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Effects of Increasing Chloride Concentrations on Growth Performance of 15- to 25-lb Nursery Pigs

Abstract

A total of 300 nursery pigs (initially 15.5 lb; Line 241 × 600; DNA, Columbus, NE) were used in a 21-d trial to determine effects of increasing dietary Cl on nursery pig growth performance. Upon entry to the nursery, pigs were allotted by BW and fed a common starter diet (0.33% Na and 0.76% Cl) for 7 d. On d 7 after weaning, considered d 0 in the trial, pens were assigned to 1 of 6 dietary treatments that were fed from d 0 to 14. Experimental treatments included a control diet containing 0.33% Na and 0.55% Cl provided by 0.78% added salt, or 5 diets with 0.33% Na and added potassium chloride to provide 0.09, 0.21, 0.32, 0.45, or 0.55% Cl. A common diet (0.18% Na and 0.49% Cl) was then fed from d 14 to 21.

From d 0 to 14, ADG, ADFI, and F/G improved (quadratic, $P < 0.05$) as dietary Cl increased from 0.09 to 0.32% with no further benefits observed thereafter. Pigs fed the 0.55% Cl diet had greater ($P < 0.05$) ADFI, but tended ($P = 0.053$) to have poorer F/G than pigs fed the control diet with 0.55% Cl from added salt. Pigs fed the control diet and the 0.55% Cl diet had similar ADG. When pigs were fed the common diet from d 14 to 21, ADG decreased (linear, $P = 0.045$) and ADFI increased (linear, $P = 0.033$) in pigs previously fed increasing dietary Cl concentration. Pigs previously fed increasing Cl concentration had poorer (quadratic, $P < 0.001$) F/G. Pigs previously fed the 0.55% Cl diet had greater ($P = 0.009$) ADFI but tended ($P = 0.059$) to have poorer F/G than pigs previously fed the control diet with 0.55% Cl from added salt. There was no evidence of difference to indicate that previously feeding the control diet or the 0.55% Cl diet affected ADG. From d 0 to 21, ADG improved (quadratic, $P = 0.002$) as dietary Cl increased from 0.09 to 0.32% with no further benefits observed thereafter. Average daily feed intake increased (linear, $P = 0.002$) as dietary Cl increased. Pigs fed the 0.55% Cl diet had increased ($P < 0.05$) ADFI but poorer F/G than pigs fed the control diet with no evidence of difference to indicate that dietary treatments affected ADG. In conclusion, results of this study indicate a dietary Cl concentration of 0.32% would optimize ADG, ADFI, and F/G of 15 to 25 lb pigs, which is slightly lower than the NRC current estimate of 0.45%.

Keywords

chloride, nursery pig, salt, sodium

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D.J. Shawk, K.N. Nemechek, R.D. Goodband, J.C. Woodworth, M.D. Tokach, S.S. Dritz,[1] and J.M. DeRouchey

Summary

A total of 300 nursery pigs (initially 15.5 lb; Line 241 × 600; DNA, Columbus, NE) were used in a 21-d trial to determine effects of increasing dietary Cl on nursery pig growth performance. Upon entry to the nursery, pigs were allotted by BW and fed a common starter diet (0.33% Na and 0.76% Cl) for 7 d. On d 7 after weaning, considered d 0 in the trial, pens were assigned to 1 of 6 dietary treatments that were fed from d 0 to 14. Experimental treatments included a control diet containing 0.33% Na and 0.55% Cl provided by 0.78% added salt, or 5 diets with 0.33% Na and added potassium chloride to provide 0.09, 0.21, 0.32, 0.45, or 0.55% Cl. A common diet (0.18% Na and 0.49% Cl) was then fed from d 14 to 21.

