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Effects of Sodium and Chloride Source and Concentration on 15- to 25-lb Nursery Pig Growth Performance

D. J. Shawk
Kansas State University, Manhattan, dshawk@ksu.edu

M. D. Tokach
Kansas State University, Manhattan, mtokach@k-state.edu

J. C. Woodworth
Kansas State University, Manhattan, jwoodworth@k-state.edu

See next page for additional authors

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Effects of Sodium and Chloride Source and Concentration on 15- to 25-lb Nursery Pig Growth Performance

Abstract

A total of 360 barrows (initially 15.6 lb; Line 200 × 400; DNA, Columbus, NE) were used in a 21-day trial to determine effects of source and concentration of dietary Na and Cl on nursery pig growth performance. Upon entry to the nursery, pigs were randomly allotted by body weight and fed a common starter diet (0.33% Na and 0.76% Cl) for 8 days. On day 8 after weaning, considered day 0 in the trial, pens were blocked by body weight and randomly assigned to 1 of 6 dietary treatments that were fed from day 0 to 14. Experimental treatments included two added salt diets (providing 0.13% Na and 0.35% Cl or 0.35% Na and 0.68% Cl), three diets with Na and Cl provided by $NaHCO_3$ and KCl (0.13, 0.35, or 0.57% Na and 0.50% Cl), or a diet with $NaHCO_3$ and $CaCl_2$ (0.35% Na and 0.50% Cl). From day 0 to 14, average daily gain (ADG) and average daily feed intake (ADFI) improved (quadratic, $P < 0.05$) as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Day 14 body weight tended ($P < 0.089$) to increase as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Feed efficiency (F/G) was not influenced by the dietary Na concentration. There was no evidence to indicate differences in growth performance due to Na or Cl source. From day 14 to 21 when pigs were fed a common diet, compensatory gain was observed with pigs previously fed low Na diets having increased (linear, $P < 0.05$) ADG and improved F/G compared with pigs previously fed higher Na diets regardless of Na source. Previous source and concentration of Cl did not affect subsequent ADG. In conclusion, growth performance improved up to the Na concentration of 0.35% regardless of the dietary source of the Na and Cl ions.

Keywords

chloride, nursery pig, salt, sodium

Authors

D. J. Shawk, M. D. Tokach, J. C. Woodworth, R. D. Goodband, S. S. Dritz, and J. M. DeRouchey

Effects of Sodium and Chloride Source and Concentration on 15- to 25-lb Nursery Pig Growth Performance

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

Summary

A total of 360 barrows (initially 15.6 lb; Line 200 × 400; DNA, Columbus, NE) were used in a 21-day trial to determine effects of source and concentration of dietary Na and Cl on nursery pig growth performance. Upon entry to the nursery, pigs were randomly allotted by body weight and fed a common starter diet (0.33% Na and 0.76% Cl) for 8 days. On day 8 after weaning, considered day 0 in the trial, pens were blocked by body weight and randomly assigned to 1 of 6 dietary treatments that were fed from day 0 to 14. Experimental treatments included two added salt diets (providing 0.13% Na and 0.35% Cl or 0.35% Na and 0.68% Cl), three diets with Na and Cl provided by $NaHCO_3$ and KCl (0.13, 0.35, or 0.57% Na and 0.50% Cl), or a diet with $NaHCO_3$ and $CaCl_2$ (0.35% Na and 0.50% Cl). From day 0 to 14, average daily gain (ADG) and average daily feed intake (ADFI) improved (quadratic, $P < 0.05$) as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Day 14 body weight tended ($P < 0.089$) to increase as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Feed efficiency (F/G) was not influenced by the dietary Na concentration. There was no evidence to indicate differences in growth performance due to Na or Cl source. From day 14 to 21 when pigs were fed a common diet, compensatory gain was observed with pigs previously fed low Na diets having increased (linear, $P < 0.05$) ADG and improved F/G compared with pigs previously fed higher Na diets regardless of Na source. Previous source and concentration of Cl did not affect subsequent ADG. In conclusion, growth performance improved up to the Na concentration of 0.35% regardless of the dietary source of the Na and Cl ions.

