neomycin sulfate, 25.0 mg/L of water and oxytetracycline HCl, 25.0 mg/L of water.

§ Feed and antimicrobial costs per kg of gain (FAC) based on cost of $19.28/L for water-based neomycin sulfate solution (200 mg/mL); and cost of $0.03/kg for water-soluble oxytetracycline powder (55.1 mg oxytetracycline HCl/g). Assumes cost of negative-control feed at $0.23/kg and cost of positive-control feed at $0.24/kg. Assumes market price of $0.94/kg. All currency in $US.

¶ Margin over feed and antimicrobial costs (MOF) calculated as (gain × $0.94/kg) – (feed and water cost per pig).

[abc] Means in the same row with no common superscript differ ($P < .05$; analysis of variance).

Table 3: Disappearance and calculated consumption per kg of bodyweight (BW) of neomycin sulfate in drinking water in a group of nursery pigs treated for 28 days (Experiment One)*

Study day	Mean weight (kg)	Water disappearance (% of BW)	Neomycin sulfate (mg/kg BW) Disappearance	Neomycin sulfate (mg/kg BW) Consumption†
0 to 7	6.58	38.0	9.49	2.50
8 to 14	8.78	32.8	8.20	2.50
15 to 28	14.25	24.8	6.21	2.50
0 to 28	10.97	30.1	7.53	2.50

* A total of 350 weanling pigs (PIC L337 × C22), initially 5.9 ± 0.9 kg and 21 ± 3 days of age. Each value is the mean of 14 experimental units (28 pens) provided 250 mg neomycin sulfate per L of drinking water.

† Calculation of medication consumption is based on water consumption estimated as 10% of BW.

measures in pigs provided water-based antimicrobials were numerically lower than in pigs provided in-feed antimicrobials, and numerically higher than in pigs provided nonmedicated feed and water. There were no significant differences in growth performance among groups on water-based antimicrobial treatments in Experiment One, and there was no additive benefit when oxytetracycline was used with neomycin sulfate in the water. Therefore, we used only neomycin sulfate for water-based antimicrobial treatments in Experiment Two. Growth performance in Experiment One was intermediate in the group provided water-based neomycin sulfate at a dosage of 25.0 mg per L of water; therefore, higher dosages were used in Experiment Two. Growth performance in pigs provided water-based neomycin sulfate at all dosages in Experiment Two was similar to that of pigs provided in-feed antimicrobials.

We believe the major difference in the response to water-based neomycin sulfate between the two experiments is due to the difference in dosage calculation and, thus, delivered antimicrobial concentration. Calculation of water-based antimicrobial concentrations in Experiment One were based on a predicted water disappearance of 10% of BW, which was based on the estimated water intake requirement of nursery pigs.[7] However, in Experiment One, we assumed that water intake would be efficient, and did not account for wastage. As a result of our underestimation of wastage, pigs did not receive the desired dosage of water-based antimicrobial per kg of BW and thus growth performance was intermediate in Experiment One. In Experiment Two, calculations of water-based antimicrobial concentrations were based on an estimated intake of 10% of BW, rather than on water disappearance.

The desired dosage of water-based antimicrobial for each experiment was intended to be similar to the dosage of neomycin sulfate provided by the neo-oxy in-feed treatment in each experiment, which provided 154 mg per kg neomycin sulfate. Overall ADFI for this treatment in Experiment One indicates that pigs consumed 9.11 mg of neomycin sulfate per kg of BW each day. However, assuming an estimated water intake of 10% of BW, pigs treated with neomycin in the water in Experiment One consumed 2.50 mg of neomycin sulfate per kg of BW each day. Their lower growth performance measures can be explained in part by this direct comparison. Pigs provided water-based neomycin sulfate consumed 73% less antimicrobial per kg of BW than did pigs provided in-feed neomycin sulfate, and therefore growth rate was significantly lower. The lower calculated antimicrobial consumption in water-based treatments was not correlated with lower feed or water intake, but simply with an inadequate dosage in the drinking water.

In Experiment Two, ADG was similar in pigs provided 3.80 mg of neomycin sulfate per kg of BW through the water (assuming water intake of 10% of BW) and pigs provided in-feed treatments of 8.05, 8.20, and 16.39 mg of neomycin sulfate per kg

Table 4: Growth performance measures (least squares means) in early-weaned nursery pigs provided neomycin sulfate in the drinking water and feed during Days 0 to 24 of Experiment Two, costs of feed and treatment, and margin over costs*