From d 0 to 14, ADG, ADFI, and F/G improved (quadratic, $P < 0.05$) as dietary Cl increased from 0.09 to 0.32% with no further benefits observed thereafter. Pigs fed the 0.55% Cl diet had greater ($P < 0.05$) ADFI, but tended ($P = 0.053$) to have poorer F/G than pigs fed the control diet with 0.55% Cl from added salt. Pigs fed the control diet and the 0.55% Cl diet had similar ADG. When pigs were fed the common diet from d 14 to 21, ADG decreased (linear, $P = 0.045$) and ADFI increased (linear, $P = 0.033$) in pigs previously fed increasing dietary Cl concentration. Pigs previously fed increasing Cl concentration had poorer (quadratic, $P < 0.001$) F/G. Pigs previously fed the 0.55% Cl diet had greater ($P = 0.009$) ADFI but tended ($P = 0.059$) to have poorer F/G than pigs previously fed the control diet with 0.55% Cl from added salt. There was no evidence of difference to indicate that previously feeding the control diet or the 0.55% Cl diet affected ADG. From d 0 to 21, ADG improved (quadratic, $P = 0.002$) as dietary Cl increased from 0.09 to 0.32% with no further benefits observed thereafter. Average daily feed intake increased (linear, $P = 0.002$) as dietary Cl increased. Pigs fed the 0.55% Cl diet had increased ($P < 0.05$) ADFI but poorer F/G than pigs fed the control diet with no evidence of difference to indicate that dietary treatments affected ADG. In conclusion, results of this study indicate a dietary Cl concentration of 0.32% would optimize ADG, ADFI, and F/G of 15 to 25 lb pigs, which is slightly lower than the NRC[2] current estimate of 0.45%.

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[1] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[2] NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.

Introduction

Mahan et al.[3,4] observed that dietary salt addition was positively correlated to ADG and F/G in nursery pigs. When analyzing dietary Cl concentrations independently, Mahan et al.[3] observed that ADG improved up to a total dietary Cl concentration of 0.50% in diets containing dried whey, though in a second study, the optimal Cl concentration in diets containing spray-dried animal plasma was 0.32%.[4] The NRC[2] requirement estimate for 15 to 24 lb pigs is 0.35% and 0.45% for Na and Cl, respectively. In a previous study, Shawk et al.[5] observed that pigs fed a diet that was formulated to meet NRC[2] estimates for Na (0.37%) and exceeded the Cl (0.60%) requirement estimate had improved ADG and ADFI compared to pigs fed a diet that was deficient in both Na (0.18) and Cl (0.36%). Pigs that were fed a diet with added sodium bicarbonate and potassium chloride, 0.37% Na and 0.35% Cl were intermediate. The pigs fed the sodium bicarbonate and potassium chloride diet could have been intermediate in growth performance due to the source of the Na and Cl or the diets may have simply been deficient in Cl since the NRC[2] requirement estimate is 0.45%. Therefore, the objective of this study was to determine the dietary Cl requirement of nursery pigs weighing 15 to 25 lb when diets were formulated to meet the Na requirement estimate.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Each pen was equipped with a 4-hole, dry self-feeder and a nipple waterer to provide ad libitum access to feed and water.

A total of 300 pigs (initially 15.5 lb; Line 241 × 600; DNA, Columbus, NE) were used in a 21-d growth trial. Pigs were weaned at approximately 21 d of age and moved to the nursery. Pigs were randomly allotted to pens of 5 based on their initial BW. Pigs were fed a common diet (0.33% Na and 0.77% Cl) for 7 d after weaning. On d 7 after weaning, considered d 0 in the trial, pens were randomly assigned to 1 of 6 dietary treatments with 10 replications per treatment. Experimental treatments included a control diet containing 0.33% Na and 0.55% Cl provided by 0.78% added salt or 5 diets with 0.33 % Na, and added potassium chloride to provide 0.09, 0.21, 0.32, 0.45, or 0.55% Cl. Treatment diets were fed for 14 d with a common diet (0.18% Na and 0.49% Cl) fed from d 14 to 21. Pens of pigs were weighed and feed disappearance was recorded on d 0, 7, 14, and 21 to determine ADG, ADFI, and F/G.

All experimental diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS. Dietary treatments were corn-soybean meal-based with 7.2% crystalline lactose and were fed in meal form (Table 1).

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[3] Mahan, D. C., E. A. Newton, and K. R. Cera. 1996. Effect of supplemental sodium chloride, sodium phosphate, or hydrochloric acid in starter pig diets containing dried whey. J. Anim. Sci. 74:1217-1222.

[4] Mahan, D. C., T. D. Wiseman, E. Weaver, and L. Russell. 1999. Effect of supplemental sodium chloride and hydrochloric acid added to initial starter diets containing spray-dried blood plasma and lactose on resulting performance and nitrogen digestibility of 3-week-old weaned pigs. J. Anim. Sci. 77:3016-3021.