Introduction

Sodium and Cl are common electrolytes found in the body and serve several roles such as acid base balance and electrolyte balance. In two separate studies, in which Na and Cl were independently evaluated, Mahan et al.[2] observed improvements in ADG up to a

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

[2]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. doi:10.2527/1996.7461217x

dietary Na and Cl concentration of 0.34 and 0.50% in diets containing dried whey and added HCl and Na_2PO_4. Based on these studies and others, the NRC[3] estimated the requirement for 15- to 24-lb pigs to be 0.35% and 0.45% for Na and Cl, respectively. More recently, Shawk et al.[4] observed improvements in ADG with up to 0.60% added salt. Typically, the Na and Cl requirement of nursery pigs is established through added salt. The challenge with added salt is that Na and Cl are not independently evaluated. However, there is limited research available to determine if the source of the Na and Cl ions influences the requirement. Therefore, the objective of this experiment was to evaluate the effects of source and concentration of Na and Cl on the growth performance of nursery pigs weighing 15 to 25 lb.

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 Segregated Early Weaning Facility in Manhattan, KS. Each pen (4 × 4 ft) 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 360 maternal line barrows (initially 15.6 lb; Line 200 × 400; DNA, Columbus, NE) were used in a 21-day growth trial. Pigs were weaned at 21 days of age and placed into the nursery. Pigs were randomly allotted to pens of 5 based on initial body weight. A common diet (0.33% Na and 0.77% Cl) was then fed for 8 days after weaning. On day 8 after weaning, considered day 0 in the trial, pens of pigs were blocked by body weight and randomly assigned to 1 of 6 dietary treatments with 12 replications per treatment. Experimental treatments included two added salt diets (providing 0.13% Na and 0.35% Cl or 0.35% Na and 0.68% Cl), three diets with Na and Cl provided by $NaHCO_3$ and KCl (0.13, 0.35, or 0.57% Na and 0.50% Cl), or a diet with $NaHCO_3$ and $CaCl_2$ (0.35% Na and 0.50% Cl). Experimental diets were fed for 14 days with a common diet (0.28% Na and 0.50% Cl) fed from day 14 to 21. Pens of pigs were weighed and feed disappearance was recorded every 7 days 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. Prior to manufacturing treatment diets, dried whey samples were collected at the mill, pooled, subsampled, and submitted for Na and Cl analysis (Cumberland Valley Analytical Service, Maugansville, MD). Nutrient values used in diet formulation were derived from NRC (2012)[3] with the exception of Na and Cl in soybean meal and dried whey. Analyzed Na and Cl values for dried whey and NRC (1998)[5] Na and Cl values for soybean meal were used in diet formulation. Dietary treatments were corn-soybean meal-based with dried whey and were fed in meal form (Table 1). Sand was replaced by salt, KCl, $CaCl_2$, or $NaHCO_3$ to create the treatment diets. Diet samples were collected from 8 feeders per dietary treatment, subsampled, and submitted to Cumberland Valley Analytical Service, (Maugansville, MD) for analysis of Na and Cl and to Kansas State University Analytical Laboratory (Manhattan, KS) for dry matter and crude protein.

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[3]NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.
[4]D.J. Shawk, J.M. DeRouchey, M.D. Tokach, R.D. Goodband, S.S. Dritz , J.C. Woodworth, H. E. Williams, and A. B. Clark. 2016. Effects of increasing salt concentration for 15 to 22 lb nursery pigs. Kansas Swine Industry Day, 17-118-J. KAES Research Reports, Volume 2, Issue 8, 2016.
[5]NRC. 1998. Nutrient requirements of swine. 10th rev. ed. Natl. Acad. Press, Washington, DC.

Data were analyzed as a randomized complete block design using PROC GLIMMIX in SAS (Version 9.3, SAS Institute, Inc., Cary, NC) with pen as the experimental unit and body weight as a blocking factor. Contrasts were used to determine the linear and quadratic response of Na concentration and inclusion of $NaHCO_3$ and KCl. Contrasts were used to compare the two diets with added salt. The 0.35% Na and 0.50% Cl diet provided by $NaHCO_3$ and KCl was compared to the 0.35% Na and 0.50% Cl diet provided by $NaHCO_3$ and $CaCl_2$, and the 0.13% Na and 0.50% Cl diet provided by $NaHCO_3$ and KCl to the 0.13% Na and 0.35% Cl diet provided by added salt. Another contrast was used to compare the 0.35% Na and 0.50% Cl diet provided by $NaHCO_3$ and KCl to the 0.35% Na and 0.50% Cl diet provided by $NaHCO_3$ and $CaCl_2$ and to the 0.35% Na and 0.68% Cl diet provided by added salt. 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 and Cl concentration of the treatment diets was similar to formulated values (Table 1).

From day 0 to 14, ADG and ADFI improved (quadratic, $P < 0.05$) as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Day 14 BW tended ($P < 0.089$) to increase as dietary Na concentration increased from 0.13 to 0.35%, with no further benefits observed thereafter. Feed efficiency was not influenced by the dietary Na concentration. There was no evidence to indicate differences in growth performance due to Na or Cl source.

