# Influence of chromium propionate dose and feeding regimen on growth performance and carcass composition of pigs housed in a commercial environment[1,2]

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**ABSTRACT:** Although chromium (Cr) feeding study results have been variable, our hypothesis was feeding a regimen that changed dosage over time would result in a larger positive response in growth performance and carcass characteristics. In Exp. 1, a total of 1,206 pigs (PIC 337 × 1050, initial BW 28.7 kg) were used with 27 pigs per pen and 9 pens per treatment. Diets were corn–soybean meal-dried distillers grains with solubles based and were fed in a five-phase feeding program. Treatments were arranged as a 2 × 2 + 1 factorial with a control diet containing no added Cr propionate (Kemin Industries Inc., Des Moines, IA), or diets with either 100 or 200 µg/kg added Cr during the grower (dietary phases 1 and 2) and/or finisher (dietary phases 3, 4, and 5) periods. During the grower period, ADG and G:F were similar among pigs fed the control or 100 µg/kg added Cr diets, but decreased in pigs fed 200 µg/kg Cr (quadratic, $P \leq 0.001$). During the finisher period, pigs supplemented with 200 µg/kg added Cr had the greatest ADG and G:F (quadratic, $P \leq 0.019$). Overall, increasing Cr had no effect on ADG or ADFI; but G:F was greatest (quadratic, $P = 0.020$) when pigs were fed 100 µg/kg of added Cr throughout. Carcass characteristics were not influenced by Cr dosage or feeding regimen. In Exp. 2, a total of 1,206 pigs (PIC 359 × 1050, initial BW 48.9 kg) were used with 27 pigs per pen and 15 pens per treatment. Diets were corn–soybean meal, dried distillers grains with solubles based and were fed in four phases. There were three dietary treatments: a diet with no added Cr for both grower (dietary phase 1 and 2) and finisher (dietary phase 3 and 4) periods, a diet with 200 µg/kg added Cr during the grower and 100 µg/kg added Cr during the finisher periods, or a diet with 200 µg/kg added Cr for both periods. Addition of 200 µg/kg Cr in both periods marginally increased ($P < 0.10$) ADG compared with pigs fed no added Cr. There was no evidence ($P \geq 0.523$) of added Cr influencing overall ADFI and G:F. Percentage carcass yield was reduced ($P = 0.018$) when Cr was added at 200 µg/kg for both periods, with no evidence of differences ($P \geq 0.206$) in other carcass characteristics. In summary, overall G:F was improved in Exp. 1, and ADG in Exp. 2, by added Cr, but there was no evidence that different feeding regimens will consistently result in improved performance. However, these data are consistent with the literature in that added Cr in growing-finishing pigs diets improves, albeit small, ADG or G:F.

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



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## INTRODUCTION

Chromium (Cr) has been shown to be involved in carbohydrate, lipid, and protein metabolism (Pechova and Pavlata, 2007; NRC, 2012). Historically, the most notable mode of action is its influence on insulin sensitivity as component of the molecule known as glucose tolerance factor (Steele et al., 1977; Hill and Spears, 2001); however, additional research has indicated chromodulin is the likely oligopeptide responsible for its activity (Pechova and Pavlata, 2007). With regard to the effects of Cr on swine growth performance, the published literature contains significant variability regarding growth and carcass characteristics. Because of the variability in ingredient basal Cr levels and inconsistent performance, there is currently no quantitative estimate for Cr requirements for swine (NRC, 2012). A meta-analysis was conducted that included 31 different studies evaluating added Cr in finishing pig diets. The meta-analysis suggested variable but overall positive improvements in ADG and G:F, as well as reducing backfat and increasing percentage lean, which can be beneficial in some situations with supplemental Cr (Sales and Jancik, 2011). However, Lindeman (2007) indicated that as body mass increases, there are reduced tissue concentrations of Cr. This might suggest that using feeding regimens that combine different Cr dosages and feeding durations could result in even greater improvements in growth or carcass performance. Therefore, the objective of this experiment was to determine the effects of Cr propionate dosage and feeding regimen on growth performance and carcass composition of pigs housed in a commercial environment.