[5] Shawk, D.; Moniz, M.; Clark, A. B.; Goodband, R. D.; Woodworth, J. C.; Tokach, M. D.; Dritz, S. S.; and DeRouchey, J. M. (2016) "Evaluation of Added Sodium and Chloride for 15 to 24 lb Nursery Pigs," *Kansas Agricultural Experiment Station Research Reports*: Vol. 2: Iss. 8. https://doi.org/10.4148/2378-5977.1301.

Salt, potassium chloride, or sodium bicarbonate replaced sand in the diets to provide the different dietary treatments. All diets were formulated to have a dietary Na concentration of 0.33% with either the inclusion of salt at 0.78% or sodium bicarbonate at 23 lb/ton. Diet samples were collected at the feed mill, subsampled, and submitted to Ward Laboratories, Inc., (Kearney, NE) and Cumberland Valley Analytical Service, (Maugansville, MD) for analysis of DM, CP, Na, and Cl (Table 2).

Data were analyzed as a randomized complete block design using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Linear and quadratic polynomials were used to evaluate increasing added Cl. Means of the 0.55% Cl treatment and the control diet were separated using the least square mean method. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Chemical analysis indicated that the dietary Na concentration of the treatment diets was similar to formulated values, except for the 0.55% Cl diet, which analyzed at a slightly greater concentration than expected (Table 2). Dietary Cl concentrations of the treatment diets were similar to formulated values, except for the 0.55% Cl diet and control diet which had slightly lower Cl concentrations than formulated but within acceptable analytical variation.

From d 0 to 14, ADG, ADFI, and F/G improved (quadratic, $P < 0.05$) as dietary Cl concentration increased from 0.09 to 0.32% with no further benefits observed thereafter (Table 4). Pigs fed the 0.55% Cl diet had increased ($P < 0.05$) ADFI compared with pigs fed the control diet with 0.55% Cl from added salt. Pigs fed the 0.55% Cl diet tended ($P = 0.53$) to have poorer F/G than pigs fed the control diet with added salt. Pigs fed the control diet and the 0.55% Cl diet had similar ADG.

From d 14 to 21, when pigs were fed a common diet, compensatory gain was observed for pigs previously fed the low chloride diet. Average daily gain decreased (linear, $P = 0.045$) and ADFI increased (linear, $P = 0.033$) with increasing dietary Cl previously fed from d 0 to 14. Pigs previously fed increasing Cl had poorer (quadratic, $P = 0.020$) F/G. Pigs previously fed the 0.55% Cl diet had greater ($P = 0.009$) ADFI and tended ($P = 0.059$) to have poorer F/G than pigs previously fed the control diet with 0.78% added salt. There was no evidence of difference in ADG between pigs previously fed the control diet or the 0.55% Cl diet.

For the overall experimental period that included the treatment and common periods (d 0 to 21), ADG increased (quadratic, $P = 0.002$) as dietary Cl increased from 0.09 to 0.32% with no further benefits observed thereafter. Average daily feed intake increased (linear, $P = 0.002$) as dietary Cl increased. Pigs fed the 0.55% Cl diet had greater ($P < 0.05$) ADFI but poorer F/G than pigs fed the control diet with 0.55% Cl from added salt with no evidence of difference between these two diets for ADG.

On d 14 and 21, BW increased (quadratic, $P = 0.006$) as dietary Cl increased from 0.09 to 0.32%, with no further benefits observed thereafter. Overall, there was no difference in BW between the control diet and the 0.55% dietary Cl diet.

In conclusion, results of this study would indicate a dietary Cl concentration of 0.32% optimized ADG, ADFI, and F/G of pigs from approximately 15 to 25 lb. A Cl concentration of 0.32% is slightly lower than the NRC[2] current requirement estimate of 0.45%. A Cl concentration of 0.32% would also be lower than the optimal Cl concentration reported by Mahan et al.,[3] who suggested a dietary Cl requirement of 0.50% for 13 to 31 lb pigs, but would agree with the results of another study, which indicated the Cl requirement for 13 to 26 lb pigs was 0.32%.[4] When comparing the 0.55% Cl diet to the control diet, there was no evidence of difference for ADG, but pigs fed the control diet with added salt had a lower ADFI and tended to have improved F/G. This would possibly suggest that source of the Na and Cl ions influences growth performance and may explain why Shawk et al.[5] observed an intermediate growth response to a diet containing sodium bicarbonate and potassium chloride when compared to diets containing added salt. Results of this study indicates the minimum dietary Cl requirement for 15 to 25 lb pigs is 0.32%.

