Effects of Increasing Copper from Tri-basic Copper Chloride or a Copper-Chelate on Growth Performance of Nursery Pigs[1]

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Summary

A total of 1,452 pigs [Group 1; 350 barrows (DNA 200 × 400; initially 13.2 lb)] and [Group 2; 1,102 barrows and gilts (PIC 1050 × 280; initially 13.3 lb)] were used to determine the effects of added Cu source and level on nursery pig performance. There were 5 pigs per pen and 10 replications per treatment in group 1, and 24 to 27 pigs per pen and 6 replications per treatment in group 2. Pens of pigs were allotted by BW to 1 of 7 dietary treatments arranged as a 2 × 3 factorial plus a control diet, with main effects of Cu source: IntelliBond-C (TBCC; Micronutrients, Indianapolis, IN), or Mintrex-Cu (Cu-chelate; Novus, St. Charles, MO) and Cu level (50, 100, or 150 ppm). Diets were corn-soybean meal-based and were fed in meal form in 2 phases (d 0 to 14 and 14 to 35). All diets contained a trace mineral premix formulated to contribute 17 ppm of Cu from $CuSO_4$ to the complete diet.

Overall (d 0 to 35), a Cu source × level interaction was observed (linear, $P = 0.042$) for ADG where the rate of improvement with increasing Cu was greater in pigs fed Cu-chelate diets compared to those fed TBCC diets. Increasing added Cu increased (linear, $P = 0.001$) ADG, ADFI, and improved F/G. Although Cu source did not influence F/G, pigs fed Cu from Cu-chelate had greater ($P \leq 0.007$) ADG and ADFI than those fed Cu from TBCC. In summary, these results suggest that increasing TBCC or Cu-chelate can improve growth performance of nursery pigs and it appears that pigs provided Cu from Cu-chelate have greater ADG, ADFI, and d 35 BW, than those provided Cu from TBCC.

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Introduction

The NRC[4] reports weanling pigs have a nutritional Cu requirement of 6 ppm. However, according to Flohr et al.,[5] many US swine nutritionists formulate nursery pig diets to contain as low as 11 ppm and as high as 250 ppm Cu. Feeding high levels of added Cu (125 to 250 ppm) in addition to what is provided by the trace mineral premix has resulted in increased ADFI and ADG. Huang et al.[6] compared two inorganic sources [tri-basic copper chloride (TBCC) and $CuSO_4$] of added Cu that ranged from 11 to 327 ppm in nursery pig diets and found growth benefits from feeding added Cu but no difference in growth between sources was observed.

Organic Cu sources are argued to be more bioavailable to the young pig due to their chemical structure compared to inorganic sources. It has also been documented in other species that both TBCC and Cu-chelate are more bioavailable than more typically used sources of Cu.[7,8] Tri-basic copper chloride and Mintrex-Cu (Cu-chelate; Novus, St. Charles, MO) differ in their chemical characteristics. Tri-basic copper chloride is an inorganic mineral source, which is non-hygroscopic and poorly soluble in water but highly soluble in acidic conditions.[9] Mintrex-Cu is an organic form of Cu [$Cu(HMTBa)_2$] that has been shown to be more bioavailable to the pig because of decreased binding activity with other dietary constituents, therefore suggesting less supplementation required in comparison with inorganic minerals in nursery pigs.[10] There is limited research available that directly compares the effects of increasing Cu from TBCC or Cu-chelate on growth performance of nursery pigs. Therefore, this study was designed to investigate the effects of increasing Cu from either TBCC or Cu-chelate on growth performance of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocols used for this study. Two groups of pigs were used for the experiment. Group 1 pigs were housed at the K-State Segregated Early Weaning Facility in Manhattan, KS. Group 2 pigs were housed in a commercial research facility in southwestern Minnesota. The research facilities were environmentally controlled. In group 1, each pen (4.0 × 4.0 ft.) had tri-bar flooring and contained one 4-hole dry self-feeder and one cup waterer to provide ad libitum access to feed and water. For group 2, each pen

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(12.1 × 7.5 ft.) had plastic slatted flooring and contained one 6-hole dry self-feeder and one pan waterer to provide ad libitum access to feed and water. Dietary treatments for group 1 were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS. Dietary treatments for group 2 were manufactured at a commercial feed mill located in Pipestone, MN.

