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Effect of Copper Source on Finishing Pig Growth Performance and Carcass Characteristics

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 2,160 pigs (PIC 337 × 1050; initially 53.1 ± 1.31 lb) were used in a 113-day study with 27 pigs per pen and 20 replications per treatment across two barns. Pens of pigs were blocked by weight and randomly allotted to one of four dietary treatments: a control diet containing a base level of Cu, or a pharmacological level of one of three sources, tribasic copper chloride (TBCC) source 1 (TBCC, 58%, SAM Nutrition, Bloomington, MN), TBCC source 2 (Intellibond C, 54%, Selko, Tilburg, Netherlands), or $CuSO_4$. All diets contained a base level of $CuSO_4$ provided by the trace mineral premix contributing 16 mg/kg Cu in phases 1 and 2, 13 mg/kg Cu in phase 3, and 11 mg/kg Cu in phase 4. An additional 150 mg/kg Cu was added from each specific source. Treatment diets were formulated in four phases from approximately 50 to 110 lb, 110 to 165 lb, 165 to 220 lb, and 220 lb to marketing (approximately 280 lb). Mortality and removals were recorded for the duration of the trial, and economics were calculated. In the grower period (d 0 to 56), pigs fed pharmacological levels of Cu had greater ($P < 0.001$) ADG and BW compared to pigs fed the base Cu level. No evidence of a difference was observed between Cu sources when fed at pharmacological levels. A tendency ($P \leq 0.059$) for increased ADFI and improved F/G was observed in pigs fed pharmacological levels of Cu compared to the base level. In the finishing period (d 56 to trial end), there was no evidence of any differences in ADG, ADFI, or F/G between treatments. Overall, pigs fed pharmacological levels of Cu had greater ($P = 0.018$) ADG and a tendency for a greater ($P = 0.072$) ADFI than pigs fed the base level of Cu. Hot carcass weight was greater ($P = 0.031$) in pigs fed pharmacological levels of Cu than in pigs fed the base level of Cu. No evidence of differences was found for other carcass characteristics or removals and mortality. There was a tendency ($P = 0.083$) for pigs fed pharmacological levels of Cu to have higher feed cost per lb/gain than pigs that were fed basal levels of Cu. However, it did not impact IOFC, and no other differences in economic criteria were observed. These data suggest that feeding pharmacological levels of Cu improves growth performance, with the largest benefit observed during the grower period; however, there were no differences between Cu sources when fed at pharmacological levels.

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

Introduction

There are many different sources of copper (Cu) available for use in swine diets. The most used is copper sulfate ($CuSO_4$) with tribasic copper chloride (TBCC) as another option. The dietary copper requirement estimate for pigs weighing between 12 and 290 lb is 3 to 6 mg/kg; however, numerous studies have observed improvements in ADG and ADFI when pharmacological levels (125 to 250 mg/kg) of Cu are included in the diet.[3] These benefits are typically observed in the early growing period, although research has also observed positive effects in later finishing stages.[4,5] For example, one study demonstrated a linear improvement in growth performance and hot carcass weight (HCW) in finishing pigs when supplementing diets with 75 mg/kg and 150 mg/kg Cu from either $CuSO_4$ or TBCC.[6] As new Cu sources become available, further research is needed to characterize their effect in swine diets. Therefore, the objective of this study was to compare the effects of three Cu sources fed at a pharmacological level (TBCC Source 1, TBCC Source 2, or $CuSO_4$) compared to a control diet containing a base level of Cu provided from the trace mineral premix on growth performance and carcass characteristics in finishing pigs in a commercial research barn.

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 (10 × 18 ft) was equipped with a five-hole stainless steel dry self-feeder (Thorp Equipment, Thorp, WI) and a bowl waterer to provide *ad libitum* access to feed and water throughout the experiment. 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.