## MATERIALS AND METHODS

### *General*

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments. The studies were conducted at a commercial research-finishing site in southwest Minnesota using two identical barns. The barns were naturally ventilated and double-curtain-sided. Each pen (5.5 × 3.0 m) was equipped with a four-hole stainless steel feeder and cup waterer for ad libitum access to feed and water and allowed approximately 0.61 $m^2$/pig. All feed additions to each individual pen were made and recorded by a robotic feeding system (FeedPro; Feedlogic Corp, Wilmar, MN).

### *Animals and Diets*

In Exp. 1, a total of 1,206 pigs (PIC 337 × 1050; PIC, Hendersonville, TN), with initial BW 28.7 kg, were used in a 125-d growth trial with 27 pigs per pen and 9 pens per treatment. Pigs were split by sex on arrival at the facility, with four blocks of each gender and a final mixed sex gender block. Gender blocks were randomly allotted to groups of five pen locations within the barn. Diets were corn–soybean meal-based and fed in meal form, with dietary phases formulated for 27 to 45, 45 to 61, 61 to 77, 77 to 104, and 104 to 127 kg BW ranges. All diets were formulated to meet or exceed the NRC (2012) nutrient requirement estimates within phase. Ingredient nutrient profiles and standardized ileal digestibility coefficients were derived from NRC (2012), 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 main effects of Cr dose (100 or 200 μg/kg of Cr from Cr propionate; Kemin Industries Inc., Des Moines, IA) and feeding regimen (grower or finisher periods) and a control diet containing no added Cr. Ractopamine hydrochloride (HCl) (Paylean; Elanco Animal Health, Greenfield, IN) was added in phase 5 diets when pigs were an average of 104 kg BW and was fed for the final 38-d of the trial. Diets were manufactured in a commercial feed mill in southwest Minnesota (New Horizon Feeds, Pipestone, MN; Table 1).

In Exp. 2, a total of 1,206 pigs (PIC 359 × 1050), with initial BW 48.9 kg, were used in an 84-d growth trial with 27 pigs per pen and 15 pens per treatment. Pigs were placed in mixed-gender pens with similar numbers of barrows and gilts in each pen and equalized by treatment. Pens were blocked by average BW and randomly assigned to treatment at initiation of the experiment. Diets were corn–soybean meal-based and fed in meal form, with dietary phases formulated for 45 to 68, 68 to 91, 91 to 109, and 109 to 127 kg BW ranges. All diets were formulated to meet or exceed the NRC (2012) nutrient requirement estimates within phase. Three dietary treatments were offered that included a control with no added Cr for both grower (dietary phase 1

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

| | BW range, kg | | | | |
|---|---|---|---|---|---|
| Item | 27 to 45 | 45 to 61 | 61 to 77 | 77 to 104 | 104 to 127 |
| 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 |
| Dried distillers grains with solubles | 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 HCl[2] | — | — | — | — | 0.03 |
| Phytase[3] | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Trace mineral premix[4] | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin premix[5] | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Cr[6] | +/− | +/− | +/− | +/− | +/− |
| Total | 100 | 100 | 100 | 100 | 100 |
| Calculated analysis[7] | | | | | |
| 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/kg | 3,311 | 3,320 | 3,327 | 3,331 | 3,320 |
| NE, kcal/kg | 2,429 | 2,465 | 2,491 | 2,513 | 2,476 |
| 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 |
| STTD P, % | 0.33 | 0.29 | 0.28 | 0.27 | 0.29 |

CP = crude protein; STTD = standardized total tract digestibility.

[1]Treatment diets were fed to 1,206 pigs (PIC 337 × 1050; PIC, Hendersonville, TN; initial BW 28.7 kg) for 125 d in a five-phase feeding program with 27 pigs per pen and 9 replications per treatment.

[2]Paylean (Elanco, Greenfield, IN).

[3]Optiphos 2000 (Huvepharma, Sofia, Bulgaria) provided an estimated release of 0.10% STTD P.