In group 1, 350 barrows (DNA 200 × 400; initially 13.2 lb) were weaned at approximately 21 d of age and allotted to pen based on initial BW, with 5 pigs per pen and 10 replicate pens per treatment. In group 2, 1,102 pigs (PIC 1050 × 280; initially 13.3 lb) were weaned and randomly placed over 2 consecutive days with 24 to 27 pigs per pen and 3 replicate pens per treatment for each day. Group 1 and 2 pigs were fed a common starter diet for 7 d post-weaning. On d 7 post-weaning, pens were allotted by BW to 1 of 7 dietary treatments arranged as a 2 × 3 factorial plus one control diet, with main effects of Cu source: IntelliBond-C (TBCC; Micronutrients, Indianapolis, IN) or Mintrex-Cu (Cu chelate; Novus, St. Charles, MO) and Cu level (50, 100, or 150 ppm). Diets were corn-soybean meal-based and fed in meal form in 2 phases (d 0 to 14 and 14 to 35; Table 1). The trace mineral premix added to all diets provided complete diets with 17 ppm Cu from $CuSO_4$. For each group, pigs and feeders were weighed on d 0, 7, 14, 21, 28, and 35 to calculate ADG, ADFI, and F/G.

Complete diet samples were collected from a minimum of 6 feeders and combined to make 1 composite sample per treatment and phase. Each sample was then split, ground, and sent to a commercial lab for analysis of DM, CP, crude fiber, Ca, P, ether extract, ash, and Cu concentrations. Group 1 samples were sent to University of Missouri-Columbia Agriculture Chemical Laboratories (Columbia, MO) for analysis of DM, CP, crude fiber, ether extract, ash, and Cu concentrations, and Ward Laboratories Inc. (Kearney, NE) for analysis of Ca, P, and Cu concentrations. Group 1 Cu concentrations were determined by averaging the analyzed values from each lab. Group 2 samples were sent to Midwest Laboratories (Omaha, NE) for duplicate analysis of DM, CP, crude fiber, ether extract, ash, Ca, P, and Cu concentration. Final nutrient concentrations represent the combined average of the chemical analyses of diets across pig groups 1 and 2.

Data were combined from both groups and analyzed as a randomized complete block design using PROC GLIMMIX (SAS Institute, Inc., Cary, NC) with pen as the experimental unit and dietary treatment as the fixed effect. The random effect of block within group was used in the model. The main effects of source and level, as well as their interaction, were considered significant with $P < 0.05$ and marginally significant when $P < 0.10$ and ≥ 0.05.

Results and Discussion

The chemical analyses of the complete diets were similar to the intended formulation, and Cu additions increased across dietary treatments (Table 2). However, the chemical analysis for Cu concentration was slightly higher than expected for the control diets. Total Ca and P concentrations were similar among diets across each dietary phase.

From d 0 to 14 (13. 2 to 21.5 lb), there were no Cu source × level interactions observed (Table 3). Increasing added Cu increased (linear, $P \leq 0.003$) ADG and ADFI, which tended to improve (linear, $P = 0.052$) F/G. Although Cu source did not influence F/G, pigs fed added Cu from Cu-chelate tended to have greater ($P = 0.081$) ADG and ($P = 0.053$) ADFI than those fed added Cu from TBCC.

From d 14 to 35 (21.5 to 49.7 lb), there was a source × level interaction (linear, $P = 0.011$) for ADG reflective of a linear increase in ADG with each increasing level of Cu from Cu-chelate; however, pigs fed increasing levels of Cu from TBCC only had increased ADG at 150 ppm. Increasing Cu increased (linear, $P = 0.001$) ADFI and improved (linear, $P = 0.001$) F/G. Similar to performance from d 0 to 14, Cu source did not influence F/G; however, pigs fed Cu from Cu-chelate had greater ($P \leq 0.009$) ADG and ADFI than those fed Cu from TBCC.

Overall d 0 to 35 (13.2 to 49.7 lb), a Cu source × level interaction was observed (linear, $P = 0.042$) for ADG where the rate of improvement with increasing Cu was greater in pigs fed Cu-chelate diets compared to those fed TBCC diets. Increasing added Cu increased (linear, $P = 0.001$) ADG, ADFI, F/G, and d 35 BW. Even though Cu source did not influence F/G; pigs fed Cu from Cu-chelate had greater ($P \leq 0.007$) ADG, ADFI, and d 35 BW than those fed added Cu from TBCC.