Animals and diets

A total of 2,160 pigs (PIC 337 × 1050; initially 53.1 ± 1.31) were used in a 113-day study with 27 pigs per pen and 20 replications per treatment across two barns. Pigs were randomly assigned a pen upon arrival in the barn and fed a common diet until they reached approximately 50 lb. Pens of pigs were then blocked by weight and randomly allotted to one of four dietary treatments: a control diet containing a base level of Cu, or a pharmacological level of one of three sources: TBCC source 1 (TBCC, 58%, SAM Nutrition, Bloomington, MN), TBCC source 2 (Intellibond C, 54%, Selko, Tilburg, Netherlands), and $CuSO_4$. All treatments contained a base level of $CuSO_4$ provided by the trace mineral premix, which provided 16 mg/kg Cu in phases 1 and 2, 13 mg/kg Cu in phase 3, and 11 mg/kg Cu in phase 4 based on a tapered inclusion of the trace mineral premix throughout the experiment. An additional 150 mg/kg Cu was added

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[3] NRC. 2012. Nutrient Requirements of Swine. 11th rev. ed. National Academy Press, Washington, DC.

[4] NCR-42 Committee on Swine Nutrition. 1974. Cooperative regional studies with growing swine: Effects of vitamin E and levels of supplementary copper during the growing-finishing period on gain, feed conversion, and tissue storage in swine. J. Anim. Sci. 39:512–520. doi:10.2527/jas1974.393512x

[5] Hastad, C. W., J. L. Nelssen, M. D. Tokach, R. D. Goodband, S. S. Dritz, 2001. Evaluation of different copper sources as a growth promoter in swine finishing diets. Kansas Agric. Exp. Stn. Res. Rep. Vol. 0: Iss. 10. https://doi.org/10.4148/2378-5977.6660

[6] Coble, K. F., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. C. Woodworth, and J. L. Usry. 2017. The effects of copper source and concentration on growth performance, carcass characteristics, and pen cleanliness in finishing pigs. J. Anim. Sci. 95:4052. doi:10.2527/jas2017.1624.

from the other three sources. Test ingredients were mixed into hand-add packs using approximately 2 lb of ground corn per ton of feed to create the treatments. Treatment diets (Table 1) were formulated in four phases and fed based on weight: phase 1 from approximately 50 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 lb to marketing at approximately 280 lb.

Pen weights, feed delivery, and feed disappearance were recorded approximately every 14 d to determine ADG, ADFI, and F/G. Feed delivered was recorded for each pen, with any feed remaining in feeders recorded on each weigh day by a feeder measurement. When the average pig weight reached approximately 240 lb, the three heaviest pigs per pen were selected and marketed at a USDA inspected processing facility (JBS Foods, Worthington, MN). No carcass data were collected during this first marketing event. At the end of the study, approximately two to three weeks after the first marketing event, the remaining pigs were marketed. Standard carcass measurements of backfat, loin depth, percentage lean, and carcass weight were collected for each individual carcass and summarized by pen. 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.

Feed cost per pig was calculated by multiplying the diet feed cost times the feed intake per phase divided by pigs placed. Feed cost per lb of gain was calculated by dividing total feed cost per pig by total gain per pig. Revenue was calculated by multiplying total gain by carcass yield and carcass price. Income over feed cost (IOFC) was calculated by subtracting feed cost per pig from revenue. Prices for calculations were: carcass price, \$1.10/lb; corn, \$4.00/bushel; soybean meal, \$300/ton; DDGS, \$150/ton; liquid lysine, \$0.60/lb; DL-Met, \$1.40/lb; Thr-Pro, \$0.85/lb; and L-Trp, \$3.50/lb.

Data analysis

Data were analyzed using R Studio (Version 4.3.1 R Core Team, Vienna, Austria) using a one-way ANOVA and the lmer function including treatment as a fixed effect with weight block and barn serving as random effects, and HCW serving as a covariate for carcass data. A contrast was used to test for the effect of base level Cu vs. pharmacological levels of Cu. The P values 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. No meaningful deviations from the expected Cu levels were observed when accounting for analytical variation and Cu levels coming from basal ingredients, nor were any observed for other nutrients (Table 2).