[4]Provided per kg of premix: 110 g Fe from iron sulfate; 110 g Zn from zinc sulfate; 33 g Mn from manganese oxide; 17 g Cu from copper sulfate; 330 mg I from calcium iodate; and 300 mg Se from sodium selenite.

[5]Provided per kg of premix: 7,054,798 IU vitamin A; 1,102,312 IU vitamin D3; 35,242 IU vitamin E; 3,528 mg vitamin K; 26.5 mg vitamin B12; 39,683 mg niacin; 22,046 mg pantothenic acid; and 6,173 mg riboflavin.

[6]Cr (Cr propionate; Kemin Industries Inc., Des Moines, IA) was added at 0.25 kg/tonne (100 µg/kg Cr) or 0.5 kg/tonne (200 µg/kg Cr) at the expense of corn.

[7]NRC (2012).

and 2) and finisher (dietary phase 3 and 4) phases, the control diet plus 200 µg/kg added Cr during the grower and 100 µg/kg added Cr during the finisher periods, or the control diet plus 200 µg/kg added Cr for both the grower and finisher periods. All diets were manufactured at a commercial feed mill (New Horizon Feeds; Table 2) and were fed in meal form. No ractopamine HCl was used in Exp. 2.

In both experiments, pens of pigs were weighed and feeder measurements were recorded a minimum of every 14-d and such events included dietary phase changes, first marketing, and conclusion

**Table 2.** Diet composition (as-fed basis), Exp. 2[1]

| | BW range, kg | | | |
|---|---|---|---|---|
| Item | 45 to 68 | 68 to 91 | 91 to 109 | 109 to 127 |
| Ingredient, % | | | | |
| Corn | 62.76 | 67.86 | 70.89 | 79.71 |
| Soybean meal, 46.5% CP | 14.99 | 9.91 | 6.90 | 8.22 |
| Dried distillers grains with solubles | 20.00 | 20.00 | 20.00 | 10.00 |
| Calcium carbonate | 1.28 | 1.23 | 1.20 | 1.03 |
| Monocalcium phosphate, 21% P | — | — | — | 0.10 |
| Salt | 0.35 | 0.35 | 0.35 | 0.35 |
| L-Lys HCl | 0.39 | 0.40 | 0.40 | 0.33 |
| L-Thr | 0.04 | 0.05 | 0.06 | 0.07 |
| L-Trp | 0.01 | 0.02 | 0.02 | 0.01 |
| Phytase[2] | 0.01 | 0.01 | 0.01 | 0.01 |
| Trace mineral premix[3] | 0.10 | 0.10 | 0.10 | 0.10 |
| Vitamin premix[4] | 0.08 | 0.08 | 0.08 | 0.08 |
| Cr[5] | +/− | +/− | +/− | +/− |
| Total | 100 | 100 | 100 | 100 |
| Calculated analysis[6] | | | | |
| Standardized ileal digestible (SID) amino acids, % | | | | |
| Lys | 0.89 | 0.78 | 0.71 | 0.65 |
| Ile:Lys | 60 | 59 | 58 | 58 |
| Leu:Lys | 158 | 166 | 173 | 166 |
| Met:Lys | 29 | 30 | 31 | 30 |
| Met and Cys:Lys | 56 | 58 | 60 | 59 |
| Thr:Lys | 60 | 61 | 63 | 65 |
| Trp:Lys | 18.0 | 18.0 | 18.0 | 18.0 |
| Val:Lys | 69 | 69 | 70 | 69 |
| Total Lys, % | 1.04 | 0.92 | 0.84 | 0.76 |
| ME, kcal/kg | 3,322 | 3,329 | 3,333 | 3,333 |
| NE, kcal/kg | 2,474 | 2,504 | 2,522 | 2,549 |
| SID Lys:ME, g/Mcal | 2.68 | 2.34 | 2.13 | 1.95 |
| SID Lys:NE, g/Mcal | 3.60 | 3.11 | 2.81 | 2.55 |
| CP, % | 17.5 | 15.6 | 14.4 | 12.9 |
| Ca, % | 0.57 | 0.53 | 0.52 | 0.46 |
| P, % | 0.39 | 0.37 | 0.35 | 0.35 |
| STTD P, % | 0.33 | 0.28 | 0.27 | 0.26 |

CP = crude protein; STTD = standardized total tract digestibility.

