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Effects of Standardized Ileal Digestible Lysine Level and Added Tribasic Copper Chloride on Growth Performance, Carcass Characteristics, and Economics in Finishing Pigs[1]

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Summary

A total of 1,267 pigs (PIC 337 × 1050; initially 58.3 lb) were used in a 120-d study. Before initiating the trial, pigs were fed a common diet for 9 d containing 188 ppm Cu from tribasic copper chloride (TBCC). On d 0, pens of pigs were allotted to 1 of 8 dietary treatments in a randomized complete block design with 26 to 27 pigs (similar number of barrows and gilts) per pen and 6 pens per treatment. Treatments were arranged in a split-plot design. Whole-plot treatments were 2 levels of the estimated standardized ileal digestible lysine (SID Lys) requirement (92.5 or 100%). Within each level of Lys, there was a 2 × 2 factorial arrangement of treatments with either 0 or 150 ppm Cu from TBCC with two feeding durations (60 or 120 d). All diets were corn-soybean meal–based with 30% dried distillers grains with solubles (DDGS) and contained 17 ppm of Cu from copper sulfate ($CuSO_4$) provided by the trace mineral premix. Overall (d 0 to 120), no TBCC × SID Lys interactions were observed for growth performance, final BW, or caloric efficiency. Pigs fed 100% of the SID Lys requirement had increased ($P < 0.05$) ADG and final BW as well as improved F/G, compared with those fed 92.5% of the estimated requirement. The improvements in F/G also led to improvements in caloric efficiency on both an ME and NE basis. For carcass characteristics, a significant TBCC × SID Lys interaction ($P < 0.05$) was observed for carcass yield and backfat depth. Hot carcass weight and ADG were improved ($P < 0.05$) in pigs fed 100% SID Lys compared with those fed 92.5% and tended ($P < 0.10$) to improve in pigs fed TBCC compared with those not fed TBCC.

Economically, pigs fed 92.5% of their SID Lys requirement had lower ($P < 0.05$) total feed cost, cost per pound of gain, and value of the weight gained during the experiment (gain value) compared with those fed 100% SID Lys. Despite the increased feed cost, income over feed cost (IOFC) was greater ($P < 0.05$) for pigs fed 100% compared with those fed 92.5% of the estimated Lys requirement. When economics were calculated on a constant weight basis, pigs fed 92.5% SID Lys had poorer ($P < 0.05$) adjusted F/G. The lower ADG for pigs fed 92.5% of their SID Lys requirement resulted in an increase ($P < 0.05$) in facility cost compared with those fed 100% of their SID Lys requirement because of the increased time required for those pigs to reach the assumed market weight of 275 lb.

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In conclusion, increasing SID Lys from 92.5 to 100% resulted in increased ADG, HCW, HCW ADG, and improved F/G. There were no differences among pigs fed different TBCC feeding strategies, but pigs fed 150 ppm Cu from TBCC had increased yield and HCW, which led to an increase in HCW ADG and improved HCW F/G.

Key words: copper, finishing pig, lysine

Introduction

Past experiments have suggested that feeding supplemental copper (Cu) in the form of copper sulfate ($CuSO_4$) did not provide growth benefits beyond 135 lb (Hastad et al., 2001[4]). A more recent study suggested that supplementing Cu in the form of tri-basic copper chloride (TBCC; Intellibond C, Micronutrients, Indianapolis, IN) during the finishing period can influence growth much longer than previously reported (Coble et al., 2013[5]). Supplementing finishing diets with 150 ppm of Cu from TBCC increased feed intake and consequently gain, even after the pigs had reached 195 lb. These diets were formulated 0.05% below the estimated standardized ileal digestible (SID) lysine (Lys) level requirement, because previous work in poultry has suggested that when TBCC was added to diets containing marginal levels of Lys, growth performance of broilers was similar to those fed diets adequate in Lys with no additional Cu.

