Influence of Chromium Dose and Feeding Regimen on Growth Performance and Carcass Composition of Pigs Housed in a Commercial Environment[1,2]

J.T. Gebhardt, J.C. Woodworth, M.D. Tokach, J.M. DeRouchey, R.D. Goodband, J.A. Loughmiller,[3] and S.S. Dritz[4]

Summary

A study was conducted to determine the effects of increasing chromium propionate (KemTRACE Cr; Kemin Industries Inc., Des Moines, IA) and feeding regimen on growth performance and carcass characteristics of finishing pigs housed in a commercial environment. There were a total of 1,206 pigs (PIC 337 × 1050; initial BW = 63.2 lb) with 27 pigs/pen and 9 pens/treatment. Pigs were split by gender upon arrival at the facility, with 4 blocks of each gender and a final mixed gender block. Gender blocks were randomly allotted to groups of 5 pen locations within the barn. Diets were corn-soybean meal-dried distillers grains with solubles-based and were fed in a 5-phase feeding program. Treatments were arranged as a 2 × 2 + 1 factorial with a control diet containing no added Cr, or diets containing either 100 or 200 ppb of Cr fed during the grower (dietary Phases 1 and 2; 63 to 138 lb BW) and/or finisher (dietary Phases 3, 4, and 5; 138 to 307 lb BW) periods. For growth performance, there was no effect of changing Cr supplementation between the growing and finishing periods. Therefore, only linear and quadratic effects of increasing Cr within growth period were considered using all treatments, as well as linear and quadratic effects of the 3 treatments fed increasing Cr for the full duration of the study. Increasing Cr during the grower period decreased (quadratic, $P < 0.001$) ADG and worsened F/G. During the finisher period, increasing Cr tended (quadratic, $P = 0.061$) to improve F/G, with the best F/G observed in pigs fed 100 ppb. Overall, increasing Cr had no impact on ADG or ADFI; however, F/G was optimized (quadratic, $P = 0.018$) when pigs were fed 100 ppb of added Cr. Carcass characteristics were not influenced by added Cr level or Cr feeding regimen. In summary, increasing dietary Cr supplementation elicited minor changes in growth performance with the best F/G observed with 100 ppb of added Cr.

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[3] Kemin Industries, Des Moines, IA.
[4] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

Key words: chromium propionate, duration, finishing pig, level

Introduction

Research evaluating the impacts of supplemental Cr in finishing pig diets has been conducted since the mid 1990's. Evidence has shown Cr plays a role in carbohydrate, lipid, protein, and nucleic acid metabolism.[5,6] In addition, Cr is associated with insulin sensitivity in the form of glucose tolerance factor.[7] The results of many of these past studies were highly variable in regards to animal performance and carcass composition. Corn-soybean meal-based diets contain a significant amount of Cr ranging from 1,000 to 3,000 ppb but are thought to have a lower bioavailability relative to other forms of chromium.[8] Due to the variability in ingredient chromium levels and inconsistent performance, there is currently no quantitative estimate for Cr requirements for swine.[5]

Recently, a meta-analysis was conducted including 31 different studies that evaluated Cr supplementation in finishing pig diets. The analysis observed that improvements in growth performance (ADG and F/G) and carcass composition (reduced backfat and increased percentage lean) can be expected with Cr supplementation.[9] The meta-analysis also suggested that chromium dosage and supplementation duration could affect the degree of improvement observed. This would suggest feeding strategies that combine Cr dosage and feeding duration could be optimized to achieve the greatest overall benefit. Therefore, the objective of this experiment was to determine the effects of Cr dosage and feeding regimen on growth performance and carcass composition of pigs housed in a commercial environment.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research-finishing site in southwest Minnesota. The barn was naturally ventilated and double-curtain-sided. Each pen (18 × 10 ft) was equipped with a 4-hole stainless steel feeder and cup waterer for ad libitum access to feed and water and allowed approximately 6.5 ft^2/pig. Hourly ambient barn temperatures were recorded throughout the experiment (EasyLog Data Loggers; Lascar Electronics, Erie, PA). Feed additions to each individual pen were made and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN).