[1]Treatment diets were fed to 1,206 pigs (PIC 337 × 1050; PIC, Hendersonville, TN; initial BW 48.9 kg] for 84 d in a four-phase feeding program with 27 pigs per pen and 15 replications per treatment.

[2]Optiphos 2000 (Huvepharma, Sofia, Bulgaria) provided an estimated release of 0.10% STTD P.

[3]Premix provided per kg of premix: 110 g Fe from iron sulfate; 110 g Zn from zinc sulfate; 33 g Mn from manganese oxide; 17 g Cu from copper sulfate; 330 mg I from calcium iodate; and 300 mg Se from sodium selenite.

[4]Premix provided per kg of premix: 7,054,798 IU vitamin A; 1,102,312 IU vitamin D3; 35,242 IU vitamin E; 3,528 mg vitamin K; 26.5 mg vitamin B12; 39,683 mg niacin; 22,046 mg pantothenic acid; and 6,173 mg riboflavin.

[5]Cr (Cr propionate; Kemin Industries Inc., Des Moines, IA) was added at 0 or 0.5 kg/tonne (200 µg/kg added Cr) during dietary phase 1 and 2, and 0, 0.25 (100 µg/kg added Cr) or 0.5 kg/tonne (200 µg/kg added Cr) during dietary phase 3 and 4 at the expense of corn.

[6]NRC (2012).

of the trial to determine ADG, ADFI, and G:F. The three heaviest pigs per pen were selected using visual evaluation by trained personnel and marketed at an average barn weight (Exp. 1: 116 kg on day 97; Exp. 2: 110 kg on day 68) following the routine farm protocol with no carcass data collected from these pigs. At the conclusion of the trial (Exp. 1, day 125; Exp. 2, day 84), the remaining pigs 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 HCW, backfat, percentage carcass lean, and loin depth. Backfat and loin depth were measured using an optical probe inserted between the third and fourth ribs from the caudal aspect of the carcass at a distance approximately 7 cm from dorsal midline as described by Coble et al. (2017). Percentage carcass lean was calculated using a proprietary formula using HCW, backfat depth, and loin depth. In addition, percentage carcass yield was calculated by dividing pen average HCW by pen average live weight collected at the research facilities before transport to processing facility.

### *Chemical Analysis*

For both experiments, complete diet samples were collected from multiple feeders within treatment, combined within phase when applicable, and subsampled for analysis. All feed samples were submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of dry matter (DM) (AOAC 934.01, 2006), crude protein (CP) (AOAC 990.03, 2006), ether extract (AOAC 920.39 A, 2006), crude fiber (AOAC 978.10, 2006) and to University of Guelph Agriculture and Food Laboratory (Guelph, ON) for analysis of Cr (US EPA 6020a, 1998).

### *Statistical Analysis*

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. In Exp. 1, 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 within treatments fed at a constant level for the full duration of the trial. An additional pairwise contrast was analyzed to determine the impact of changing Cr concentrations between the grower and finisher periods. In Exp. 2, weight block was included in the model as a random effect that accounted for initial BW at the time of allotment. Growth performance during the grower period was analyzed to compare 0 vs. 200 µg/kg added Cr. During the finishing period, growth performance characteristics were analyzed using linear and quadratic contrast statements comparing the effect of increasing dietary Cr supplementation (0, 100, and 200 µg/kg Cr). Overall growth performance and carcass characteristics were analyzed using an *F*-test to determine if at least one treatment differed from another, and LSMEANS procedure with the DIFF and LINES options to separate significant differences among treatments (0/0, 200/100, 200/200 µg/kg added Cr, corresponding to grower/finisher Cr, respectively). In both experiments, backfat, loin depth, and percentage lean were adjusted to a common carcass weight for analysis using HCW as a covariate, and percentage yield was calculated by dividing the pen average HCW by pen average live weight as measured at the research barn before transport to processing facility. Results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

## RESULTS

### *Chemical Analysis*

Chemical analysis of complete diets revealed no notable differences in proximate analysis including DM, CP, ether extract, and crude fiber among treatments (Tables 3 and 4). Although variable, analyzed Cr values were greater in diets with added Cr, as expected.