A second, more recent study (see "Effects of Standardized Ileal Digestible Lysine Level in Diets Containing Tribasic Copper Chloride on Finishing Pig Growth Performance, Carcass Characteristics, and Fat Quality," p. 138) further investigated the response to Cu in diets differing in SID lysine content by investigating the effects of feeding diets to finishing pigs that contained 100, 92.5, or 85% of the estimated SID Lys requirement with or without 150 ppm Cu from TBCC. In this study, the response to TBCC again increased ADG and final BW. Pigs fed increasing levels of SID Lys also had higher ADG with similar ADFI, which resulted in improved F/G. However, the growth rates of the pigs in this study were lower than in previous studies; as a result, the understanding of how nutrient density can affect the response to TBCC is unclear. Therefore, the objectives of this study were (1) to understand how a limited SID Lys diet affects the growth performance of pigs fed Cu from TBCC, and (2) to understand the effects of feeding TBCC during only early finishing or late finishing or for the entire finishing period.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted in a commercial research finishing barn in southwest Minnesota. The barn was naturally ventilated and double-curtain-sided. Pens had completely slatted flooring and deep pits. Each pen was equipped with a 4-hole stainless steel feeder and cup waterer for ad libitum access to feed and water. Feed additions were made by a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that measured feed amounts for each individual pen.

A total of 1,267 pigs (PIC 337 × 1050; initially 58.3 lb) were used in a 120-d study. Before initiating the trial, pigs were fed a common diet containing 188 ppm added

[4] Hastad et al., Swine Day 2001, Report of Progress 880, pp. 111–117.
[5] Coble et al., Swine Day 2013, Report of Progress 1092, pp. 168–180.

Cu from TBCC. On d 0, pens of pigs were allotted to 1 of 8 dietary treatments in a randomized complete block design with 26 to 27 pigs (similar number of barrows and gilts) per pen and 6 replications per treatment. Treatments were arranged in a split-plot design. Whole-plot treatments were 2 levels of the estimated SID Lys requirement (92.5 or 100%). Within each level of Lys, there was a 2 × 2 factorial arrangement of treatments with either 0 or 150 ppm Cu from TBCC with two feeding durations (60 or 120 d). All diets were corn-soybean meal–based with 30% dried distillers grains with solubles (DDGS) and contained 17 ppm of Cu from copper sulfate ($CuSO_4$) provided by the trace mineral premix. Treatment diets were fed in 5 phases (Tables 1, 2, and 3). During the last phase, all diets contained 4.5 g/ton of ractopamine HCl (Paylean; Elanco Animal Health, Greenfield, IN). Each treatment diet was sampled at the start and before the last day of each phase change to form a composite sample and was analyzed for Cu (Table 4).

Pens of pigs were weighed and feed disappearance was recorded on d 21, 38, 60, 95, 101, and 120 to determine ADG, ADFI, and F/G. Caloric efficiency on both an ME and NE basis were calculated for each treatment by dividing the sum of total feed intake and dietary energy (kcal) by total gain. On d 101, the 5 heaviest pigs in each pen were visually selected, weighed, and sold according to standard farm procedures. Prior to marketing, the remaining pigs were individually tattooed with a pen ID number to allow for carcass measurements to be recorded on a pen basis. On d 120, final pen weights were taken and pigs were transported to a commercial packing plant in southwestern Minnesota (JBS Swift and Company, Worthington, MN) for processing and carcass data collection. Carcass measurements included HCW, loin depth, backfat depth, and percentage lean. Percentage carcass yield was calculated by dividing the average pen HCW by the average final live weight at the farm. Hot carcass weight ADG was calculated by subtracting the assumed initial HCW (d-0 wt × an estimated 75% yield) from HCW, then dividing the value by 120 d. Carcass F/G was calculated by dividing ADFI by HCW ADG.

At the conclusion of the study, an economic analysis was calculated on both a constant days on feed or constant market weight basis to determine the value of feeding TBCC and two levels of SID Lys in two scenarios. For calculating on a constant days on feed basis, economics were determined using the treatment means from the trial. To determine the economics on a constant weight basis, feed efficiency was adjusted to a common final BW by a factor of 0.005 per pound of final weight. The actual ADG and adjusted F/G were then used to determine the difference in total number of days and feed need to reach a common weight of 275 lb.