From day 14 to 21, when pigs were fed a common diet, compensatory gain was observed with pigs previously fed low Na diets having increased (linear, $P < 0.05$) ADG and improved F/G compared with pigs previously fed higher Na diets, regardless of Na source. Previous source and concentration of Cl did not affect subsequent ADG.

In conclusion, ADG was optimized with a Na concentration of 0.35% regardless of the dietary source of Na and Cl. The Na concentration of 0.35% would agree with NRC[3] Na requirement estimate of 0.35%. It would also agree with the findings of Mahan et al.[2] who observed improvements in ADG up to a dietary Na concentration of 0.34% in diets containing dried whey with added Na_2PO_4. Results of this trial would indicate that dietary source of the Na and Cl ions does not influence growth performance when diets are formulated to similar Na and Cl concentrations. However, it is important to note that there was no significant difference among the two added salt diets (0.13 and 0.35% Na), which would not agree with findings of Mahan et al.[2] in which ADG improved with up to 0.40% added salt nor Shawk et al.[4] who observed improvements in ADG with up to 0.60% added salt.

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

Na source:	NaCl		NaHCO$_3$				Common Phase 3 diet[2]
Cl source:	NaCl		KCl			CaCl$_2$	
Na, %:	0.13	0.35	0.13	0.35	0.57	0.35	
Cl, %:	0.35	0.68	0.50	0.50	0.50	0.50	
Corn	54.72	54.72	54.72	54.72	54.72	54.72	60.28
Soybean meal (48% CP)[3]	23.36	23.36	23.36	23.36	23.36	23.36	34.65
Dried whey[4]	10.00	10.00	10.00	10.00	10.00	10.00	---
HP 300[5]	5.00	5.00	5.00	5.00	5.00	5.00	---
Choice white grease	0.95	0.95	0.95	0.95	0.95	0.95	1.30
Monocalcium P (21% P)	1.10	1.10	1.10	1.10	1.10	1.10	1.15
Calcium carbonate	0.81	0.81	0.81	0.81	0.81	0.50	0.88
L-Lysine HCl	0.50	0.50	0.50	0.50	0.50	0.50	0.35
DL-Methionine	0.24	0.24	0.24	0.24	0.24	0.24	0.16
L-Threonine	0.24	0.24	0.24	0.24	0.24	0.24	0.14
L-Tryptophan	0.03	0.03	0.03	0.03	0.03	0.03	0.00
L-Valine	0.12	0.12	0.12	0.12	0.12	0.12	0.04
Trace mineral premix	0.15	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	0.25
Phytase[6]	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25	---
Sodium bicarbonate	---	---	0.18	1.00	1.80	1.00	---
Potassium chloride	---	---	0.48	0.48	0.48	---	---
Calcium chloride	---	---	---	---	---	0.46	---
Salt	0.13	0.68	---	---	---	---	0.65
Sand	2.15	1.60	1.62	0.80	---	1.12	---
TOTAL	100	100	100	100	100	100	100

continued

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

Na source:	NaCl		$NaHCO_3$				
Cl source:	NaCl		KCl			$CaCl_2$	Common Phase 3 diet[2]
Na, %:	0.13	0.35	0.13	0.35	0.57	0.35	
Cl, %:	0.35	0.68	0.50	0.50	0.50	0.50	
Calculated analysis							
Standardized ileal digestible (SID) AA, %							
Lysine	1.35	1.35	1.35	1.35	1.35	1.35	1.30
Isoleucine:lysine	55	55	55	55	55	55	61
Leucine:lysine	111	111	111	111	111	111	124
Methionine:lysine	37	37	37	37	37	37	35
Methionine and cystine:lysine	58	58	58	58	58	58	58
Threonine:lysine	65	65	65	65	65	65	62
Tryptophan:lysine	18.7	18.7	18.7	18.7	18.7	18.7	18.5
Valine:lysine	68	68	68	68	68	68	69
Total lysine, %	1.47	1.47	1.47	1.47	1.47	1.47	1.45
Net energy, kcal/lb	1,110	1,110	1,110	1,110	1,110	1,110	1,112
Crude protein, %	20.5	20.5	20.5	20.5	20.5	20.5	22.1
Calcium, %	0.71	0.71	0.71	0.71	0.71	0.71	0.7
Phosphorus, %	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Available phosphorus, %	0.48	0.48	0.48	0.48	0.48	0.48	0.43
Sodium, %	0.13	0.35	0.13	0.35	0.57	0.35	0.28
Chloride, %	0.35	0.68	0.50	0.50	0.50	0.50	0.50
Potassium, %	1.02	1.02	1.26	1.26	1.26	1.02	0.97
Dietary electrolyte balance, mEq/kg[7]	218	221	237	334	428	272	229
Chemical analysis, %							
Dry matter	91.07	87.89	90.26	89.22	88.85	89.34	---
Crude protein	21.52	21.71	22.44	20.88	21.01	19.73	---
Na	0.18	0.39	0.19	0.40	0.60	0.39	---
Cl	0.34	0.61	0.49	0.47	0.47	0.56	---