### *Experiment 1*

Overall, growth performance and carcass characteristics were compared between pigs fed 100/200 and 200/100 µg/kg added Cr during the grower and finisher periods, respectively. No evidence of a difference ($P \geq 0.416$) between treatments was detected, indicating no benefit was observed with changing dosages between growth periods. With no benefit associated with feeding regimen observed, 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 three treatments that had a constant Cr dosage throughout.

Increasing Cr during the grower period resulted in no benefit when 100 µg/kg Cr was fed compared with control fed pigs, but reduced (quadratic, $P < 0.001$; Table 5) ADG and G:F with 200 µg/kg added Cr. No differences ($P \geq 0.229$) in ADFI were detected within the grower period as Cr dosage increased. During the finisher period, pigs fed with diets 100 µg/kg added Cr had the greatest (quadratic, $P < 0.019$) ADG, while G:F was equally improved (quadratic, $P < 0.001$) by either Cr dose. Overall, increasing Cr resulted in no evidence of an effect on ADG or ADFI ($P \geq 0.136$); however, G:F was greatest (quadratic, $P = 0.020$) when pigs were fed 100 µg/kg added Cr in both grower and finishing phases. There was no evidence of difference ($P \geq 0.115$) in carcass characteristics among different Cr dosages or feeding regimen.

**Table 3.** Chemical analysis of diets (as-fed basis), Exp. 1[1]

| | Added Cr, µg/kg[2] | | |
|---|---|---|---|
| BW range, kg | 0 | 100 | 200 |
| 27 to 45 | | | |
| DM, % | 88.1 | 88.7 | 88.5 |
| CP, % | 19.4 | 17.9 | 20.0 |
| Ether extract, % | 3.1 | 2.9 | 3.4 |
| Crude fiber, % | 3.3 | 3.1 | 3.3 |
| Cr, µg/kg | 590 | 600 | 790 |
| 45 to 61 | | | |
| DM, % | 85.1 | 89.0 | 89.0 |
| CP, % | 18.8 | 15.3 | 20.2 |
| Ether extract, % | 4.6 | 3.6 | 3.6 |
| Crude fiber, % | 3.2 | 3.1 | 3.7 |
| Cr, µg/kg | 540 | 610 | 710 |
| 61 to 77 | | | |
| DM, % | 88.6 | 88.6 | 88.7 |
| CP, % | 19.5 | 16.9 | 15.2 |
| Ether extract, % | 3.6 | 3.8 | 3.7 |
| Crude fiber, % | 3.4 | 3.1 | 3.2 |
| Cr, µg/kg | 500 | 430 | 590 |
| 77 to 104 | | | |
| DM, % | 88.7 | 88.2 | 89.1 |
| CP, % | 15.1 | 14.5 | 14.1 |
| Ether extract, % | 3.8 | 3.9 | 3.8 |
| Crude fiber, % | 3.0 | 3.0 | 3.2 |
| Cr, µg/kg | 480 | 490 | 620 |
| 104 to 127 | | | |
| DM, % | 88.9 | 88.3 | 88.7 |
| CP, % | 17.3 | 16.6 | 17.7 |
| Ether extract, % | 3.1 | 3.0 | 2.9 |
| Crude fiber, % | 2.6 | 2.6 | 3.0 |
| Cr, µg/kg | 430 | 480 | 610 |

CP = crude protein; DM = dry matter.

[1]A composite sample was collected from feeders within treatment and phase, subsampled, and submitted to Ward Laboratories, Inc. (Kearney, NE) for proximate analysis and to the University of Guelph Agriculture and Food Laboratory (Guelph, ON) for Cr analysis.