A total of 1,206 pigs (PIC 337 × 1050; initial BW = 63.2 lb) were used in a 125-d growth trial with 27 pigs/pen and 9 pens/treatment. Pigs were split by gender upon arrival at the facility, with 4 blocks of each gender and a final mixed sex gender block. Gender blocks were randomly allotted to groups of 5 pen locations within the barn. Diets were corn-soybean meal-based and fed in meal form, with dietary phases formulated for 60 to 100, 100 to 135, 135 to 170, 170 to 230, and 230 to 280 lb BW ranges.

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[5] NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington, D.C..

[6] Trace Elements in Human and Animal Nutrition. 1977. 4th ed. Academic Press Inc., New York, NY.

[7] Swine Nutrition. 2001. 2nd ed. CRC Press LLC, Boca Raton, FL.

[8] Lindemann, M. D., 2007. Use of chromium as an animal feed supplement. In: J. B. Vincent, editor, The Nutritional Biochemistry of Chromium (III). Elsevier, Amsterdam. p. 85–118.

[9] Sales, J., and F. Jancik. 2011. Effects of dietary chromium supplementation on performance, carcass characteristics, and meat quality of growing-finishing swine: A meta-analysis. J. Anim. Sci. 89: 4054-4067.

All nutrients were formulated to meet or exceed the NRC (2012) requirement estimates within phases. The treatment phases were divided into two specific growth ranges including a grower period (dietary Phases 1 and 2) and a finisher period (dietary Phases 3, 4, and 5). Treatments were arranged as a 2 × 2 + 1 factorial with a control diet containing no added Cr or as diets containing either 100 or 200 ppb of Cr (KemTRACE Cr; Kemin Industries Inc., Des Moines, IA) fed during the grower (dietary Phase 1 and 2; 63 to 138 lb BW) and/or finisher (dietary Phase 3 to 5; 138 to 307 lb) periods. Thus, three treatments received the same level of Cr supplementation throughout the entire trial (0, 100, or 200 ppb added Cr), while two treatments alternated supplementation levels between the grower and finisher period (100 ppb in grower followed by 200 ppb in finisher or 200 ppb in grower followed by 100 ppb in finisher, respectively). Three diets per phase were manufactured and supplemented with 0, 100, or 200 ppb Cr at a commercial feedmill (New Horizon Feeds, Pipestone, MN; Table 1) and were fed to the respective pens. Ractopamine HCl (Paylean 9 g/ton; Elanco Animal Health, Greenfield, IN) was included in Phase 5 diets and was fed for 38 d.

Samples of the complete feed were taken from the feeder at the beginning and end of each phase. Subsamples of each diet were then submitted for proximate analysis (Ward Laboratories, Inc., Kearney, NE) and Cr analysis (University of Guelph Agriculture & Food Laboratory; Geulph, ON). Pens of pigs were weighed and feeder measurements were recorded at the time of dietary phase changes, first marketing, and conclusion of the trial (d 0, 20, 39, 53, 87, 97, and 125) to determine ADG, ADFI, and F/G. The 3 largest pigs/pen were selected and marketed at an average barn weight of 256 lb on d 97 following the routine farm protocol with no carcass data collected on these animals. At the conclusion of the trial (d 125), the remaining animals were given a tattoo corresponding to pen number and were transported to a commercial packing facility (JBS Swift and Company; Worthington, MN) for processing and carcass data collection. Carcass measurements taken at the plant included live pen weight, HCW, backfat, percentage carcass lean, and loin depth. Additionally, percentage yield was calculated by dividing HCW by mean animal live plant weight for the corresponding pen.