For the constant days on feed and constant weight economic evaluation, total feed cost per pig, cost per pound of gain, gain value, and income over feed cost (IOFC) were calculated. Feed cost was calculated by multiplying ADFI by the feed cost per pound and the number of days in each respective period, then taking the sum of those values for each period calculated the total feed cost per pig. Cost per pound of gain was calculated by dividing the total feed cost per pig by the total pounds gained overall. The value of the weight gained during the experiment (gain value) was calculated by subtracting the product of initial pig weight times the assumed carcass price of $110.34 per cwt from final pig weight times $110.34 per cwt. Income over feed cost was calculated by subtracting total feed cost from gain value. The income over feed and facilities cost

(IOFFC) was calculated for the constant market weight evaluation because pigs with faster growth rates will reach 275 lb sooner, therefore decreasing the cost of housing the pigs. Facility cost was calculated by multiplying the number of overall days the pigs need to reach 275 lb based on their respective growth rate by $0.10 per-day facility cost.

Experimental data were analyzed in a randomized complete block design using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen serving as the experimental unit and initial BW serving as the blocking factor. The random effect of block was included in the model. The 3-way interaction of Early TBCC × Late TBCC × SID Lys (Treatments B, C, F, and G vs. A, D, E, and H), and 2-way interactions of Early TBCC × SID Lys (Treatments A, C, F, and H vs. B, D, E, and G), Late TBCC × SID Lys (Treatments C, D, E, and F vs. A, B, G, and H), and Early TBCC × Late TBCC (Treatments B and F vs. C and G) were tested, and no interactions were observed. Treatments A, D, E, and H were used to test the interaction of TBCC × SID Lys, the main effect of TBCC, and the main effect of SID Lys for the overall period. Hot carcass weight served as a covariate for the analysis of backfat, loin depth, and lean percentage. Results from the experiment were considered significant at $P < 0.05$ and a tendency between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

All diets from each phase were analyzed for Cu, except for Phase 5 diets, which were not available for analysis (Table 4). Considering the Cu originating from both the trace mineral premix and the ingredients used in formulation, these results were similar to expected values.

For any of the measured responses, no 3-way interactions for early TBCC × late TBCC × SID Lys or 2-way interactions for early TBCC × SID Lys, late TBCC × SID Lys, or early TBCC × late TBCC were observed (Table 5).

For growth performance during the early finishing period (d 0 to 60), there was a TBCC × SID Lys interaction ($P < 0.05$; treatments A and H vs. D and E) for ADFI and a tendency ($P < 0.10$) for F/G. These were the result of pigs fed 100% of the estimated SID Lys requirement having an increase in ADFI with added Cu from TBCC, whereas those fed 92.5% had a decrease in ADFI. Without a significant interaction for ADG, this led to pigs fed 100% of the estimated SID Lys requirement having worse F/G when Cu from TBCC was added to the diet, whereas those fed 92.5% had an improvement in F/G with added Cu. Pigs fed 100% of the SID Lys requirement had increased ($P < 0.05$; Treatments A and D vs. E and H) ADG and BW on d 60, as well as an improvement in F/G, compared with those fed 92.5% of their requirement. These results are similar for the late finishing period (d 60 to 120), as pigs fed 100% SID Lys also had increased ($P < 0.05$) ADG, BW on d 120, and improved F/G.

Overall (d 0 to 120), no TBCC × SID Lys interactions were observed for growth performance, final BW, or caloric efficiency; however, pigs fed 100% SID Lys had an increase ($P < 0.05$) in ADG and final BW, as well as an improvement in F/G, compared with those fed 92.5% of their SID Lys requirement. The improvements ($P < 0.05$) in F/G also led to improvements in caloric efficiency on both an ME and NE basis.

For carcass characteristics, there was a TBCC × SID Lys interaction ($P < 0.05$) for carcass yield and backfat depth and a tendency for an interaction ($P < 0.10$) for HCW F/G (Table 6). These were the result of pigs fed 92.5% SID Lys having increased carcass yield and reduced backfat depth with added TBCC, whereas those fed 100% SID Lys requirement had decreased carcass yield and increased backfat depth when TBCC was added to the diet. Hot carcass weight and HCW ADG improved ($P < 0.05$) when pigs were fed 100% of their SID Lys requirement compared with 92.5% and tended ($P < 0.10$) to improve in pigs fed TBCC compared with those not fed TBCC (Treatments A and E vs. D and H).

