Evaluation of Organic and Inorganic Acids in Various Feeding Programs as Alternatives to Antibiotic Growth Promoters for Nursery Pigs

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Introduction

During the past 50 years, nursery pig diets have been fortified with various antibiotics in prophylactic doses against gastrointestinal disorders and to obtain the economic benefits in terms of improved growth rates (4 to 15%) and feed efficiency (2 to 6%; Mroz, 2003).

However, in recent years there has been growing public concern about the use of antibiotics in animal agriculture and the risk of developing cross-resistance of pathogens to antibiotics used in human therapy. This has prompted the swine industry to seek out alternatives to antibiotics that will give similar pig performance. The objective of this study was to evaluate the potential of organic and inorganic acids in various feeding programs as alternatives to a growth promotion antibiotic in nursery pig diets.

Materials and Methods

Three hundred pigs were weaned at 17.7 days of age and were assigned to one of six treatments. Pigs were allotted based on genetics, sex and initial body weight. Treatments were as follows; A) Basal diet, no antibiotics (negative control); B) Basal diet plus Carbadox at 45.4g/ton (50 ppm; positive control); C) .4% Organic acid blend added to Diet A by substituting for corn; D) .2% Inorganic acid based blend added to Diet A by substituting for corn; E) Crossover 1 diet, .4% organic acid blend for the first week of the study followed by .2% inorganic acid based blend for the remaining four weeks of the study; F) Crossover 2 diet, .2% inorganic acid based blend for the first week of the study followed by the .4% organic acid blend for the remaining four weeks of the study.

Pigs were weighed and feed intake was recorded weekly during the five-week trial. There were ten pigs per pen (2.33 sq. ft./pig) and five pens per treatment. All pigs had unlimited access to feed and water through a five-hole self feeder and a single nipple waterer in each pen. Phase 1 diets were fed from day 0 to 7 (Table 1), Phase 2 diets were fed from day 7 to 21 (Table 2), and Phase 3 diets were fed from day 21 to 35 (Table 3). All diets were formulated to meet or exceed the nutrient requirements for each phase of growth based on NRC (1998). Experimental treatments were continued during all three phases.

Three pigs per pen had fresh feces samples collected at day 32 of the study for measurement of fecal pH. These three samples were then pooled on an equal weight basis to form a pen composite that was plated for *E. coli* and salmonella.

The procedure used for plating *E. coli* and salmonella were as follows:

A 1g sub-sample of each pen composite fecal sample was mixed into 9 mL of peptone broth, serially diluted and used to inoculate MacConkey agar plates for *E. coli* isolation. The *E. coli* plates were inoculated at 3 dilutions and in triplicate at each dilution (10^3, 10^4 and 10^5 cfu/µg). The MacConkey agar plates were then incubated for 24 h at 98.6 ^{o}F, and following removal from the incubator *E. coli* colonies were immediately counted.

For salmonella, the serially diluted peptone broth tubes were then incubated overnight at 98.6 °F, and 1 mL was then transferred to 9 mL tetrathionate broth and incubated for 48 h at 107.6 °F. From these tubes, 1 mL was used to inoculate Pappaport Vassiliadis broth and incubated for 48 h at 107.6°F. The Pappaport broth was then used to inoculate XLT4 plates for salmonella isolation. Salmonella was then presumptively identified using LIA and TSI agar tubes.

Results

Growth performance. At the beginning of this study, there were no significant differences in initial bodyweight in pigs among the different treatments (Table 4). Throughout Phase 1 of the study (d 0 to d 7), there was no effect (P<.05) of dietary treatment on ADG, ADFI, feed efficiency, or d 7 body weights.