While research has been conducted comparing Cu sources in swine diets, it is our understanding that there is only one other published study that has directly compared the effects of increasing Cu from TBCC to a Cu-chelate (Mintrex-Cu) on nursery pig performance. Carpenter et al.[11] reported that nursery pigs (12.8 to 47.7 lb) fed diets containing increasing added Cu from either TBCC or Mintrex-Cu had improved ADG and ADFI in the initial nursery period and improved ADG in the overall period. In addition, Carpenter et al.[11] suggested that nursery pig growth performance is similar for pigs fed either TBCC or Mintrex Cu. The results from Carpenter et al.[11] are inconsistent with the study herein. The results from this study suggest that pigs fed diets containing increasing level of added Cu have improved growth performance in the initial, final and overall growth periods and that nursery pigs fed Cu from Cu-chelate have greater growth performance than those fed Cu from TBCC.

In this study, it appears the typical improved ADFI response to increasing added Cu helps to explain the growth response, in that increasing added Cu in the early (13.2 to 21.5 lb), late (21.5 to 49.7 lb), and overall (13.2 to 49.7 lb) nursery periods of the study improved both ADG and F/G. Others have found similar responses in previous studies with nursery pigs.[12,13]

In summary, these results suggest that increasing TBCC or Cu-chelate can improve growth performance of nursery pigs. From our data, it also appears pigs provided Cu

[11] Carpenter, C. B.; Woodworth, J. C.; DeRouchey, J. M.; Tokach, M. D.; Goodband, R. D.; Dritz, S. S.; and Usry, J. (2016) "Effects of Increasing Copper from Tri-basic Copper Chloride or a Copper-Amino Acid Complex on Growth Performance of Nursery Pigs," Kansas Agricultural Experiment Station Research Reports: Vol. 2: Iss. 8. https://doi.org/10.4148/2378-5977.1297.

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from Cu-chelate may have greater ADG, ADFI, and d 35 BW than those provided Cu from TBCC. However, the study herein adds to an already conflicting database in the literature on whether nursery pig growth performance is dependent on Cu source.

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

Item	Phase 1	Phase 2
Ingredient, %		
Corn	48.47	57.30
Soybean meal (47.7% CP)	27.68	33.73
Dried whey	10.00	---
Liquid fat[2]	5.00	5.00
Limestone	0.85	0.85
Monocalcium P (21% P)	1.60	1.70
Salt	0.30	0.35
L-Lys-HCl	0.33	0.33
L-Thr	0.15	0.16
HMB[3]	0.22	0.18
HP 300[4]	5.00	---
Vitamin premix	0.15	0.15
Trace mineral premix	0.25	0.25
Cu source[5,6]	---	---
Total	100.00	100.00
Calculated analysis		
Standardized ileal digestible (SID) AA, %		
Lys	1.30	1.25
Ile:Lys	63	62
Leu:Lys	122	124
Met:Lys	36	35
Met + Cys:Lys	58	58
Thr:Lys	65	65
Trp:Lys	18.4	18.4
Val:Lys	67	67
NE, kcal/lb	1,201	1,188
SID Lys:NE, g/Mcal	4.91	4.77
CP, %	21.7	21.3
Ca, %	0.85	0.80
P, %	0.78	0.75
Available P, %	0.49	0.44

[1] Phase 1 and 2 were fed from d 0 to 14 and 14 to 35, respectively. Dietary treatments were formed by adding 50, 100, or 150 ppm of Cu from either TBCC or Cu-chelate at the expense of corn. The trace mineral premix was formulated to contribute 17 ppm of Cu in the complete diet.

[2] Group 1 (choice white grease) and group 2 (beef tallow).

[3] Hydroxymethylthio-butanoic acid, Novus International (Saint Charles, MO).

[4] HP 300, Hamlet Protein, Findlay, OH, formulated with 3.25% SID lysine.

[5] Mintrex Cu, copper methionine hydroxy analogue (St. Charles, MO).

[6] IntelliBond-C, TBCC (Micronutrients, Indianapolis, IN).