For any of the calculated economics, no TBCC × SID Lys interactions were observed. For economics calculated on a constant days on feed basis, pigs fed 92.5% of their SID Lys requirement had lower ($P < 0.05$) total feed cost, cost per pound of gain, and value of the weight gained during the experiment (gain value) compared with those fed 100% SID Lys (Table 7). Despite the increased feed cost, IOFC was greater ($P < 0.05$) for pigs fed 100% compared with those fed 92.5% of the estimated Lys requirement. When the economics were calculated on a constant weight basis, pigs fed 92.5% of their SID Lys requirement had worse ($P < 0.05$) adjusted F/G. The lower ADG for pigs fed 92.5% of their SID Lys requirement resulted in an increase ($P < 0.05$) in facility cost compared with those fed 100% of their SID Lys requirement because of increased time required for those pigs to reach the assumed market weight of 275 lb.

In conclusion, there were no differences in overall growth performance, carcass characteristics, or economics among pigs fed different TBCC feeding strategies, but there was a TBCC × Lys interaction for carcass yield, backfat, and HCW F/G. Increasing SID Lys from 92.5 to 100% of their estimated requirement resulted in increased ADG, HCW, and HCW ADG and improved F/G. Poorer performance among pigs fed the reduced SID Lys diets also led to a reduction in IOFC. There were no improvements in overall growth performance in pigs supplemented with Cu from TBCC, which is not consistent with previous trials completed in the same facility; however, pigs fed 150 ppm Cu from TBCC had an increase in yield and HCW, which led to an increase in HCW ADG and improved HCW F/G.

Table 1. Diet composition for Phases 1 and 2 (as-fed basis)[1]

	Phase 1		Phase 2	
SID Lys,[2] %:	92.5	100.0	92.5	100.0
Ingredient, %				
Corn	56.06	52.94	59.94	57.20
Soybean meal, 46.5 CP	11.23	14.33	7.56	10.29
DDGS[3]	30.00	30.00	30.00	30.00
Limestone	1.60	1.60	1.45	1.45
Salt	0.35	0.35	0.35	0.35
L-lysine HCl	0.48	0.48	0.45	0.45
DL-methionine	0.01	0.01	0.04	0.03
L-threonine	0.05	0.05	0.03	0.04
L-tryptophan	0.04	0.04	0.04	0.04
Phytase[4]	0.01	0.01	0.01	0.01
Vitamin premix	0.08	0.08	0.08	0.08
Trace mineral premix[5]	0.10	0.10	0.10	0.10
Added Cu[6]	---	---	---	---
Total	100.0	100.0	100.0	100.0

continued

Table 1. Diet composition for Phases 1 and 2 (as-fed basis)[1]

	Phase 1		Phase 2	
SID Lys,[2] %:	92.5	100.0	92.5	100.0
Calculated SID Lys requirement[2], %	1.03	1.03	0.91	0.91
Calculated analysis				
SID amino acids, %				
Lysine	0.95	1.03	0.84	0.91
Isoleucine:lysine	62	62	63	63
Leucine:lysine	171	166	184	177
Methionine:lysine	31	32	32	31
Met & Cys:lysine	58	58	61	59
Threonine:lysine	62	62	62	62
Tryptophan:lysine	19.0	19.0	19.0	19.0
Valine:lysine	71	70	73	73
Total lysine, %	1.14	1.22	1.02	1.09
ME, kcal/lb	1,505	1,503	1,509	1,507
NE, kcal/lb	1,114	1,105	1,125	1,118
SID lysine:ME, g/Mcal	2.87	3.11	2.53	2.74
CP, %	19.3	20.5	17.7	18.8
Ca, %	0.65	0.66	0.58	0.59
P, %	0.42	0.42	0.39	0.40
Available P, %	0.28	0.28	0.26	0.27
Diet cost,[7] $/ton	215.72	225.70	203.20	211.61