[2]Cr (Cr propionate; Kemin Industries Inc) was added at 0.25 kg/tonne (100 µg/kg Cr) or 0.5 kg/tonne (200 µg/kg Cr) at the expense of corn.

### *Experiment 2*

In Exp. 2, there was no evidence ($P \geq 0.197$) of differences between the treatments for ADG, ADFI, or G:F in the grower period (Table 6). In the finishing period, addition of Cr resulted in a marginally significant increase (linear; $P = 0.061$) in ADG as Cr increased with no evidence of an effect ($P \geq 0.157$) on ADFI or G:F. For the overall period, addition of 200 µg/kg Cr in both grower and finisher periods increased ($P < 0.05$) ADG compared to pigs fed the control, with pigs fed 200 µg/kg Cr fed in grower followed by 100 µg/kg fed in finisher intermediate. There was no evidence ($P \geq 0.523$) of added Cr on overall ADFI and G:F. Percentage carcass yield was decreased ($P = 0.018$) when Cr was added at 200 µg/kg for both the grower and finishing periods compared to the other treatments. There was no evidence of differences ($P \geq 0.206$) in HCW, loin depth, backfat, or percentage lean among treatments.

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

| | Added Cr, µg/kg[2] | | |
|---|---|---|---|
| BW range, kg | 0 | 100 | 200 |
| 45 to 68 | | | |
| DM, % | 90.7 | — | 90.9 |
| CP, % | 18.1 | — | 18.7 |
| Ether extract, % | 3.5 | — | 3.4 |
| Crude fiber, % | 1.5 | — | 3.8 |
| Cr, µg/kg | 330 | — | 440 |
| 68 to 91 | | | |
| DM, % | 90.8 | — | 90.6 |
| CP, % | 15.9 | — | 16.1 |
| Ether extract, % | 3.7 | — | 3.7 |
| Crude fiber, % | 3.7 | — | 3.8 |
| Cr, µg/kg | 280 | — | 310 |
| 91 to 109 | | | |
| DM, % | 90.9 | 90.8 | 90.8 |
| CP, % | 15.2 | 14.9 | 15.5 |
| Ether extract, % | 3.8 | 4.0 | 3.7 |
| Crude fiber, % | 3.6 | 3.5 | 3.6 |
| Cr, µg/kg | 290 | 390 | 510 |
| 109 to 127 | | | |
| DM, % | 90.7 | 90.9 | 91.0 |
| CP, % | 13.6 | 16.5 | 14.9 |
| Ether extract, % | 3.3 | 3.9 | 3.5 |
| Crude fiber, % | 3.0 | 3.5 | 3.3 |
| Cr, µg/kg | 480 | 640 | 680 |

CP = crude protein; DM = dry matter.

[1]A composite sample was collected from feeders within treatment and phase, subsampled, and submitted to Ward Laboratories, Inc. (Kearney, NE) for proximate analysis and to the University of Guelph Agriculture and Food Laboratory (Guelph, ON) for Cr analysis.

[2]Cr (Cr propionate; Kemin Industries Inc., Des Moines, IA) was added at 0 or 0.5 kg/tonne (200 µg/kg added Cr) during dietary phase 1 and 2, and 0, 0.25 (100 µg/kg added Cr) or 0.5 kg/tonne (200 µg/kg added Cr) during dietary phase 3 and 4 at the expense of corn.

## DISCUSSION

Cr is associated with metabolism of glucose, lipids, protein, and nucleic acids (NRC, 2012). The specific role in glucose metabolism historically was believed to be through its presence on the glucose tolerance factor (Steele et al., 1977; Page et al., 1993; Matthews et al., 2001); however, additional research has indicated chromodulin is the likely oligopeptide responsible for activity (Pechova and Pavlata, 2007). With regard to growth performance