During Phase 2 of the study (d 7 to d 21), the ADG of pigs fed the carbadox diet was similar to the ADG of pigs fed the crossover 1 diet sequence. Both of these treatments tended to be higher than the ADG of pigs on all other treatments (P<.10), with the exception of the crossover 2 treatment which was intermediate. Pigs fed the crossover 1 diet sequence had the highest ADFI during this period that was similar to the ADFI of pigs fed the carbadox diet (P>.10). The feed intake of the crossover 1 treatment was significantly higher than the ADFI of pigs being fed the crossover 2 diet (P<.05) and tended to be higher than the ADFI of pigs fed the organic acid blend treatment (P<.10). Pigs fed the carbadox diet tended (P<.10) to have greater ADFI than pigs fed the organic acid blend and crossover 2 treatments. The feed conversion efficiency of pigs being fed the crossover 2 diet sequence and the carbadox treatment tended to be higher than the feed conversion efficiency of pigs being fed the negative control diet (P<.10), with all other acid treatments being intermediate. At day 21, there tended to be a difference in bodyweight between treatment groups, with the pigs fed the crossover 1 diet weighing more than pigs being fed the organic acid blend diet (P<.10).

Results from Phase 3 of the study (d 21 to d 35) show that there was a significant effect of dietary treatment on ADG, ADFI and weight at day 35 (P<.05). Pigs fed the medicated diet had significantly higher ADG (P<.05) than pigs on all other dietary treatments with the exception of pigs fed the crossover 1 diet, which had similar ADG to the pigs fed carbadox. Pigs fed the crossover 1 diet also tended to have greater ADG (P<.10) than pigs fed the other acid treatments and the negative control. Pigs fed the crossover 1 diet and the carbadox diet had similar ADFI at this time period, and both of these treatments had significantly higher ADFI than pigs fed the crossover 2 diet and the inorganic acid based blend diet (P<.05). In addition, they both tended to have greater ADFI (P<.10) than pigs fed the organic acid treatment. Pigs fed the negative control diet also tended to have higher ADFI (P<.10) than the pigs fed the crossover 2 diet. The feed conversion efficiency of pigs fed the crossover 2 diet (P<.05) and the carbadox diet (P<.10) were better than pigs fed the negative control diet. At day 35, pigs fed the crossover 1 diet and the carbadox diet tended to have heavier bodyweights than pigs on any other treatment (P<.10).

Overall, the pigs fed the carbadox diet and the crossover 2 diet had significantly higher ADG than all other treatment groups (P<.05). The ADFI of these two groups was also significantly higher than all other acid treatment groups (P<.05), and tended to be higher than the pigs fed the negative control treatment (P<.10). Numerically, the carbadox treatment group had the most favorable feed efficiency for the entire study, however, statistically there were no differences among treatment groups in feed efficiency.

Bacteria counts. E. coli and salmonella colonies shed were determined from fecal samples taken on day 32 of the study. There was no significant effect of treatment on either *E. coli* or salmonella fecal shedding at this time point among dietary treatments (Table 5). Numerically, pigs fed the crossover 1 diet shed the most *E. coli* colonies and pigs fed the crossover 2 diet shed the least. The presence of unidentified bacteria was also quantified at this time. There were no differences in the amount of this bacteria shed among dietary treatments. The presence of salmonella was only noted in pigs fed the crossover 2 diet and the negative control diet. In each of these treatment groups there was a 20% positive occurrence for salmonella.

Fecal pH values were also determined from samples taken on day 32 of the study (Table 5). The fecal pH of pigs fed the crossover diet 1 tended to be higher than the fecal pH of pigs fed the negative control diet, inorganic acid based blend, and the crossover 2 diets (P<.10).

Discussion

The objective of this study was to evaluate the use of organic and inorganic acid based blends in various crossover feeding programs and their potential as alternatives to antibiotics in nursery pig diets. The results from this study demonstrate that the use of organic and inorganic acid based blends in crossover feeding programs can enhance the growth performance of the nursery pig. It has been previously reported that the addition of antibiotic growth promoters to the diet can significantly increased the growth performance of the nursery pig over diets containing no antibiotics. In this study, in concurrence with previous results, the overall growth performance of pigs fed a diet containing carbadox was significantly higher than the growth performance of the pigs that were fed no antibiotic growth promoters. It was also found that the growth performance of pigs fed the crossover 1 diet, which sequenced organic acid blend for the first 7 days followed by inorganic acid bawed blend for 28 days, was similar to that of pigs fed the carbadox diet, and this growth performance was significantly higher than pigs on all other acid treatments or the negative control treatment. Consequently, these results would lead us to believe that feeding an organic acid blend diet for the first week followed by four weeks of an inorganic based blend diet has similar effects on nursery pigs as feeding carbadox. A possible reason why the crossover 1 diet was superior to the crossover 2 diet may be the sequence in which the acids were fed. During Phase 1, the average of the organic acid treatments ADFI is higher than the inorganic acid fed pigs. But intake is suppressed by the organic acid blend through Phase 2 and both acids have reduced feed intake in Phase 3. The higher inclusion rate of acid in the organic acid blend diet may also be a contributing factor (0.4% vs. 0.2%) to the reduced growth performance and feed intake. Additionally, the organic acid during Phase 1 may help establish beneficial bacterial populations (i.e. lactobacillus, etc.), and then sequencing with inorganic acids during Phases 2 and 3 may help reduce the *E. coli* populations and assist with the digestion of a simpler diet containing more corn and soybean meal in Phases 2 and 3 diets.