[1] Phase 1 diets were fed from d 0 to 21 (58.3 to 94.8 lb); Phase 2 diets were fed from d 21 to 38 (94.8 to 130.8 lb).
[2] Standardized ileal digestible lysine values were based on 100% of the estimated SID Lys requirement for finishing pigs within this production system.
[3] Dried distillers grains with solubles (Valero, Aurora, SD).
[4] Optiphos 2000 (Huvepharma, Inc, Peachtree City, GA) provided 1,816,000 phytase units (FTU)/lb, with a release of 0.10% available P.
[5] Trace mineral premix provided 17 ppm Cu in the form of $CuSO_4$ to each diet.
[6] Supplemental copper provided in the form of tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) at 150 ppm at the expense of corn.
[7] Cost of corn = $4.26/bushel; soybean meal = $465/ton; DDGS = $164/ton; L-Lys = $0.62 /lb; TBCC = $3.85/lb.

Table 2. Diet composition for Phases 3 and 4 (as-fed basis)[1]

	Phase 3		Phase 4	
SID Lys,[2] %:	92.5	100.0	92.5	100.0
Ingredient, %				
Corn	62.61	60.20	64.14	61.98
Soybean meal, 46.5 CP	5.04	7.45	3.65	5.81
DDGS[3]	30.00	30.00	30.00	30.00
Limestone	1.38	1.38	1.30	1.30
Salt	0.35	0.35	0.35	0.35
L-lysine HCl	0.40	0.40	0.35	0.35
L-threonine	---	0.01	---	---
L-tryptophan	0.04	0.04	0.03	0.03
Phytase[4]	0.01	0.01	0.01	0.01
Vitamin premix	0.08	0.08	0.08	0.08
Trace mineral premix[5]	0.10	0.10	0.10	0.10
Added Cu[6]	---	---	---	---
Total	100.0	100.0	100.0	100.0

continued

Table 2. Diet composition for Phases 3 and 4 (as-fed basis)[1]

	Phase 3		Phase 4	
SID Lys,[2] %:	92.5	100.0	92.5	100.0
Calculated SID Lys requirement[2], %	0.80	0.80	0.72	0.72
Calculated analysis				
SID amino acids, %				
Lysine	0.74	0.80	0.67	0.72
Isoleucine:lysine	65	66	69	69
Leucine:lysine	201	193	218	209
Methionine:lysine	35	34	38	36
Met & Cys:lysine	66	64	71	69
Threonine:lysine	62	62	66	65
Tryptophan:lysine	19.5	19.5	19.5	19.5
Valine:lysine	78	77	83	82
Total lysine, %	0.91	0.97	0.83	0.89
ME, kcal/lb	1,511	1,510	1,512	1,511
NE, kcal/lb	1,132	1,126	1,137	1,131
SID lysine:ME, g/Mcal	2.22	2.40	2.00	2.16
CP, %	16.7	17.6	16.0	16.9
Ca, %	0.55	0.55	0.52	0.52
P, %	0.38	0.39	0.37	0.38
Available P, %	0.25	0.25	0.23	0.24
Diet cost,[7] $/ton	193.75	201.26	187.89	194.53

[1] Phase 3 diets were fed from d 38 to 60 (130.8 to 173.8 lb); Phase 4 were diets fed from d 60 to 95 (173.8 to 244.1 lb).
[2] Standardized ileal digestible lysine values were based on 100% of the estimated SID Lys requirement for finishing pigs within this productions system.
[3] Dried distillers grains with solubles (Valero, Aurora, SD).
[4] Optiphos 2000 (Huvepharma, Inc, Peachtree City, GA) provided 1,816,000 phytase units (FTU)/lb, with a release of 0.10% available P.
[5] Trace mineral premix provided 17 ppm Cu in the form of $CuSO_4$ to each diet.
[6] Supplemental copper provided in the form of tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) at 150 ppm at the expense of corn.
[7] Cost of corn = $4.26/bushel; soybean meal = $465/ton; DDGS = $164/ton; L-Lys = $0.62 /lb; TBCC = $3.85/lb.