**Table 5.** Effects of added Cr propionate on finishing pig growth and carcass characteristics, Exp. 1[1,2]

| | | | | | | | *P* value | |
|---|---|---|---|---|---|---|---|---|
| Grower added Cr, μg/kg: | 0 | 100 | 200 | 100 | 200 | | | |
| Finisher added Cr, μg/kg: | 0 | 100 | 200 | 200 | 100 | SEM | Linear[3] | Quadratic[3] |
| BW, kg | | | | | | | | |
| Initial | 28.7 | 28.6 | 28.7 | 28.6 | 28.7 | 0.47 | <0.955 | <0.720 |
| End grower | 63.5 | 63.4 | 61.3 | 64.1 | 60.8 | 0.71 | <0.001 | <0.006 |
| Final | 139.0 | 139.9 | 138.7 | 140.2 | 139.4 | 1.36 | <0.824 | <0.354 |
| Grower[4] | | | | | | | | |
| ADG, kg | 0.89 | 0.89 | 0.83 | 0.91 | 0.82 | 0.012 | <0.001 | <0.001 |
| ADFI, kg | 1.77 | 1.77 | 1.75 | 1.78 | 1.74 | 0.028 | <0.229 | <0.341 |
| G:F | 0.50 | 0.50 | 0.48 | 0.51 | 0.47 | 0.006 | <0.001 | <0.001 |
| Finisher[5] | | | | | | | | |
| ADG, kg | 0.89 | 0.91 | 0.91 | 0.89 | 0.93 | 0.011 | <0.157 | <0.019 |
| ADFI, kg | 2.45 | 2.42 | 2.44 | 2.44 | 2.46 | 0.045 | <0.656 | <0.860 |
| G:F | 0.36 | 0.37 | 0.38 | 0.37 | 0.38 | 0.005 | <0.015 | <0.001 |
| Overall | | | | | | | | |
| ADG, kg | 0.89 | 0.90 | 0.89 | 0.90 | 0.89 | 0.009 | <0.796 | <0.136 |
| ADFI, kg | 2.23 | 2.21 | 2.21 | 2.23 | 2.23 | 0.037 | <0.472 | <0.651 |
| G:F | 0.40 | 0.41 | 0.40 | 0.40 | 0.40 | 0.004 | <0.463 | <0.020 |
| Carcass characteristics[6] | | | | | | | | |
| HCW, kg | 101.7 | 102.6 | 100.9 | 102.4 | 101.7 | 0.92 | <0.370 | <0.115 |
| Backfat, mm | 16.27 | 16.32 | 16.20 | 16.37 | 16.23 | 0.580 | <0.870 | <0.805 |
| Lean, % | 57.34 | 57.41 | 57.44 | 57.37 | 57.47 | 0.406 | <0.702 | <0.939 |
| Loin depth, mm | 69.98 | 70.88 | 70.54 | 70.80 | 70.90 | 0.738 | <0.503 | <0.394 |
| Yield, %[7] | 73.2 | 73.3 | 72.8 | 73.1 | 73.0 | 0.24 | <0.234 | <0.370 |

[1]A total of 1,206 finisher pigs (PIC 337 × 1050; PIC, Hendersonville, TN; initial BW 28.7 kg) were used in a 125-d study with a five-phase feeding program with 27 pigs per pen and 9 replications per treatment.

[2]Treatment diets were fed in two growth stages, grower (dietary phase 1 and 2) and finisher (dietary phase 3 to 5) and contained 0, 100, or 200 μg/kg Cr (Cr propionate; Kemin Industries Inc., Des Moines, IA).

[3]Linear and quadratic effects of increasing Cr within the grower and finisher periods were evaluated, as well as linear and quadratic effects of added Cr for treatments at the same level for the full experiment. In addition, a contrast was constructed comparing the overall growth performance between the two treatments supplemented with 100/200 and 200/100 during the grower and finisher periods, respectively, with no evidence of a difference ($P \geq 0.416$) among treatments in overall growth performance or carcass characteristics.

[4]Dietary phase 1 and 2 fed from day 0 to 39.

[5]Dietary phase 3 to 5 fed from day 39 to 125.

[6]Carcass characteristics other than yield were adjusted to a common HCW by using HCW as a covariate in the statistical model.