Data were analyzed as a randomized complete block design using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Block was included in the model as a random effect and accounted for gender, location within barn, and initial BW at the time of allotment. Linear and quadratic effects of increasing Cr within growth period were considered using all treatments, as well as linear and quadratic effects of increasing Cr fed at a constant level for the full duration of the trial. An additional contrast was analyzed to determine the impact of changing Cr concentrations between the grower and finisher periods. Backfat, loin depth, and percentage lean were adjusted to a common carcass weight for analysis using HCW as a covariate. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

As expected, chemical analysis of complete diets revealed no notable differences among treatments (Tables 2 to 4). The analyzed level of dietary Cr generally followed the basal target addition rates.

The crossover contrast did not indicate any differences ($P > 0.446$) in performance (ADG, ADFI, F/G, and carcass characteristics) among treatments changing Cr supplementation levels between the grower and finisher periods. This indicated there was no benefit associated with changing supplementation levels between growth periods. Because no differences for this contrast were observed, only linear and quadratic effects of increasing Cr within growth period were considered using all treatments, as well as linear and quadratic effects of increasing Cr for the full duration using the 3 treatments that had a constant Cr supplementation level throughout.

Increasing Cr during the grower period reduced (quadratic, $P < 0.001$; Table 5) ADG and worsened F/G. During the finisher period, increasing Cr tended (quadratic, $P = 0.061$) to improve F/G with the best F/G observed in pigs fed 100 ppb of added Cr. Overall, increasing Cr had no impact on ADG or ADFI ($P > 0.05$); however, F/G was optimized (quadratic, $P = 0.018$) when pigs were fed 100 ppb added Cr. Carcass characteristics were not influenced by added Cr level or feeding regimen.

Meta-analysis conducted by Sales and Jancik (2011) attempted to summarize and quantify the effect of dietary chromium supplementation on carcass characteristics of finishing swine, as the variability among studies is quite significant. Their evaluation included studies which supplemented chromium in the form of Cr Met chelate, Cr nanocomposite, Cr nicotinate, Cr propionate, Cr tripicolinate, and Cr yeast. The analysis would suggest a reduction ($P < 0.05$) in 10th-rib backfat thickness and an increase in percentage lean and loin muscle area (Hedge's *g* standardized effect size = -0.416, 0.491, and 0.494, respectively). However, these differences in carcass composition were not observed with the current study. Additionally, the meta-analysis would suggest an improvement ($P < 0.05$) in ADG and G:F would be expected with Cr supplementation (Hedge's g standardized effect size = 0.149 and 0.302, respectively), which was not observed in the current study.

In summary, increasing dietary Cr supplementation elicited minor changes in growth performance in our current study, with the best F/G observed with 100 ppb of added Cr.

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

	Dietary phase				
Item	1	2	3	4	5
Ingredient, %					
Corn	56.00	61.25	65.80	69.25	67.25
Soybean meal, 46.5% CP	21.65	16.50	12.00	8.55	20.65
DDGS[2]	20.00	20.00	20.00	20.00	10.00
Calcium carbonate	1.25	1.28	1.23	1.20	1.03
Monocalcium phosphate, 21% P	0.15	---	---	---	0.10
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys HCl	0.36	0.37	0.39	0.39	0.28
DL-Met	0.01	---	---	---	0.04
L-Thr	0.05	0.04	0.05	0.06	0.07
L-Trp	---	0.01	0.02	0.02	---
Ractopamine[3]	---	---	---	---	0.03
Phytase[4]	0.01	0.01	0.01	0.01	0.01
Trace mineral premix	0.10	0.10	0.10	0.10	0.10
Vitamin premix	0.08	0.08	0.08	0.08	0.08
KemTRACE Cr[5]	+/-	+/-	+/-	+/-	+/-
Total	100	100	100	100	100