Table 3. Diet composition for Phase 5 (as-fed basis)[1]

	Phase 5	
SID Lys,[2] %:	92.5	100.0
Ingredient, %		
Corn	60.63	57.92
Soybean meal, 46.5 CP	7.16	9.87
DDGS[3]	30.00	30.00
Limestone	1.10	1.10
Salt	0.35	0.35
L-lysine HCl	0.45	0.45
L-threonine	0.06	0.06
L-tryptophan	0.05	0.04
Ractopamine HCl[4]	0.03	0.03
Phytase[5]	0.01	0.01
Vitamin premix	0.08	0.08
Trace mineral premix[6]	0.10	0.10
Added Cu[7]	---	---
Total	100.00	100.00

continued

Table 3. Diet composition for Phase 5 (as-fed basis)[1]

	Phase 5	
SID Lys,[2] %:	92.5	100.0
Calculated SID Lys requirement.[2], %	0.90	0.90
Calculated analysis		
SID amino acids, %		
Lysine	0.83	0.90
Isoleucine:lysine	63	63
Leucine:lysine	185	178
Methionine:lysine	32	31
Met & Cys:lysine	61	59
Threonine:lysine	65	65
Tryptophan:lysine	19.5	19.5
Valine:lysine	73	73
Total lysine, %	1.01	1.08
ME, kcal/lb	1,514	1,513
NE, kcal/lb	1,130	1,123
SID lysine:ME, g/Mcal	2.49	2.70
CP, %	17.6	18.7
Ca, %	0.46	0.46
P, %	0.39	0.40
Available P, %	0.23	0.24
Diet cost,[8] $/ton	221.80	230.24

[1] Phase 5 diets were fed from d 95 to 120 (244.1 to 289.2 lb).
[2] Standardized ileal digestible lysine values were based on 100% of the estimated SID Lys requirement for finishing pigs within this production system.
[3] Dried distillers grains with solubles (Valero, Aurora, SD).
[4] Paylean, 9 g/lb (Elanco Animal Health, Indianapolis, IN).
[5] Optiphos 2000 (Huvepharma, Inc., Peachtree City, GA) provided 1,816,000 phytase units (FTU)/lb, with a release of 0.10% available P.
[6] Trace mineral premix provided 17 ppm Cu in the form of $CuSO_4$ to each diet.
[7] Supplemental copper provided in the form of tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) at 150 ppm at the expense of corn.
[8] Cost of corn = $4.26/bushel; soybean meal = $465/ton; DDGS = $164/ton; L-Lys = $0.62 /lb; TBCC = $3.85/lb.

Table 4. Copper analysis of complete diets (ppm, as-fed)[1]

	TBCC,[2] ppm:			
	0		150	
SID lysine,[3] %:	92.5	100.0	92.5	100.0
Total Cu, ppm				
Phase 1	37	31	249	201
Phase 2	31	28	272	214
Phase 3	38	42	246	210
Phase 4	34	32	246	219
Phase 5[4]	---	---	---	---

[1] Values represent means from one composite sample, analyzed in duplicate.
[2] Copper from tri-basic copper chloride (Intellibond C; Micronutrients, Indianapolis, IN).
[3] Standardized ileal digestible (SID) lysine values were based on 100% of the estimated SID Lys requirement finishing pigs within this production system.
[4] Phase 5 diets were not available for analysis.

Table 5. Effects of standardized ileal digestible lysine (SID Lys) and duration of feeding copper on growth performance of finishing pigs[1]