Variable	Negative control†	Positive control†	Neomycin sulfate (mg/L water)			Neomycin sulfate (mg/kg feed)		Combo‡
			38.0	75.5	113.5	157	314	
ADG (g)	368[a]	405[bc]	414[bc]	402[b]	410[bc]	411[bc]	424[bc]	432[c]
ADFI (g)	485[a]	519[b]	528[bc]	512[ab]	528[bc]	531[bc]	535[bc]	556[c]
G:F	0.76	0.78	0.79	0.79	0.78	0.78	0.79	0.78
FAC ($)§	0.25[a]	0.25[a]	0.26[a]	0.29[b]	0.32[c]	0.20[a]	0.26[a]	0.30[bc]
MOF ($)§	6.09[a]	6.66[bc]	6.73[bc]	6.24[ab]	6.11[a]	6.76[bc]	6.92[c]	6.60[bc]

* A total of 360 weanling pigs, initially 6.4 ± 1.0 kg and 21 ± 3 days of age (PIC L337 × C22). Treatments included antimicrobials in the feed or water consumed over the 24-day experimental period. Values are the mean of nine replications.

† Negative control: no antimicrobial in the feed or water; Positive control: feed containing neomycin sulfate (154 mg/kg) and oxytetracycline HCl (154 mg/kg).

‡ Drinking water containing neomycin (75.5 mg/L); feed containing neomycin sulfate (154 mg/kg) and oxytetracycline HCl (154 mg/kg).

§ Feed and antimicrobial costs per kg of gain (FAC) based on cost of $19.28/L for water-based neomycin sulfate solution (200 mg/mL); cost of $14.33/kg for feed-based neomycin sulfate (220.5 g/kg); and cost of $1.39/kg for feed-grade combination of neomycin sulfate (22.0 g/kg) and oxytetracycline (22.0 g/kg). Assumes cost of negative-control feed at $0.23/kg and cost of positive-control feed at $0.24/kg. Assumes market price of $0.94/kg. All currency in $US.

[abc] Values in the same row with no common superscript differ ($P < .05$; analysis of variance)

Table 5: Probability values (P) for growth performance of early-weaned nursery pigs provided neomycin sulfate (neo) in the water and feed for 24 days (Experiment Two)*

	Probability†												
	Neg control versus			Pos control versus					Water med		Feed med		
Variable	Pos control	Water med	Feed med	Water med	Feed med	Combo	Combo versus water neo 75.5 mg/L	Feed med versus water med	Lin	Quad	Lin	Quad	SE
ADG (g)	.02	< .01	< .01	.77	.35	.09	.06	.38	.03	.08	< .01	.24	12.07
ADFI (g)	.048	< .01	< .01	.82	.34	.04	.02	.32	.04	.27	< .01	.15	15.71
G:F	.15	.04	.05	.79	.78	.87	.57	.98	.20	.11	.03	.96	0.011
FAC ($)‡	.72	< .01	.36	< .01	.60	< .01	.11	< .01	< .01	.06	.29	.99	0.003
MOF ($)‡	.04	.24	< .01	.19	.47	.83	.19	< .01	.62	.06	< .01	.29	0.280

* Experimental design and controls described in Table 4. Neg = negative control; Pos = positive control; Med = medication; Neo = neomycin; Combo = neo and oxytetracycline in the feed plus neo in the water.

† Linear (Lin) and quadratic (Quad) polynomial contrasts were used to determine the effects of increasing dosages of water-based or feed-based medication. Other data were analyzed by using an analysis of variance model.

‡ Calculations described in Table 4.

Table 6: Disappearance and calculated consumption per kg of bodyweight (BW) of neomycin sulfate provided in drinking water at three dosages in a group of nursery pigs treated for 24 days (Experiment Two)*

Study days	Mean weight (kg)	Water disappearance (% of BW)	Neomycin sulfate (mg/kg BW)					
			Disappearance			Consumption†		
			38.0 mg/L	75.5 mg/L	113.5 mg/L	38.0 mg/L	75.5 mg/L	113.5 mg/L
0 to 7	7.10	22.0	7.86	16.51	34.39	3.80	7.55	11.35
8 to 14	9.28	27.6	10.10	23.09	37.07	3.80	7.55	11.35
15 to 24	13.47	22.1	7.80	19.74	25.64	3.80	7.55	11.35
0 to 24	9.95	23.9	8.59	19.78	32.37	3.80	7.55	11.35

* A total of 360 weanling pigs, initially 6.4 ± 1.0 kg and 21 ± 3 days of age (PIC L337 × C22). Each value is the mean of two replications.

† Calculation of medication consumption is based on water consumption estimated at 10% of BW.

of BW. These data indicate that growth performance of pigs receiving neomycin sulfate was better regardless of whether feed or water carried the antimicrobial.