In the grower period (d 0 to 56), pigs fed pharmacological levels of Cu had greater ($P < 0.001$) ADG and BW compared to the control diet containing a basal level of Cu. No evidence of a difference was observed between Cu sources when fed at pharmacological levels. A tendency ($P \leq 0.059$) for increased ADFI and improved F/G was observed in pigs fed pharmacological levels of Cu compared to those fed the control diet. In the finishing period (d 56 to trial end), there was no evidence of any differences in ADG, ADFI, or F/G between treatments or when comparing pigs fed pharmacological levels of Cu to those fed the control diet.

Overall, pigs fed pharmacological levels of Cu had greater ($P = 0.018$) ADG and a tendency for greater ($P = 0.072$) ADFI compared to pigs fed the base level of Cu. Hot carcass weight was greater ($P = 0.031$) in pigs fed pharmacological levels of Cu than in pigs fed the base level of Cu. No evidence of any differences was observed for other carcass characteristics or removals and mortality.

There was a tendency ($P = 0.083$) for pigs fed pharmacological levels of Cu to have higher feed cost per lb/gain than pigs fed the control diet with basal levels of Cu. However, it did not affect IOFC nor other differences in economic criteria.

In summary, there were no differences between Cu sources when fed at the pharmacological level of 150 mg/kg of the diet. However, feeding pharmacological levels of Cu improved growth performance, with the greatest response observed in the early growing period.

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]

Item	Phase 1	Phase 2	Phase 3	Phase 4
Ingredient, %				
Corn	57.53	62.81	67.87	85.56
Soybean meal (47.7% CP)	19.48	14.36	9.59	12.23
Dried distillers grains with solubles	20.00	20.00	20.00	---
Calcium carbonate	1.38	1.35	1.28	0.93
Salt	0.35	0.35	0.35	0.35
Calcium phosphate (monocalcium)	0.23	0.20	0.05	0.23
Liquid Lys, 55%[2]	0.66	0.62	0.59	0.44
DL-Met	0.05	0.01	---	0.02
Thr[3]	0.14	0.12	0.10	0.11
L-Trp	0.04	0.04	0.04	0.03
Vitamin/trace mineral premix	0.11	0.11	0.11	0.08
Phytase[4]	0.05	0.05	0.05	0.05
Cu source[5]	+/-	+/-	+/-	+/-
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.10	0.95	0.82	0.72
Ile:Lys	60	60	60	60
Leu:Lys	148	159	171	153
Met:Lys	31	30	31	30
Met and Cys:Lys	57	57	60	58
Thr:Lys	64	64	65	65
Trp:Lys	19.1	19.1	19.0	19.3
Val:Lys	69	72	74	70
His:Lys	42	43	45	43
NE, kcal/lb	1,088	1,102	1,118	1,160
CP, %	20.2	18.1	16.2	13.2
Ca, %	0.62	0.59	0.52	0.43
STTD P, %	0.39	0.37	0.33	0.27
Ca:P	1.20	1.21	1.20	1.20

[1] Phase one from approximately 50 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 lb to marketing at approximately 280 lb.
[2]L-Lys 55% liquid, CJ America Bio, Downers Grove, IL.
[3]Threopro CJ America Bio, Downers Grove, IL.
[4]Quantum Blue 2G (AB Vista, Marlborough, England) was added at 454 FTU/lb and provided an estimated release of 0.12% STTD P.
[5]Cu sources were included at 0.026%, 0.028% and 0.06% of the diet for TBCC, 58% (SAM Nutrition, Bloomington, MN), Intellibond C, 54% (Selko, Tilburg, Netherlands) and $CuSO_4$ at the expense of corn to provide 150 mg/kg of Cu.

