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Effects of Copper Feeding Strategy on Growth Performance of Nursery Pigs

Samantha A. Swanson, Jordan T. Gebhardt,[1] Jason C. Woodworth, Mike D. Tokach, Joel M. DeRouchey, Robert D. Goodband, Katelyn N. Gaffield, and Matt Einarson[2]

Summary

A total of 2,204 pigs (PIC 337 × 1050, initially 11.76 ± 0.19 lb) were used in a 38-d study to determine the effect of copper (Cu) feeding strategy on the growth performance of nursery pigs. Pigs were weaned at approximately 20 d of age and randomly allotted to pens with 29 pigs per pen. Pens of pigs were blocked by initial BW and allotted to one of four treatments in a randomized complete block design with 19 pens per treatment across two rooms. Treatment diets were formulated in three phases and fed based on feed budgets of 4 lb/pig and 12 lb/pig for phases 1 and 2, respectively, and phase 3 was fed for the remainder of the trial. Four Cu feeding strategies consisting of increased levels of Cu in the different nursery phases were evaluated. Feeding strategy 1 served as the control with no pharmacological levels of Cu, strategy 2 included pharmacological Cu levels in only phase 3, strategy 3 consisted of pharmacological Cu in phases 2 and 3, and strategy 4 included pharmacological Cu in all three phases. Within each experimental phase, there were two diets provided, either a base level of Cu (17 mg/kg) or pharmacological levels (167 mg/kg) of Cu. The base level of Cu was provided from CuSO in the vitamin/trace mineral premix. In diets that fed Cu above the base level, 150 mg/kg Cu from tribasic copper chloride (SAM Nutrition, Bloomington, MN) was added in addition to the base level. Diets followed common industry practice of Zn supplementation using ZnO in phases 1 and 2 to provide Zn inclusion above basal nutritional levels (approximately 3,000 mg/kg Zn in phase 1, approximately 2,000 mg/kg Zn in phase 2, and 110 mg/kg Zn in phase 3 for all treatments). Pigs were weighed and feed disappearance was measured to determine ADG, ADFI, and feed efficiency. From d 0 to 10 (phase 1), there was no evidence of difference ($P > 0.10$) in performance between pigs fed the base level of Cu and pigs fed a diet containing 167 mg/kg added Cu. From d 10 to 24 (phase 2), pigs fed added Cu had a greater ADG ($P = 0.012$) and ADFI ($P = 0.021$) compared to pigs fed the base level of Cu, with no evidence of a difference for F/G. Pigs fed added Cu for phases 1 and 2 had a greater ADG than pigs fed the control with no pharmacological levels of Cu ($P = 0.047$), with pigs fed pharmacological Cu levels in only phase 3, and pigs fed pharmacological Cu in phases 2 and 3 being intermediate. From d 24 to 38 (phase 3), there were no differences in performance between pigs fed the base level Cu and those fed diets with added Cu. However, pigs fed pharmacological Cu in phases 2 and 3 had numerically greater ADG

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

[2] SAM HPRP Chemicals, Inc. DBA SAM Nutrition, Bloomington, MN.

compared with the other feeding strategies. There were no differences between feeding strategies in overall growth performance (d 0 to 38) or removals and mortality. These data suggest that when pharmacological levels of Zn are used, nursery growth performance can be improved by the addition of pharmacological levels of Cu in the phase 2 diet; however, the improvement did not have an effect on the overall ADG, ADFI, feed efficiency, removals or mortality.

Introduction

Copper sulfate (CuSO) is a common inorganic source of Cu used in swine diets. Tribasic copper chloride (TBCC), a more concentrated form of Cu, can also be used and has been observed to be an effective source of Cu for pigs. The NRC (2012) requirement estimate for Cu is 3 to 5 mg/kg for 11 to 298 lb pigs. However, pharmacological levels of Cu are known to increase growth performance.[3] A review of different levels and sources of added Cu in nursery diets identified that the inclusion of pharmacological levels of dietary Cu, independent of source, increased ADG and improved feed efficiency, particularly in nursery pigs.[4] However, there is limited research in recent years evaluating the most beneficial strategies for feeding pharmacological levels of Cu when fed in combination with pharmacological levels of Zn provided by ZnO. Therefore, the objective of this study was to compare the effects of feeding pharmacological levels of Cu, provided by TBCC, throughout three nursery phases on growth performance.