continued

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

	Dietary phase				
Item	1	2	3	4	5
Calculated analysis[6]					
Standardized ileal digestible (SID) amino acids, %					
Lys	1.02	0.91	0.82	0.74	0.90
Ile:Lys	63	62	60	59	64
Leu:Lys	152	159	164	171	150
Met:Lys	29	29	30	31	32
Met and Cys:Lys	55	56	57	59	59
Thr:Lys	61	61	61	63	65
Trp:Lys	18.4	18.4	18.4	18.4	19.0
Val:Lys	70	70	70	70	71
Total Lys, %	1.19	1.06	0.96	0.87	1.04
ME, kcal/lb	1,502	1,506	1,509	1,511	1,506
NE, kcal/lb	1,102	1,118	1,130	1,140	1,123
SID Lys:ME, g/Mcal	3.08	2.74	2.46	2.22	2.71
SID Lys:NE, g/Mcal	4.20	3.69	3.29	2.94	3.64
CP, %	20.0	18.1	16.4	15.1	17.6
Ca, %	0.61	0.57	0.54	0.52	0.50
P, %	0.45	0.40	0.38	0.36	0.40
Available P, %	0.29	0.26	0.25	0.25	0.24

[1] Diets were fed in a 5-phase feeding program formulated to 60 to 100, 100 to 135, 135 to 170, 170 to 230, and 230 to 280 lb BW ranges.
[2] DDGS = dried distillers grains with solubles.
[3] Paylean 9 g/lb (Elanco, Greenfield, IN).
[4] Optiphos 2000 (Huvepharma, Sofia, Bulgaria) provided an estimated release of 0.11% available P.
[5] KemTRACE Cr (chromium propionate; Kemin Industries Inc., Des Moines, IA) was added at 0.5 lb/ton (100 ppb Cr) or 1.0 lb/ton (200 ppb Cr) at the expense of corn.
[6] NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington D.C.

Table 2. Chemical analysis of diets, Phases 1 and 2 (as-fed basis)[1,2]

	Phase 1			Phase 2		
Item Added Cr, ppb:	0	100	200	0	100	200
DM, %	88.08	88.73	88.52	85.1	89.02	89.02
CP, %	19.4	17.9	20.0	18.8	15.3	20.2
Ether extract, %	3.1	2.9	3.4	4.6	3.6	3.6
Crude fiber, %	3.3	3.1	3.3	3.2	3.1	3.7
Cr, ppb	590	600	790	540	610	710

[1] A composite sample was collected from feeders within treatment and phase, subsampled, and submitted to Ward Laboratories (Kearney, NE) for proximate analysis and to University of Guelph Agriculture & Food Laboratory (Guelph, ON) for Cr analysis.
[2] Phase 1 was fed from approximately 60 to 100 lb and Phase 2 fed from approximately 100 to 135 lb.

Table 3. Chemical analysis of diets, Phases 3 and 4 (as-fed basis)[1,2]

		Phase 3			Phase 4	
Item Added Cr, ppb:	0	100	200	0	100	200
DM, %	88.57	88.55	88.69	88.67	88.22	89.11
CP, %	19.5	16.9	15.2	15.1	14.5	14.1
Ether extract, %	3.6	3.8	3.7	3.8	3.9	3.8
Crude fiber, %	3.4	3.1	3.2	3.0	3.0	3.2
Cr, ppb	500	430	590	480	490	620

[1] A composite sample was collected from feeders within treatment and phase, subsampled, and submitted to Ward Laboratories (Kearney, NE) for proximate analysis and to University of Guelph Agriculture & Food Laboratory (Guelph, ON) for Cr analysis.
[2] Phase 3 was fed from approximately 135 to 170 lb and Phase 4 fed from approximately 170 to 235 lb.

Table 4. Chemical analysis of diets, Phase 5 (as-fed basis)[1,2]

		Phase 5	
Item Added Cr, ppb:	0	100	200
DM, %	88.92	88.27	88.67
CP, %	17.3	16.6	17.7
Ether extract, %	3.1	3.0	2.9
Crude fiber, %	2.6	2.6	3.0
Cr, ppb	430	480	610

[1] A composite sample was collected from feeders within treatment and phase, subsampled, and submitted to Ward Laboratories (Kearney, NE) for proximate analysis and to University of Guelph Agriculture & Food Laboratory (Guelph, ON) for Cr analysis.
[2] Phase 5 was fed from approximately 230 to 280 lb.