Table 1. Diet composition (as-fed basis)[1]

	Chloride, %					Control diet
Item	0.09	0.21	0.32	0.45	0.55	0.33 Na, 0.55% Cl
Ingredient, %						
Corn	47.41	47.41	47.41	47.41	47.41	47.41
Soybean meal (48% CP)[2]	29.82	29.82	29.82	29.82	29.82	29.82
Lactose	7.20	7.20	7.20	7.20	7.20	7.20
HP 300[3]	7.80	7.80	7.80	7.80	7.80	7.80
Choice white grease	1.95	1.95	1.95	1.95	1.95	1.95
Monocalcium P (21% P)	1.10	1.10	1.10	1.10	1.10	1.10
Limestone	1.30	1.30	1.30	1.30	1.30	1.30
L-Lys-HCl	0.30	0.30	0.30	0.30	0.30	0.30
DL-Met	0.17	0.17	0.17	0.17	0.17	0.17
L-Thr	0.16	0.16	0.16	0.16	0.16	0.16
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Phytase[4]	0.02	0.02	0.02	0.02	0.02	0.02
Sand	0.98	0.73	0.49	0.23	---	1.35
Potassium chloride	---	0.25	0.49	0.75	0.98	---
Sodium bicarbonate	1.15	1.15	1.15	1.15	1.15	---
Salt	---	---	---	---	---	0.78
Total	100.00	100.00	100.00	100.00	100.00	100.00

continued

Table 1, *continued*. Diet composition (as-fed basis)[1]

	Chloride, %					Control diet
Item	0.09	0.21	0.32	0.45	0.55	0.33 Na, 0.55% Cl
Calculated analysis						
Standardized ileal digestible (SID) AA, %						
Lys	1.35	1.35	1.35	1.35	1.35	1.35
Ile:Lys	63	63	63	63	63	63
Leu:Lys	122	122	122	122	122	122
Met:Lys	35	35	35	35	35	35
Met and Cys:Lys	58	58	58	58	58	58
Thr:Lys	65	65	65	65	65	65
Tryp:Lys	19	19	19	19	19	19
Val:Lys	67	67	67	67	67	67
Total Lys, %	1.49	1.49	1.49	1.49	1.49	1.49
NE kcal/lb	1,110	1,110	1,110	1,110	1,110	1,110
SID Lys:NE, g/Mcal	5.52	5.52	5.52	5.52	5.52	5.52
CP, %	23.0	23.0	23.0	23.0	23.0	23.0
Ca, %	0.82	0.82	0.82	0.82	0.82	0.82
P, %	0.68	0.68	0.68	0.68	0.68	0.68
Available P, %	0.51	0.51	0.51	0.51	0.51	0.47
Na, %	0.33	0.33	0.33	0.33	0.33	0.33
Cl, %	0.09	0.21	0.32	0.45	0.55	0.55
K, %	1.01	1.14	1.26	1.40	1.51	1.01
Dietary electrolyte balance	375	375	375	375	374	244

[1] Experimental diets were fed from d 7 to 21 after weaning.

[2] Soybean meal was analyzed for dietary Na and Cl and analyzed values were used in formulation.

[3] Hamlet Protein, Findlay, OH.

[4] HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), providing 184.3 phytase units (FTU)/lb and an estimated release of 0.10% available P.

Table 2. Phase 3 diet composition (as-fed basis)[1]

Item	Percentage
Ingredient	
Corn	62.92
Soybean meal (48% CP)	33.68
Monocalcium P (21% P)	1.15
Limestone	0.95
L-Lys-HCl	0.30
DL-Met	0.12
L-Thr	0.12
Salt	0.35
Trace mineral premix	0.15
Vitamin premix	0.25
Phytase[2]	0.02
Total	100.00
Calculated analysis	
Standardized ileal digestible (SID) AA, %	
Lys	1.24
Ile:Lys	63
Leu:Lys	129
Met:Lys	33
Met and Cys:Lys	57
Thr:Lys	63
Tryp:Lys	19
Val:Lys	69
Total Lys, %	1.39
NE kcal/lb	1090
SID Lys:ME, g/Mcal	3.79
CP, %	21.7
Ca, %	0.70
P, %	0.65
Available P, %	0.43
Na, %	0.18
Cl, %	0.49
K, %	0.96
Dietary electrolyte balance	185

[1] Common phase 3 diet was fed 7 d following treatment feeding.