[1]Experimental diets were fed to pigs from d 8 to 22 after weaning. Sand was removed and replaced with either sodium bicarbonate, potassium chloride, salt, or calcium chloride to create the treatment diets.
[2]Common Phase 3 diet was fed 7 d following treatment feeding.
[3]Sodium and Cl values from NRC (1998) were used for soybean meal. Values for all other ingredients except for the Na and Cl values for dried whey are from NRC (2012).
[4]Dried whey was analyzed for dietary Na (0.61%) and Cl (1.37%) and analyzed values were used in formulation.
[5]Hamlet Protein, Findlay, OH.
[6]Ronozyme HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), providing 184.3 phytase units (FTU)/lb and an estimated release of 0.10% available P.
[7]Calculated as (Na × 434.98) + (K × 255.74) – (Cl × 282.06).

Table 2. Effects of Na and Cl source and concentration on nursery pig growth performance[1]

Na Source:	NaCl		$NaHCO_3$					Probability, $P <$[2]							
Cl Source:	NaCl		KCl			$CaCl_2$									
Na, %:	0.13	0.35	0.13	0.35	0.57	0.35		$NaHCO_3$ and KCl		Na					
Cl, %:	0.35	0.68	0.50	0.50	0.50	0.50	SEM	Linear	Quadratic	Linear	Quadratic	1	2	3	4
d 0 to 14[3]															
ADG, lb	0.68	0.70	0.63	0.66	0.62	0.69	0.026	0.726	0.262	0.273	0.038	0.587	0.430	0.232	0.877
ADFI, lb	0.89	0.90	0.84	0.88	0.83	0.89	0.024	0.785	0.163	0.259	0.039	0.654	0.706	0.159	0.682
F/G	1.32	1.30	1.34	1.35	1.35	1.29	0.030	0.869	0.948	0.547	0.281	0.770	0.208	0.476	0.815
d 14 to 21 (post treatment)															
ADG, lb	1.22	1.07	1.19	1.12	1.09	1.14	0.032	0.021	0.554	0.002	0.159	0.001	0.549	0.420	0.115
ADFI, lb	1.67	1.51	1.55	1.56	1.53	1.60	0.042	0.629	0.634	0.090	0.743	0.007	0.537	0.049	0.124
F/G	1.37	1.41	1.31	1.40	1.41	1.41	0.028	0.012	0.193	0.042	0.200	0.378	0.963	0.115	0.998
BW, lb															
d 0	15.6	15.6	15.6	15.6	15.6	15.6	0.169	0.601	0.955	0.797	0.998	0.846	0.684	0.549	0.831
d 14	25.1	25.4	24.4	24.9	24.5	25.3	0.398	0.887	0.390	0.568	0.089	0.617	0.403	0.206	0.907
d 21	33.8	32.9	32.8	32.7	32.1	33.3	0.485	0.319	0.663	0.036	0.516	0.137	0.328	0.093	0.511

[1]A total of 360 barrows (Line 200 × 400; DNA, Columbus, NE) were used in a 14-d study with 5 pigs per pen and 12 pens per treatment. Pigs were weaned at approximately 21 d, fed a common starter diet for 7 d post-weaning, then placed on experimental diets.

[2]Contrasts were (1) 0.13% Na and 0.35% Cl provided by added salt vs. 0.35% Na and 0.68% Cl provided by added salt (2) 0.35% Na and 0.50% Cl provided by $NaCHCO_3$ and KCl vs. 0.35% Na and 0.50% Cl provided by $NaHCO_3$ and $CaCl_2$, (3) 0.13% Na and 0.50% Cl provided by $NaCHCO_3$ and KCl vs. 0.13% Na and 0.35% Cl provided by NaCl, and (4) 0.35% Na and 0.50% Cl provided by $NaCHCO_3$ and KCl vs. 0.35% Na and 0.50% Cl provided by $NaHCO_3$ and $CaCl_2$ vs. 0.35% Na and 0.68% Cl provided by NaCl.

[3]Experimental diets were fed from d 0 to 14 and a common Phase 3 diet was fed from d 14 to 21.