Even though *E. coli* shedding on d 32 between treatments groups was not significantly different, all *E. coli* counts were less than the negative control with the exception of the crossover 1 diet. These results indicate that the acid blend diets have similar or may be even greater effects than carbadox in the control of *E. coli* shedding. The presence of the unidentified bacteria at this time point is also of interest. There is perhaps a competitive exclusion relationship existing between the *E. coli* population and these bacteria because as *E. coli* goes down the unknown bacteria tends to grow in population. Further research is needed to identify this bacteria and its' possible relationship with *E. coli.*

Implications

The use of organic acid and inorganic acid based blends in a crossover program in nursery pig diets has been demonstrated in this study to have similar benefits to the use of carbadox and therefore can be considered as a viable alternative to antibiotic use. Further research is needed to validate the positive response observed in this study for the sequence of organic followed by inorganic acids in nursery pig diets. Additional research also is needed to evaluate the potential for additive benefits of using dietary acids with antibiotics in nursery pig diets.

References

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Table 1. Composition of Phase 1 experimental nursery pig diets

	Neg. Control	Carbadox	Organic acid	Inorganic acid
Ingredients, %				
Corn	38.40	37.93	37.67	38.03
SBM, 48%CP	20.30	20.30	20.30	20.3
Soybean oil	5.00	5.20	5.30	5.15
Limestone	0.58	0.58	0.58	0.58
Dical.Phos	0.90	0.90	0.90	0.90
Vitamin premix[a]	0.25	0.25	0.25	0.25
TM premix[b]	0.125	0.125	0.125	0.125
Salt	0.20	0.20	0.20	0.20
Fishmeal	4.00	4.02	4.03	4.02
Dried whey	25.00	25.00	25.00	25.00
Plasma protein	5.00	5.00	5.00	5.00
Lysine-HCL	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10
Carbadox-10	---	0.25	---	---
Organic Acid Blend	---	---	0.40	---
Inorganic Acid Based Blend	---	---	---	0.20
Se 600	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated composition				
ME, kcal/lb	1598	1598	1598	1598
Lysine, %	1.55	1.55	1.55	1.55
Meth., %	0.45	0.45	0.45	0.45
M + C, %	0.89	0.89	0.89	0.89
Thre., %	1.01	1.01	1.01	1.01
Tryp., %	0.29	0.29	0.29	0.29
Ca, %	0.90	0.90	0.90	0.90
P, %	0.80	0.80	0.80	0.80
Analyzed composition				
Carbadox, g/ton	<1.00	42.9	<1.00	<1.00

[a] Trace mineral premix provided per lb of diet: Iron, 55 mg; Zinc, 55 mg; Manganese, 6.8 mg; Copper, 5.1 mg; Iodine, .21 mg.

[b] Vitamin premix provided per lb of diet: vitamin A, 2750 IU; vitamin D_3, 275 IU; vitamin E, 20 IU; menadione, .907 mg; vitamin B_{12}, 15.9 μg ; riboflavin, 3.22 mg ; d-pantothenic acid, 9.97 mg; niacin, 14.97 mg.