Table 2. Chemical analysis of diets, as-fed basis[1]

	Phase 1							Phase 2						
	Added Cu, ppm							Added Cu, ppm						
	Control	TBCC[2]			Cu-chelate[3]			Control	TBCC[2]			Cu-chelate[3]		
Item	0	50	100	150	50	100	150	0	50	100	150	50	100	150
DM, %	87.5	87.2	86.8	86.7	86.6	86.6	86.8	86.7	86.4	85.8	85.6	86.2	86.1	85.7
CP, %	21.9	21.0	20.6	20.9	20.8	20.8	20.8	19.2	20.4	19.9	21.9	18.9	19.6	21.2
Crude fiber, %	1.9	2.0	1.5	1.6	2.0	2.1	2.1	2.6	2.4	2.1	2.4	1.9	2.0	2.0
Ether extract, %	7.1	6.8	7.2	6.9	6.6	7.6	6.9	6.7	6.5	6.3	5.3	6.3	5.6	5.6
Ash, %	5.7	5.7	5.6	6.0	5.9	5.8	5.9	5.4	5.4	5.3	5.7	5.4	5.7	5.6
Ca, %	0.85	0.78	0.77	0.82	0.75	0.86	0.76	0.75	0.97	1.00	0.76	1.01	0.87	0.91
P, %	0.76	0.74	0.68	0.79	0.73	0.83	0.78	0.62	0.72	0.79	0.77	0.81	0.66	0.88
Cu, ppm	40	88	140	145	104	155	204	40	75	119	174	100	135	230

[1] Multiple samples of each diet were collected, blended and subsampled, and analyzed (Missouri Agricultural Experimentation Lab, Colombia, MO; Ward Laboratories, Kearney, NE; and Midwest Labs, Omaha, NE). All values represent the combined average of the chemical analyses of diets for the experiment.

[2] IntelliBond-C, tri-basic copper chloride (Micronutrients, Indianapolis, IN).

[3] Mintrex Cu, copper methionine hydroxy analogue (St. Charles, MO).

Table 3. Effects of increasing Cu from tri-basic copper chloride (TBCC) or Cu-chelate on growth performance of pigs[1]

	Added Cu, ppm								Probability, $P<$				
	Control	TBCC[2]			Cu-chelate[3]				Cu	Cu level		Source × level	
Item	0	50	100	150	50	100	150	SEM	Source	Linear	Quadratic	Linear	Quadratic
BW, lb													
d 0	13.2	13.2	13.2	13.2	13.3	13.3	13.2	0.12	0.112	0.998	0.613	0.372	0.402
d 14	21.1	21.0	21.5	21.7	21.5	21.8	22.0	0.38	0.030	0.001	0.941	0.462	0.318
d 35	47.4	49.1	49.4	50.3	49.9	50.6	51.5	0.54	0.001	0.001	0.031	0.019	0.384
d 0 to 14													
ADG, lb	0.55	0.55	0.59	0.60	0.59	0.60	0.62	0.023	0.081	0.001	0.953	0.780	0.377
ADFI, lb	0.79	0.78	0.82	0.82	0.82	0.82	0.85	0.032	0.053	0.003	0.917	0.511	0.718
F/G	1.42	1.41	1.40	1.36	1.39	1.38	1.38	0.023	0.620	0.052	0.887	0.720	0.302
d 14 to 35													
ADG, lb	1.25	1.33	1.33	1.36	1.35	1.37	1.40	0.015	0.001	0.001	0.004	0.011	0.568
ADFI, lb	1.85	1.92	1.90	1.95	1.96	1.97	1.99	0.030	0.009	0.001	0.159	0.167	0.222
F/G	1.49	1.45	1.43	1.44	1.45	1.44	1.42	0.018	0.891	0.001	0.206	0.533	0.452
d 0 to 35													
ADG, lb	0.97	1.02	1.03	1.05	1.05	1.06	1.09	0.013	0.001	0.001	0.027	0.042	0.334
ADFI, lb	1.43	1.46	1.47	1.49	1.50	1.51	1.53	0.021	0.007	0.001	0.279	0.211	0.277
F/G	1.47	1.44	1.42	1.42	1.44	1.43	1.41	0.013	0.730	0.001	0.167	0.623	0.710

[1] A total of 1,452 pigs [Group 1; 350 barrows (DNA 200 × 400; initially 13.2 lb)] and [Group 2; 1,102 pigs (PIC 1050 × 280; initially 13.3 lb)] were used in two 35-d growth studies. Data were combined across the 2 groups with 5 pigs per pen and 10 replications per treatment in group 1; and 24 to 27 pigs per pen and 6 replications per treatment in group 2. The treatment design was the same across both groups of pigs. The trace mineral premix was formulated to contribute 17 ppm of Cu to the complete diet.

[2] Intellibond-C, tri-basic copper chloride (Micronutrients, Indianapolis, IN).

[3] Mintrex Cu, copper methionine hydroxy analogue (St. Charles, MO).