SID Lys,[2] %	92.5				100.0							
Early TBCC[3]:	-	+	-	+	-	+	-	+				
Late TBCC[4]:	-	-	+	+	-	-	+	+		Probability, [5]*P* <		
Treatment:	A	B	C	D	E	F	G	H	SEM	TBCC × SID Lys[6]	TBCC[7]	SID Lys[8]
Weight, lb												
d 0	58.3	58.2	58.3	58.3	58.3	58.3	58.3	58.3	1.46	0.913	0.998	0.987
d 60	172.2	173.1	172.3	172.6	174.4	175.6	174.4	175.3	2.21	0.833	0.567	0.031
d 120	285.2	286.2	288.3	284.9	291.6	291.8	291.2	294.2	2.65	0.428	0.527	0.001
d 0 to 60												
ADG, lb	1.90	1.90	1.89	1.89	1.93	1.95	1.92	1.95	0.019	0.463	0.681	0.018
ADFI, lb	4.59	4.67	4.55	4.52	4.52	4.55	4.59	4.67	0.068	0.023	0.391	0.461
F/G	2.42	2.45	2.40	2.39	2.34	2.34	2.39	2.40	0.027	0.088	0.609	0.097
d 60 to 120												
ADG, lb	1.99	2.02	2.03	1.99	2.06	2.05	2.07	2.06	0.023	0.951	0.931	0.007
ADFI, lb	6.11	6.12	6.11	6.14	6.22	6.07	6.23	6.13	0.055	0.283	0.576	0.326
F/G, lb	3.07	3.04	3.02	3.08	3.03	2.97	3.00	2.98	0.033	0.332	0.608	0.034
d 0 to 120												
ADG, lb	1.94	1.96	1.96	1.94	1.99	2.00	1.99	2.00	0.015	0.566	0.732	0.001
ADFI, lb	5.33	5.36	5.30	5.30	5.34	5.28	5.38	5.38	0.049	0.365	0.900	0.235
F/G	2.74	2.74	2.71	2.73	2.68	2.65	2.70	2.69	0.020	0.755	0.865	0.009
Caloric efficiency[9]												
ME	4142	4142	4091	4126	4049	3994	4072	4052	30.6	0.754	0.832	0.007
NE	3098	3099	3059	3086	3014	2972	3031	3016	22.8	0.740	0.829	0.001

[1] A total of 1,267 pigs (PIC 337 × 1050; initially 58.3 lb) were used in a 120-d experiment with 26 to 27 pigs per pen and 6 replications per treatment.
[2] Standardized ileal digestible lysine (SID Lys) values were based on 100% of estimated SID Lys requirement finishing pigs within this production system.
[3] 150 ppm copper from tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) fed from d 0 to 60.
[4] 150 ppm copper from TBCC fed from d 60 to 120.
[5] No Early TBCC × Late TBCC × SID Lys, Early TBCC × SID Ly, Late TBCC × SID Lys, or Early TBCC × Late TBCC interactions were observed.
[6] Contrast between Treatments A and H vs. D and E.
[7] Contrast between Treatments A and E vs. D and H.
[8] Contrast between Treatments A and D vs. E and H.
[9] Caloric efficiency is expressed as kcal per pound of live weight gain.

Table 6. Effects of standardized ileal digestible lysine (SID Lys) and duration of feeding copper on carcass characteristics of finishing pigs[1]

SID Lys,[2] %	92.5				100.0							
Early TBCC[3]:	-	+	-	+	-	+	-	+				
Late TBCC[4]:	-	-	+	+	-	-	+	+		Probability,[5] $P <$		
Treatment:	A	B	C	D	E	F	G	H	SEM	TBCC × SID Lys[6]	TBCC[7]	SID Lys[8]
Carcass characteristics												
HCW, lb	215.5	218.5	220.2	221.2	221.7	222.3	220.9	222.9	2.19	0.244	0.076	0.043
Yield, %	75.06	76.11	75.74	76.74	75.89	75.35	75.60	75.76	0.383	0.022	0.048	0.847
Backfat,[9] in.	0.74	0.71	0.68	0.68	0.66	0.67	0.72	0.71	0.019	0.011	0.780	0.279
Loin depth,[9] in.	2.20	2.19	2.23	2.23	2.24	2.22	2.18	2.22	0.018	0.117	0.953	0.289
Lean,[9] %	55.78	55.56	56.53	56.51	56.97	56.26	55.42	56.29	0.450	0.115	0.953	0.286
Carcass performance												
HCW ADG, lb	1.43	1.46	1.47	1.48	1.48	1.49	1.48	1.49	0.015	0.232	0.064	0.035
HCW F/G	3.72	3.68	3.60	3.59	3.60	3.55	3.64	3.60	0.038	0.062	0.074	0.174