Table 2. Composition of Phase 2 experimental nursery diets

	Neg. control	Carbadox	Organic acid	Inorganic acid
Ingredients, %				
Corn	45.34	44.87	44.59	44.96
SBM, 48%	28.40	28.40	28.40	28.40
Soybean oil	5.00	5.18	5.31	5.15
Limestone	0.51	0.51	0.51	0.51
Dical.Phos	0.80	0.80	0.80	0.80
Vitamin premix[a]	0.25	0.25	0.25	0.25
TM premix[b]	0.125	0.125	0.125	0.125
Salt	0.30	0.30	0.30	0.30
Fishmeal	4.00	4.04	4.04	4.03
Dried whey	15.00	15.00	15.00	15.00
Plasma protein	---	---	---	---
Lysine-HCL	0.125	0.125	0.125	0.125
Methionine	0.07	0.07	0.07	0.07
Carbadox-10	---	0.25	---	---
Organic Acid Blend	---	---	0.40	---
Inorganic Acid Based Blend	---	---	---	0.20
Se 600	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated composition				
ME, kcal/lb	1597	1597	1597	1597
Lysine, %	1.40	1.40	1.40	1.40
Meth., %	0.43	0.43	0.43	0.43
M + C, %	0.79	0.79	0.79	0.79
Thre., %	0.90	0.90	0.90	0.90
Tryp., %	0.27	0.27	0.27	0.27
Ca, %	0.80	0.80	0.80	0.80
P, %	0.70	0.70	0.70	0.70
Analyzed composition				
Carbadox, g/ton	<1.00	45.2	<1.00	<1.00

[a] Trace mineral premix provided per lb of diet: Iron, 55 mg; Zinc, 55 mg; Manganese, 6.8 mg; Copper, 5.1 mg; Iodine, .21 mg.

[b] Vitamin premix provided per lb of diet: vitamin A, 2750 IU; vitamin D_3, 275 IU; vitamin E, 20 IU; menadione, .907 mg; vitamin B_{12}, 15.9 µg ; riboflavin, 3.22 mg ; d-pantothenic acid, 9.97 mg; niacin, 14.97 mg.

Table 3. Composition of Phase 3 experimental nursery diets

	Neg. control	Carbadox	Organic acid	Inorganic acid
Ingredients, %				
Corn	59.93	59.45	59.13	59.50
SBM, 48% CP	33.65	33.70	33.75	33.70
Soybean oil	---	---	---	---
Swine grease	3.00	3.18	3.3	3.18
Limestone	0.83	0.83	0.83	0.83
Dical.Phos	1.62	1.62	1.62	1.62
Vitamin premix[a]	0.25	0.25	0.25	0.25
TM premix[b]	0.125	0.125	0.125	0.125
Salt	0.35	0.35	0.35	0.35
Fishmeal	---	---	---	---
Dried whey	---	---	---	---
Plasma protein	---	---	---	---
Banmith	0.10	0.10	0.10	0.10
Lysine-HCL	0.10	0.10	0.10	0.10
Methionine	---	---	---	---
Carbadox-10	---	0.25	---	---
Organic Acid Blend	---	---	0.40	---
Inorganic Acid Based Blend	---	---	---	0.20
Se 600	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated composition				
ME, kcal/lb	1553	1553	1553	1553
CP, %	21.00	21.00	21.00	21.00
Lysine, %	1.25	1.25	1.25	1.25
Meth., %	0.325	0.325	0.325	0.325
Ca, %	0.80	0.80	0.80	0.80
P, %	0.70	0.70	0.70	0.70
Analyzed composition				
Carbadox, g/ton	<1.00	45.8	<1.00	<1.00

[a] Trace mineral premix provided per lb of diet: Iron, 55 mg; Zinc, 55 mg; Manganese, 6.8 mg; Copper, 5.1 mg; Iodine, .21 mg.

[b] Vitamin premix provided per lb of diet: vitamin A, 2750 IU; vitamin D_{3}, 275 IU; vitamin E, 20 IU; menadione, .907 mg; vitamin B_{12}, 15.9 μg ; riboflavin, 3.22 mg ; d-pantothenic acid, 9.97 mg; niacin, 14.97 mg.