Materials and Methods

The protocol used in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The experiment was conducted at a commercial research site in southwest Minnesota. Each pen was equipped with a six-hole, dry self-feeder and pan waterer to provide *ad libitum* access to feed and water. Phase 1 diets were manufactured and fed in pellet form (Hubbard Feeds, Mankato, MN). Phase 2 and 3 diets were manufactured and fed in mash form (Hord Farms West Feed Mill, Pipestone, MN). Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) that recorded feed deliveries for individual pens.

A total of 2,204 pigs (PIC 337 × 1050, initially 11.76 ± 0.19 lb) were used in a 38-d study with 29 pigs per pen and 19 replications per treatment across 2 rooms. Pigs were weaned at approximately 20 d of age and randomly allotted to pens. Pens of pigs were blocked by initial BW and allotted to one of four feeding strategies in a randomized complete block design. Treatment diets (Table 1) were formulated in three phases and fed based on feed budgets of 4 lb/pig for phase 1, 12 lb/pig for phase 2, and phase 3 was fed for the remainder of the trial. Pigs were provided *ad libitum* access to feed and water throughout the trial. Diets followed common industry practice of Zn supplementation using ZnO in phases 1 and 2 to provide Zn inclusion above basal nutritional levels (approximately 3,000 mg/kg Zn in phase 1, approximately 2,000 mg/kg Zn in phase 2, and 110 mg/kg Zn in phase 3 for all treatments). Four Cu feeding strategies were evaluated consisting of pharmacological levels of Cu in the different nursery phases.

[3] Cromwell, G. L., M. D. Lindemann, H. J. Monegue, D. D. Hall, and D. E. Orr. 1998. Tribasic copper chloride and copper sulfate as copper sources for weanling pigs. Journal of Animal Science. 76:118. doi:10.2527/1998.761118x.

[4] Galiotto Miranda, P. A., A. Remus, D. B. Dalto, R. Hilgemberg, G. Beber Jasluk, B. C. Rosário Silva, and C. R. Lehnen. 2024. A Systematic Review and Meta-Analysis of the Effects of Various Sources and Amounts of Copper on Nursery Piglets. Veterinary Sciences. 11:68. doi:10.3390/vetsci11020068.

Feeding strategy 1 served as the control with no pharmacological levels of Cu, strategy 2 included pharmacological Cu in only phase 3, strategy 3 consisted of pharmacological Cu in phases 2 and 3, and strategy 4 included pharmacological Cu in all three phases. Within each experimental phase, there were two diets provided, either a base level of Cu (17 mg/kg) or pharmacological levels (167 mg/kg) of Cu. The base level of Cu was provided from CuSOin the vitamin/trace mineral premix. In phases where pharmacological levels of Cu were fed, 150 mg/kg of TBCC (SAM Nutrition, Bloomington, MN) was added to diets as a separate ingredient.

Pens of pigs were weighed, and feed disappearance was recorded on d 10, 17, 24, 28, 31, and 38 to determine ADG, ADFI, and feed efficiency. Feed deliveries were recorded for each pen, any uneaten feed remaining in feeders was determined by feeder measurement and recorded on each day pens of pigs were weighed. Mortality and removals were recorded for the duration of the trial. Under the circumstance a pig died or was removed from the study due to inability to overcome sickness or injury, the weight of the pig and feed consumption up until that date was recorded. Removed pigs were placed in an off-test pen by treatment and continued to be fed their respective treatment diet so that mortality of these removed pigs could be determined.

Data analysis

Growth data were analyzed as a randomized complete block design with pen serving as the experimental unit and block serving as a random effect. Data were analyzed using R studio (Version 4.3.1 R Core Team, Vienna, Austria) using a one-way ANOVA using the lmer function including treatment as fixed effect and weight block as a random effect. Contrasts were used to test for the main effects of Cu level within each phase. Results were considered significant at $P < 0.05$ and marginally significant at $P \leq 0.10$.

Results and Discussion

Analysis of complete diets indicated that analyzed Cu levels were within the expected range of formulated levels while accounting for analytical variation and Cu levels coming from basal ingredients (Table 2). No meaningful deviations from expected Cu levels were observed nor was it observed for any other nutrients.

From d 0 to 10 (phase 1), there was no evidence of difference in performance between pigs fed the base level of Cu and pigs fed a diet containing pharmacological Cu (Table 3). From d 10 to 24 (phase 2), pigs fed added Cu had a greater ADG ($P = 0.012$) and ADFI ($P = 0.021$) compared to pigs fed the base level of Cu, with no evidence of a difference for F/G. Additionally, pigs fed pharmacological levels of Cu in phases 1 and 2 had greater ADG at the end of phase 2 than those fed a base level of Cu in phase 1 ($P = 0.047$), with pigs fed pharmacological Cu levels in only phase 3 and pigs fed pharmacological Cu in phases 2 and 3 being intermediate.