Table 5. Effects of added chromium on finishing pig growth and carcass characteristics[1,2,3]

							Probability, $P <$	
Grower added Cr, ppb:	0	100	200	100	200			
Finisher added Cr, ppb:	0	100	200	200	100	SEM	Linear[4]	Quadratic[4]
BW, lb								
d 0	63.3	63.0	63.4	63.0	63.2	1.03	0.955	0.720
d 39	140.1	139.8	135.2	141.3	134.1	1.57	0.001	0.005
d 125	306.4	308.5	305.7	309.0	307.3	2.99	0.824	0.354
Grower (d 0 to 39)								
ADG, lb	1.97	1.97	1.84	2.01	1.82	0.026	0.001	0.001
ADFI, lb	3.91	3.90	3.85	3.93	3.84	0.062	0.229	0.341
F/G	1.99	1.98	2.10	1.96	2.11	0.025	0.001	0.001
Finisher (d 39 to 125)								
ADG, lb	1.65	1.67	1.68	1.66	1.71	0.026	0.369	0.106
ADFI, lb	5.40	5.34	5.37	5.38	5.42	0.099	0.656	0.860
F/G	3.28	3.20	3.21	3.23	3.17	0.052	0.208	0.061
Overall (d 0 to 125)								
ADG, lb	1.96	1.99	1.96	1.98	1.97	0.020	0.796	0.136
ADFI, lb	4.91	4.87	4.88	4.91	4.91	0.083	0.472	0.651
F/G	2.50	2.45	2.49	2.48	2.49	0.027	0.507	0.018
Carcass characteristics[5]								
HCW, lb	224.2	226.0	222.6	225.8	224.4	2.03	0.404	0.136
Backfat, in	0.642	0.641	0.643	0.644	0.641	0.0218	0.943	0.924
Lean, %	57.33	57.44	57.34	57.43	57.44	0.385	0.974	0.665
Loin depth, in	2.76	2.80	2.77	2.79	2.79	0.029	0.611	0.307
Yield, %	73.21	73.27	72.80	73.09	73.01	0.238	0.235	0.370

[1] A total of 1,206 finisher pigs (initially 63.2 lb BW) were used in a 125-d finisher study with 27 pigs per pen and 9 replications per treatment. Pigs were fed in split gender pens, with 4 replicates per gender and 1 mixed gender replicate. Gender, weight, and location served as blocking factors in allotment to treatment. Diets were fed in a 5-phase feeding program formulated to 60 to 100, 100 to 135, 135 to 170, 170 to 230, and 230 to 280 lb BW ranges.

[2] Treatment diets were fed in two growth stages, grower (Phases 1-2) and finisher (Phases 3-5) and were supplemented with 0, 100, or 200 ppb chromium propionate (KemTRACE Cr; Kemin Industries Inc., Des Moines, IA).

[3] Linear and quadratic contrasts were made for the grower, finisher, and full trial periods. The full contrast statement only included treatments which received the same level of Cr supplementation for the full duration of the experiment. The two treatments having a crossover structure between the grower and finisher phases were analyzed with a crossover contrast to compare these two treatments for the full trial period. The crossover contrast was used for overall ADG, ADFI, and F/G, as well as carcass characteristics and was not significant ($P > 0.446$).

[4] Grower linear and quadratic contrasts were used for d 39 BW, grower period ADG, ADFI, and F/G. Finisher linear and quadratic contrasts were used for finisher period ADG, ADFI, and F/G. Full trial linear and quadratic contrast statements were used for d 0 BW, d 125 BW, overall ADG, ADFI, F/G, and carcass characteristics.

[5] Backfat, percentage lean, and loin depth were analyzed by adjusting for a common HCW.