Table 4. The effects of dietary acids on the growth performance of nursery pigs

	Negative control	Carbadox	Organic acid[1]	Inorganic acid[2]	Crossover 1[3]	Crossover 2[4]	SE
Pens/trt	5	5	5	5	5	5	
Pigs/pen	10	10	10	10	10	10	
Initial weight, lbs	12.44	12.45	12.45	12.43	12.40	12.42	.0252
Phase 1 (d 0 to 7)							
ADG, lbs	0.182	0.204	0.205	0.210	0.238	0.154	.0349
ADFI, lbs	0.308	0.384	0.334	0.366	0.394	0.334	.0319
G:F	0.586	0.506	0.566	0.568	0.618	0.460	.0677
d 7 weight, lbs	13.70	13.86	13.68	13.90	14.08	13.52	.2313
Phase 2 (d 7 to 21)							
ADG, lbs	0.510[b]	0.594[a]	0.502[b]	0.500[b]	0.588[a]	0.518[ab]	.0302
ADFI, lbs	0.946[xyab]	0.976[xya]	0.856[xyb]	0.904[xyab]	0.994[xa]	0.846[by]	.0425
G:F	0.542[b]	0.614[a]	0.590[ab]	0.554[ab]	0.588[ab]	0.610[a]	.0235
d 21 weight, lbs	20.87[ab]	22.17[ab]	20.70[b]	20.89[ab]	22.31[a]	20.76[ab]	.5799
Phase 3 (d 21 to 35)							
ADG, lbs	0.846[yzb]	0.922[xa]	0.836[zb]	0.814[zb]	0.906[xya]	0.830[zb]	.0221
ADFI, lbs	1.59[xyab]	1.64[xa]	1.53[xyzbc]	1.50[yzbc]	1.63[xa]	1.47[zc]	.0375
G:F	0.532[yb]	0.562[xya]	0.546[xyab]	0.544[xyab]	0.554[xyab]	0.568[xa]	.0106
d 35 weight, lbs	32.69[b]	35.08[a]	32.39[b]	32.27[b]	34.97[a]	32.37[b]	.7224
Overall (d 0 to 35)							
ADG, lbs	0.578[y]	0.648[x]	0.566[y]	0.566[y]	0.644[x]	0.574[y]	.0239
ADFI, lbs	1.03[xyb]	1.12[xa]	1.02[yb]	1.01[yb]	1.13[xa]	0.99[yb]	.0312
G:F	0.566	0.580	0.558	0.558	0.572	0.574	.0107

[1] Organic acid blend was included at .4% of the diet, Kemin Americas, Inc.
[2] Inorganic acid based blend was included at .2% of the diet , Kemin Americas, Inc.
[3] Crossover 1: organic acid blend included at .4% of the diet for the first week followed by inorganic acid based blend included at .2% of the diet for the remaining four weeks.
[4] Crossover 2: inorganic acid based blend included at .2% of the diet for the first week followed by organic acid blend included at .4% of the diet for the remaining four weeks.
[abc] Values with different superscripts differ by P<.10 by means separation using Duncan multiple range test.
[xyz] Values with different superscripts differ by P<.05 by means separation using Duncan multiple range test.

Table 5. The effect of dietary acids on *E. coli* and salmonella shedding and fecal pH in nursery pigs

	Negative control	Carbadox	Organic acid[1]	Inorganic acid[2]	Crossover 1[3]	Crossover 2[4]	SE
Phase 3, d 32							
E. coli, nlog	13.27	13.09	13.22	12.82	13.68	12.30	.5852
Unknown bacteria, nlog	12.74	14.20	11.36	14.29	13.15	14.23	1.435
Salmonella, % positive	20.00	0	0	0	0	20.00	--
Fecal pH	6.29[b]	6.45[ab]	6.49[ab]	6.28[b]	6.55[a]	6.31[b]	0.091

[1] Organic acid blend was included at .4% of the diet, Kemin Americas, Inc.

[2] Inorganic acid blend was included at .2% of the diet , Kemin Americas, Inc.

[3] Crossover 1: organic acid blend included at .4% of the diet for the first week followed by inorganic acid based blend included at .2% of the diet for the remaining four weeks.

[4] Crossover 2: inorganic acid based blend included at .2% of the diet for the first week followed by organic acid blend included at .4% of the diet for the remaining four weeks.

[abc] Values with different superscripts differ by P<.10 by means separation using Duncan multiple range test.