From d 24 to 38 (phase 3), there were no differences in growth performance between pigs fed the base level Cu and pharmacological level Cu nor any differences in any of the feeding strategies, although pigs fed pharmacological Cu in phases 2 and 3 had a numerically greater ADG than those fed other feeding strategies. There were no differences between Cu feeding strategies in the overall growth performance (d 0 to 38) or removals and mortality. The mortality of pigs that were removed from their test pen could not be traced back to their original pen; therefore, mortality including these pigs cannot be analyzed. Descriptive statistics suggest removal mortality for pigs fed pharmacological Cu in phases 2 and 3 was lower than the other strategies. However, when

considering the removal percentage and multiplying by the mortality of removed pigs, the differences between treatments are small and likely would not result in significant differences if statistical analysis were able to be performed.

In summary, these data suggest that when pharmacological levels of Zn are used, ADG and ADFI can be improved by the addition of pharmacological levels of Cu in the diet from d 10 to 24. However, the improvement in ADG and ADFI within phase 2 from the addition of pharmacological levels of Cu did not influence the overall ADG, ADFI, feed efficiency, removals, or mortality.

Acknowledgments

Appreciation is expressed to SAM Nutrition (Bloomington, MN) and Hord Farms West (Pipestone, MN) for providing partial financial support and technical support in conducting this experiment.

Table 1. Composition of experimental diets (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn	40.57	57.63	57.42
Soybean meal, 47.7% CP	17.76	29.92	28.53
Whey powder	25.00	---	---
Dried distillers grains with solubles	5.00	7.50	10.00
Microbial enhanced soybean meal[2]	5.00	---	---
Corn oil	2.50	---	---
Calcium carbonate	0.45	0.75	0.85
Calcium phosphate (monocalcium)	1.10	1.10	0.70
Sodium chloride	0.15	0.45	0.29
Liquid lysine, 55%[3]	---	0.75	0.70
L-Lys-HCl	0.45	---	---
DL-Met	0.26	0.23	0.19
L-Thr	0.18	---	---
Thr[4]	---	0.28	0.24
L-Trp	0.03	0.02	---
L-Val	0.11	0.11	0.08
Vitamin premix	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15
Choline chloride, 60%	0.04	---	---
Phytase[5]	0.06	0.06	0.06
Zinc oxide	0.40	0.26	---
Feed Aid[6]	0.55	0.55	0.55
TBCC, 58%[7]	+/-	+/-	+/-
Total	100	100	100

continued

Table 1. Composition of experimental diets (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Calculated analysis			
Standardized ileal digestible (SID) amino acids, %			
Lys	1.35	1.35	1.30
Ile:Lys	59	56	58
Leu:Lys	120	122	129
Met:Lys	39	39	38
Met and Cys:Lys	60	60	60
Thr:Lys	65	65	65
Trp:Lys	20.3	20.3	20.6
Val:Lys	70	70	70
His:Lys	34	37	39
NE, kcal/lb	1,172	1,080	1,088
CP, %	20.7	22.2	22.2
Ca, %	0.72	0.71	0.68
STTD P, %	0.62	0.51	0.44
Ca:P	1.04	1.10	1.20
Zn, mg/kg	3,000	2,000	110

[1]Phase 1 and 2 diets were provided using a feed budget of 4 and 12 lb/pig, phase 3 was fed for the remainder of the trial.
[2]ME-PRO, Prairie Aquatech, Brookings, SD.
[3]L-Lysine 55% liquid CJ America Bio, Downers Grove, IL.
[4]Threopro CJ America Bio, Downers Grove, IL.
[5]HiPhorius 2,400 (DSM-Firmenich, Maastricht, Netherlands) was added at 1,500 FYT/kg and provided an estimated release of 0.12% STTD P.
[6]Feed Aid NutriQuest, Mason City, IA.
[7]Tribasic copper chloride, (TBCC, 58%, SAM Nutrition Bloomington, MN) added at 0.03% of the diet was included at the expense of corn to provide 150 mg/kg of Cu.