Water intake and disappearance are very different, although the terms may be used interchangeably. Intake is the consumption of water by the pig, whereas water disappearance is the overall usage of water, including intake and wastage. True water intake by pigs is usually overestimated because wastage is generally not taken into account.[8] Data on water wastage is limited, but differences have been observed by using different drinker types.[9] Nipple drinkers waste 50% more than bowl drinkers, but growth performance does not change with different drinker types.[9] When drinkers are used by the pig in a manner that the designer had not intended, wastage can occur.[10] For example, some nipple drinkers are designed to be activated from a forward angle, whereas others can be used from almost any angle. Also, in densely stocked pens containing unguarded drinkers, it is common for pigs to make unintentional contact with the nipple, causing unconsumed water flow. Researchers have measured feed disappearance in growth trials knowing that there is a small percentage of waste. Even so, it is common for feed intake, and thus feed efficiency, to be calculated with wastage included. Because the percentage of wasted feed is small, usually 5% to 6%,[11,12] it is adequate to use this method to determine intake. Water wastage is much greater, however, accounting for 25% to 60% of overall water disappearance[10,13] depending on drinker type, height, and water flow rate. Because the percentage of wasted water is relatively large and variable, water-additive calculations must be based on established or carefully estimated water intake.

Water utilization by weanling pigs has been researched,[7,14-17] but estimates for intake requirements are variable. Gill et al (1986)[15] found that water intake during the first week after weaning averaged 0.49 L per day, whereas Pedersen (1994)[16] determined the water requirement for weanling pigs to be between 1 and 5 L per day. Because of this variation, as well as the use of different facilities and drinking systems throughout the swine industry, these values are difficult to utilize when calculating water medication rates for large numbers of pigs using self-operated drinkers. Furthermore, researchers have struggled with the quandary of how to consistently express water utilization in pigs. Water intake has been reported as 0.49 to 5.0 L per day for weanling pigs,[7,14-17] 2.0 to 3.0 water:feed ratio (weight:weight) for growing pigs,[8,13] and 80 mL per kg of BW for growing-finishing pigs.[13] Because of the variation in established data, especially for nursery pigs, we chose to evaluate the referenced studies on an equivalency basis and express water intake as percentage of BW. Thus, average water intake was converted to kg (assuming that 1 L of water equals 1 kg), and this was divided by average BW (kg) of the pigs to derive water intake as a percentage of BW. By using the data for body weight and measured intake per day reported in these studies, estimates for water intake of pigs in different stages of production can be calculated within the range of 7% to 10% of BW. Although we did not determine water intake, this was the justification for using the 10% of BW for actual water intake in the calculations of dose per kg of BW.

In Experiment One, unguarded nipple drinkers were used and water disappearance was 30.1% of BW for the overall period. As a result of installing new bowl drinkers for Experiment Two, overall water disappearance decreased to 23.9% of BW. Similar improvements were observed by Brumm and Heemstra (1999)[9] comparing bowl and nipple drinkers. Although water wastage, and thus disappearance, are independent of antimicrobial intake and growth performance, there are considerable effects on the cost and efficiency of delivery for water-based antimicrobials.

Margin over feed and antimicrobial costs were not different for pigs provided in-feed antimicrobials and pigs provided low dosages of water-based neomycin sulfate (25.0 and 38.0 mg per L in Experiments One and Two, respectively). In Experiment Two, however, when neomycin sulfate was included in the water at higher dosages (75.5 and 113.5 mg per L), MOF tended to be similar to that of the negative control group. This was due to the lack of improvement in growth rate with increasing dosages, and thus cost, of neomycin sulfate in the water. Increasing dosage of neomycin sulfate in the feed increased MOF mainly due to the lower cost of in-feed neomycin sulfate compared to water-based neomycin sulfate ($0.07 versus $0.10 per g, respectively).

Although the greatest numerical growth rate was observed in pigs provided the combination treatment that included in-feed neo-oxy and water-based neomycin sulfate (75.5 mg per L), MOF was intermediate in this treatment group due to the greater cost of water-based and in-feed medication used simultaneously.

While the objective of these studies was to characterize responses to antimicrobials administered using different delivery methods, some treatments resulted in extra-label use of the products. Local regulations regarding extra-label use should be followed before implementation of these results in production settings.

In conclusion, when the higher dosage water-based neomycin sulfate was used (Experiment Two), growth performance of nursery pigs was similar to that of pigs provided in-feed antimicrobials. At low dosages of neomycin sulfate in the water, MOF is not different than for in-feed antimicrobial delivery. In these experiments, the optimum dosage of water-based neomycin sulfate for growth promotion and economic return appeared to be ≥ 25.0 mg per L and ≤ 38.0 mg per L of water. In production systems where feed mills are antimicrobial-free or where producers use antimicrobials for therapeutic treatment, growth-performance benefits can be achieved from water-based neomycin sulfate.

Implications

- Under the conditions of this study, growth performance measures were better in pigs treated with water-based neomycin sulfate than in pigs provided nonmedicated feed and water.
- When adequate dosages are provided, growth performance of pigs does not differ whether neomycin sulfate is provided through the water or feed.
- Under the conditions of this study, there was no difference in MOF whether pigs were provided low dosages of water-based neomycin sulfate (25 to 38 mg per L) or in-feed neomycin sulfate.

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