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

	DM, %	CP, %	ADF, %	Ash, %	Ca, %	P, %	Mg, %	K, %	Na, %	Fe, mg/kg	Mg, mg/kg	Zn, mg/kg	Cu, mg/kg
Phase 1													
Control	86.4	18.5	3.3	6.2	0.78	0.45	0.17	0.79	0.20	151	33	131	62
TBCC Source 1	86.1	18.9	3.6	5.8	0.80	0.45	0.17	0.78	0.20	152	31	128	188
TBCC Source 2	90.6	19.5	3.8	6.2	0.88	0.48	0.18	0.83	0.21	176	35	138	183
$CuSO_4$	86.1	18.8	3.4	5.5	0.79	0.46	0.17	0.77	0.21	152	31	148	159
Phase 2													
Control	85.5	16.4	4.0	4.9	0.68	0.43	0.16	0.67	0.19	123	32	124	27
TBCC Source 1	85.4	16.7	3.3	4.8	0.72	0.46	0.17	0.71	0.20	141	32	135	196
TBCC Source 2	85.5	16.5	3.4	4.7	0.75	0.45	0.17	0.69	0.21	144	34	134	172
$CuSO_4$	85.4	16.6	3.4	5.0	0.78	0.45	0.17	0.70	0.19	149	33	125	190
Phase 3													
Control	85.2	14.5	3.3	4.1	0.65	0.39	0.15	0.60	0.17	117	24	116	47
TBCC Source 1	85.4	14.6	3.2	4.2	0.71	0.40	0.16	0.61	0.18	132	30	116	196
TBCC Source 2	85.0	14.6	2.3	4.2	0.73	0.40	0.15	0.49	0.17	123	24	114	180
$CuSO_4$	85.1	14.1	2.8	4.2	0.70	0.41	0.16	0.62	0.18	127	27	125	185
Phase 4													
Control	84.7	11.2	1.5	3.1	0.50	0.31	0.11	0.49	0.16	103	19	79	46
TBCC Source 1	85.1	11.0	1.7	3.1	0.54	0.31	0.11	0.48	0.14	93	22	82	145
TBCC Source 2	85.1	11.2	1.6	3.4	0.59	0.31	0.11	0.48	0.15	113	21	88	198
$CuSO_4$	85.1	11.4	1.6	3.1	0.50	0.27	0.10	0.50	0.14	111	21	79	184

[1]Values represent the mean of two samples (Cumberland Valley Analytical Services, Inc., Waynesboro, PA). All treatments contained a base level of $CuSO_4$ provided by the trace mineral premix. Inclusions were 16 mg/kg Cu in phases 1 and 2, 13 mg/kg Cu in phase 3, and 11 mg/kg Cu in phase 4 based on a tapered inclusion of the vitamin/trace mineral premix throughout the experiment. In addition to the base level of Cu in all diets, treatments consisted of adding 150 mg/kg of the respective Cu source, TBCC source 1 (TBCC 58%, SAM Nutrition, Bloomington MN), TBCC source 2 (Intellibond C 54%, Selko, Tilburg, Netherlands), or $CuSO_4$ on top of the base Cu level. Treatment diets were formulated in four phases: phase one from approximately 50 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 lb to marketing at approximately 280 lb.

Table 3. Effects of copper source on finishing pig growth performance and carcass characteristics[1]