[2] HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), providing 184.3 phytase units (FTU)/lb and an estimated release of 0.10% available P.

Table 3. Chemical analysis of experimental diets (as-fed basis)[1]

	Chloride, %					Control diet 0.33% Na 0.55% Cl
Item, %	0.09	0.21	0.32	0.45	0.55	
Proximate analysis, %[2]						
DM	92.7	91.8	91.4	91.4	91.6	91.8
CP	22.3	23.3	23.6	23.4	22.9	22.9
Na analysis, %						
Lab 1[3]	0.35	0.36	0.37	0.36	0.50	0.38
Lab 2[4]	0.32	0.30	0.30	0.28	0.42	0.26
Average	0.33	0.33	0.33	0.32	0.46	0.32
Cl analysis, %						
Lab 1	0.10	0.20	0.30	0.40	0.40	0.55
Lab 2	0.15	0.24	0.32	0.46	0.45	0.47
Average	0.13	0.22	0.31	0.43	0.42	0.51

[1] Samples were collected at the mill, homogenized, and then subsampled for analysis.
[2] Samples were submitted to Ward Laboratories (Kearney, NE) for proximate analysis.
[3] Cumberland Valley Analytical Service (Maugansville, MD).
[4] Ward Laboratories (Kearney, NE).

Table 4. Effects of increasing chloride for 15 to 25 lb nursery pigs[1]

	Chloride, %[2]					Control diet 0.33 Na, 0.55% Cl[3]		Probability, *P* <		
								Control diet vs. 0.55% chloride diet	Chloride	
Item	0.09	0.21	0.32	0.45	0.55		SEM		Linear	Quadratic
Treatment period (d 0 to 14)										
ADG, lb	0.60	0.77	0.82	0.77	0.79	0.77	0.022	0.676	0.001	0.001
ADFI, lb	0.96	1.08	1.12	1.05	1.11	1.03	0.030	0.046	0.003	0.035
F/G	1.60	1.41	1.37	1.37	1.43	1.34	0.032	0.053	0.001	0.001
Post treatment period (d 14 to 21)										
ADG, lb	1.22	1.09	1.15	1.10	1.12	1.08	0.032	0.271	0.045	0.079
ADFI, lb	1.74	1.80	1.87	1.80	1.90	1.72	0.046	0.009	0.033	0.652
F/G	1.43	1.65	1.63	1.65	1.70	1.61	0.037	0.059	0.001	0.020
Overall (d 0 to 21)										
ADG, lb	0.81	0.88	0.93	0.88	0.90	0.87	0.017	0.305	0.001	0.002
ADFI, lb	1.22	1.32	1.37	1.30	1.37	1.26	0.030	0.006	0.002	0.095
F/G	1.51	1.51	1.47	1.48	1.53	1.45	0.026	0.020	0.926	0.127
BW, lb										
d 0	15.5	15.7	15.6	15.6	15.6	15.6	0.241	0.997	0.913	0.756
d 14	24.0	26.4	27.0	26.5	26.6	26.4	0.446	0.674	0.001	0.001
d 21	32.5	34.0	35.1	34.2	34.5	33.9	0.520	0.362	0.004	0.006

[1] A total of 300 pigs (Line 241 × 600; DNA, Columbus, NE) were used in a 21-d study with 5 pigs per pen and 10 pens per treatment. Pigs were weaned at approximately 21 d, fed a common starter diet for 7 d post-weaning, then fed experimental diets for 14 d (d 0 to 14 of experiment). A common diet was fed to all pigs from d 14 to 21 of the experiment.

[2] Experimental diets were formulated to a dietary Na concentration of 0.33% with 23 lb/ton added sodium bicarbonate and the treatments were formed by increasing potassium chloride.

[3] Control diet was formed by including 15.5 lb/ton of salt.