Table 2. Analyzed nutrient composition of experimental diet (as-fed basis)[1]

	Phase 1		Phase 2		Phase 3	
	Base level Cu	Pharmaco-logical Cu	Base level Cu	Pharmaco-logical Cu	Base level Cu	Pharmaco-logical Cu
DM, %	88.4	91.6	86.8	86.8	86.4	86.5
CP, %	19.0	19.3	20.8	20.1	20.0	20.8
ADF, %	4.5	4.9	4.2	4.2	4.2	4.7
Ash, %	6.1	6.3	5.9	5.7	5.0	5.2
Ca, %	0.63	0.68	0.65	0.57	0.65	0.64
P, %	0.68	0.67	0.65	0.61	0.52	0.58
Mg, %	0.15	0.16	0.18	0.17	0.18	0.19
K, %	1.10	1.10	0.95	0.95	0.95	0.93
Na, %	0.34	0.37	0.32	0.31	0.23	0.26
Zn, mg/kg	3,153	2,457	1,983	1,528	182	155
Fe, mg/kg	399	413	288	253	225	244
Mn, mg/kg	64	80	58	51	47	51
Cu, mg/kg[2]	29	172	27	171	28	195

[1]Values represent the mean of two samples (Cumberland Valley Analytical Services, Inc., Waynesboro, PA).
[2]Tribasic copper chloride (TBCC, 58%, SAM Nutrition, Bloomington, MN) provided an added 150 mg/kg of Cu in treatments labeled as pharmacological Cu.

Table 3. Effects of copper feeding strategy on growth performance of nursery pigs[1]

	Cu, mg/kg						
Phase 1:	**17**	**17**	**17**	**167**		***P* =**	
Phase 2:	**17**	**17**	**167**	**167**			
Phase 3:	**17**	**167**	**167**	**167**	**SEM**	**Treatment**	**Base vs. Pharmacological Cu[2]**
BW, lb							
d 0	11.77	11.76	11.76	11.77	0.193	0.998	---
d 10	14.52	14.14	14.17	14.14	0.213	0.034	0.250
d 24	25.91	25.67	25.87	26.16	0.421	0.503	0.327
d 38	40.43	40.12	40.89	40.83	0.494	0.341	0.636
d 0 to 10 (phase 1)							
ADG, lb	0.23	0.21	0.21	0.20	0.011	0.206	0.129
ADFI, lb	0.38	0.37	0.37	0.36	0.010	0.193	0.162
F/G	1.70	1.95	1.83	1.89	0.110	0.501	0.302
d 10 to 24 (phase 2)							
ADG, lb	0.79[b]	0.80[ab]	0.82[ab]	0.83[a]	0.017	0.047	0.012
ADFI, lb	1.05	1.05	1.08	1.09	0.019	0.108	0.021
F/G	1.33	1.32	1.32	1.32	0.015	0.857	0.748
d 24 to 38 (phase 3)							
ADG, lb	1.00	0.99	1.03	1.00	0.031	0.515	0.644
ADFI, lb	1.62	1.58	1.63	1.64	0.039	0.336	0.289
F/G	1.64	1.61	1.60	1.65	0.025	0.141	0.360
Overall							
ADG, lb	0.69	0.68	0.70	0.69	0.013	0.613	---
ADFI, lb	1.04	1.02	1.05	1.05	0.017	0.273	---
F/G	1.51	1.50	1.50	1.52	0.012	0.237	---
Removals, %	20.8	21.0	22.3	21.5	2.29	0.936	---
Mortality, %							
Mortality in test pen	1.6	2.2	2.2	3.1	0.74	0.450	---
Mortality as removal	10.7	10.8	10.0	11.4	---	---	---
Total mortality	12.3	13.0	12.2	14.5	---	---	---
Pigs remaining in test pens, %	77.6	76.8	75.6	75.4	2.42	0.801	---

[a,b] Means in the same row with different superscripts differ ($P < 0.05$).

[1] A total of 2,204 (PIC 1050 ′ 337) pigs were used in a 38-d trial with 29 pigs per pen and 19 replications per treatment. All treatments contained 17 mg/kg of Cu from the trace mineral premix. Treatments consisted of added 150 mg/kg on top of the base Cu level for differing feeding strategies by phase. Treatment diets were fed based on a feed budget of 4 lb/pig for phase 1, 12 lb/pig for phase 2, and phase 3 was fed for the remainder of the trial.

[2] Compares the means of treatments with no added Cu (17 mg/kg) to treatments containing pharmacological Cu (167 mg/kg) within phase.