	Pharmacological Cu					*P* =	
	Base level Cu	TBCC Source 1	TBCC Source 2	$CuSO_4$	SEM	Treatment	Base level vs. Pharmacological Cu[2]
BW, lb							
d 0	53.1	53.1	53.1	53.0	1.31	0.998	0.962
d 56	169.0[b]	171.7[a]	172.5[a]	172.4[a]	2.90	0.001	< 0.001
Final	277.4	282.0	282.2	281.4	3.00	0.063	0.008
Grower[3]							
ADG, lb	2.06[b]	2.10[ab]	2.12[a]	2.11[a]	0.033	0.004	< 0.001
ADFI, lb	4.64	4.68	4.74	4.72	0.107	0.131	0.059
F/G	2.25	2.22	2.24	2.24	0.020	0.186	0.057
Finisher[4]							
ADG, lb	2.09	2.11	2.12	2.09	0.060	0.686	0.462
ADFI, lb	6.53	6.57	6.64	6.59	0.119	0.468	0.203
F/G	3.14	3.14	3.15	3.17	0.041	0.671	0.683
Overall[5]							
ADG, lb	2.07	2.10	2.11	2.10	0.023	0.087	0.018
ADFI, lb	5.53	5.57	5.63	5.60	0.058	0.185	0.072
F/G	2.67	2.65	2.67	2.67	0.021	0.410	0.338
Carcass characteristics							
HCW, lb[6]	206.7	209.5	209.8	209.0	2.17	0.171	0.031
Yield, %	74.1	73.8	74.0	74.0	0.22	0.671	0.363
Backfat, in	0.66	0.65	0.66	0.65	0.013	0.590	0.543
Loin depth, in	2.68	2.67	2.67	2.67	0.024	0.888	0.447
Lean, %	56.86	56.94	56.78	56.99	0.224	0.622	0.733

continued

Table 3. Effects of copper source on finishing pig growth performance and carcass characteristics[1]

	Pharmacological Cu					$P =$	
	Base level Cu	TBCC Source 1	TBCC Source 2	$CuSO_4$	SEM	Treatment	Base level vs. Pharmacological Cu[2]
Removals and mortality, %							
Removals	4.26	3.33	3.52	4.44	0.887	0.733	0.586
Mortality	0.56	1.30	1.30	1.85	0.580	0.330	0.113
Removals and mortality	4.81	4.63	4.81	6.30	1.045	0.574	0.725
Economics, $/pig placed							
Feed cost	51.97	52.72	53.09	52.61	0.757	0.442	0.769
Feed cost/lb gain[7]	0.239	0.240	0.241	0.242	0.0019	0.153	0.083
Revenue[8]	179.35	181.37	181.56	179.62	2.06	0.701	0.440
IOFC[9]	127.38	128.65	128.47	127.02	1.472	0.736	0.644

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

[1]A total of 2,160 pigs (PIC 1050 × 337 initially 53.1 ± 1.31) were used in a 113-d trial with 27 pigs per pen and 20 replications per treatment using two research barns. All treatments contained a base level of $CuSO_4$ provided by the trace mineral premix. Inclusions were 16 mg/kg Cu in phases 1 and 2, 13 mg/kg Cu in phase 3, and 11 mg/kg Cu in phase 4 based on a tapered inclusion of the vitamin/trace mineral premix throughout the experiment. In addition to the base level of Cu in all diets, treatments consisted of adding 150 mg/kg of the respective Cu source, TBCC source 1 (TBCC 58%, SAM Nutrition, Bloomington MN), TBCC source 2 (Intellibond C 54%, Selko, Tilburg, Netherlands), or $CuSO_4$ on top of the base Cu level. Treatment diets were formulated in four phases: phase one from approximately 50 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 lb to marketing at approximately 280 lb.

[2]Compares the control treatment containing a base level of Cu with the mean of treatments fed pharmacological levels of Cu within the period. Contrasts comparing Cu sources were not significant ($P > 0.10$) throughout the entire trial for any response criteria.

[3]Grower period represents d 0 to 56 for both research barns.

[4]Finisher period represents d 56 to 107 for first barn, and d 56 to 113 for second barn.

[5]Overall period represents d 0 to 107 for first barn, and d 0 to 113 for second barn.

[6] HCW served as a covariate for carcass data.

[7]Feed cost/lb gain = total feed cost per pig divided by total gain per pig.

[8]Revenue = (total gain × carcass yield) × carcass price.

[9]Income over feed cost = revenue − feed cost.