[1] 1,267 pigs (PIC 337 × 1050; initially 58.3 lb) were used in a 120-d experiment with 26 to 27 pigs per pen and 6 replications per treatment.
[2] SID Lys alues were based on 100% of estimated SID Lys requirement for finishing pigs within this production system.
[3] 150 ppm copper from tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) fed from d 0 to 60.
[4] 150 ppm copper from TBCC fed from d 60 to 120.
[5] No Early TBCC × Late TBCC × SID Lys, Early TBCC × SID Lys, Late TBCC × SID Lys, or Early TBCC × Late TBCC interactions were observed.
[6] Contrast between Treatments A and H vs. D and E.
[7] Contrast between Treatments A and E vs. D and H.
[8] Contrast between Treatments A and D vs. E and H.
[9] HCW was used as a covariate.

Table 7. Effects of standardized ileal digestible lysine (SID Lys) and duration of feeding copper on economics of finishing pigs[1]

SID Lys,[2] %	92.5				100.0							
Early TBCC[3]:	-	+	-	+	-	+	-	+				
Late TBCC[4]:	-	-	+	+	-	-	+	+		Probability, [5]*P* <		
Treatment:	A	B	C	D	E	F	G	H	SEM	TBCC × SID Lys[6]	TBCC[7]	SID Lys[8]
Constant days, $/pig												
Feed cost	64.91	65.75	65.12	65.33	67.68	67.27	68.55	68.68	0.589	0.552	0.147	0.001
Cost/lb gain	0.278	0.280	0.277	0.281	0.283	0.281	0.287	0.286	0.002	0.972	0.254	0.022
Gain value[9]	250.35	251.53	253.74	249.98	257.35	257.62	256.91	260.27	2.109	0.408	0.520	0.001
IOFC[10]	185.45	185.77	188.62	184.65	189.66	190.35	188.36	191.58	1.803	0.444	0.751	0.003
Constant weight,[11] $/pig												
Adjusted F/G[12]	2.69	2.69	2.64	2.68	2.60	2.56	2.62	2.59	0.023	0.957	0.691	0.001
Feed cost	58.90	59.08	58.20	59.31	59.13	58.52	59.81	59.44	0.507	0.922	0.484	0.727
Cost/lb gain	0.272	0.273	0.269	0.274	0.273	0.270	0.276	0.274	0.002	0.922	0.484	0.727
Gain value[9]	239.11	239.11	239.11	239.11	239.11	239.11	239.11	239.11	---	---	---	---
IOFC[10]	180.21	180.02	180.90	179.80	179.98	180.59	179.30	179.67	0.507	0.922	0.484	0.727
Facility cost[13]	11.49	11.44	11.34	11.51	11.18	11.16	11.22	11.07	0.130	0.469	0.620	0.001
IOFFC[14]	168.72	168.59	169.57	168.30	168.80	169.43	168.08	168.60	0.574	0.846	0.586	0.739

[1] 1,267 pigs (PIC 337 × 1050; initially 58.3 lb) were used in a 120-d experiment with 26 to 27 pigs per pen and 6 replications per treatment.
[2] SID Lys values were based on 100% of estimated SID Lys requirement for finishing pigs within this production system.
[3] 150 ppm copper from tri-basic copper chloride (TBCC; Intellibond C; Micronutrients, Indianapolis, IN) fed from d 0 to 60.
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[5] No Early TBCC × Late TBCC × SID Lys, Early TBCC × SID Ly, Late TBCC × SID Lys, or Early TBCC × Late TBCC interactions were observed.
[6] Contrast between Treatments A and H vs. D and E.
[7] Contrast between Treatments A and E vs. D and H.
[8] Contrast between Treatments A and D vs. E and H.
[9] Gain value calculated using (Final wt × $110.34/cwt) – (initial wt. × $110.34/cwt).
[10] Income over feed cost = carcass gain value – feed cost.
[11] Adjusted to constant final weight of 275 lb.
[12] Adjusted using a factor of 0.005 for 1 lb change in live weight.
[13] Facility cost at $0.10/hd/day.
[14] Income over feed and facility cost = IOFC – facility cost.