[7]Yield was calculated by dividing average pen HCW by average pen live weight collected at the research barn before transport to processing facility.

and carcass characteristics of finishing pigs, recent scientific literature has shown wide variability in efficacy of added Cr. A number of studies have indicated improvements in carcass characteristics as well as growth performance; however, the presence and magnitude of such responses is all but clear. As a result of the variability observed when Cr is added to swine diets, it is thought that the positive responses might be influenced by dietary nutrient concentrations, environment, and management factors (Lindeman, 2007). In addition, it is thought that the magnitude of response is related to the length of feeding, dosage, and perhaps even the BW of the pig (Lindeman, 2007). It is also theorized that some variability in response to added Cr may be due to its particle size that may affect absorption characteristics (Hung et al., 2015).

One of the major challenges with evaluating the effects of added Cr on growth performance may be attributed to the significant variability in the quantity of Cr present in feedstuffs commonly used in swine diets. Traditional corn–soybean meal-based diets can vary in Cr content from 750 to 3,000 μg/kg (NRC, 2012). Although natural sources of dietary Cr can be very variable, it is believed that only a small fraction of the total Cr present naturally is available for utilization (NRC, 2012). Lindeman (2007) proposed that organic forms of Cr are believed to be much more bioavailable. Thus, evaluation of dietary Cr though laboratory evaluation can be quite misleading, and Cr level is routinely described as quantity of organic Cr added as opposed to total analyzed Cr. In the current series of experiments, variability was observed in Cr analysis as measured by mass spectrometry,

**Table 6.** Effects of Cr propionate inclusion and feeding duration on finishing pig growth performance and carcass characteristics, Exp. 2[1,2]

| | | | | | P value | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Grower | Finisher | |
| Grower added Cr, µg/kg: | 0 | 200 | 200 | | | | | |
| Finisher added Cr, µg/kg: | 0 | 100 | 200 | SEM | Overall | 0 vs. 200 | Linear | Quadratic |
| BW, kg | | | | | | | | |
| Initial | 48.9 | 48.9 | 49.0 | 0.51 | <0.840 | — | — | — |
| End grower | 91.2 | 91.5 | 91.8 | 0.55 | — | <0.275 | — | — |
| Final | 123.6 | 123.6 | 124.6 | 0.64 | <0.304 | — | — | — |
| Grower[3] | | | | | | | | |
| ADG, kg | 0.88 | 0.88 | 0.89 | 0.007 | — | <0.197 | — | — |
| ADFI, kg | 2.40 | 2.44 | 2.42 | 0.022 | — | <0.239 | — | — |
| G:F | 0.37 | 0.36 | 0.37 | 0.003 | — | <0.861 | — | — |
| Finisher[4] | | | | | | | | |
| ADG, kg | 0.92 | 0.92 | 0.94 | 0.010 | — | — | <0.061 | <0.165 |
| ADFI, kg | 2.96 | 2.94 | 2.99 | 0.025 | — | — | <0.399 | <0.201 |
| G:F | 0.31 | 0.31 | 0.32 | 0.003 | — | — | <0.157 | <0.731 |
| Overall | | | | | | | | |
| ADG, kg | 0.89[b] | 0.90[a,b] | 0.91[a] | 0.006 | <0.086 | — | — | — |
| ADFI, kg | 2.63 | 2.64 | 2.66 | 0.021 | <0.650 | — | — | — |
| G:F | 0.34 | 0.34 | 0.34 | 0.003 | <0.523 | — | — | — |
| Carcass characteristics[5] | | | | | | | | |
| HCW, kg | 95.3 | 95.3 | 95.7 | 0.52 | <0.741 | — | — | — |
| Loin depth, mm | 62.54 | 63.28 | 62.86 | 0.516 | <0.590 | — | — | — |
| Backfat, mm | 18.43 | 18.03 | 18.64 | 0.273 | <0.229 | — | — | — |
| Lean, % | 55.13 | 55.44 | 55.03 | 0.168 | <0.206 | — | — | — |
| Yield, %[6] | 77.1[a] | 77.1[a] | 76.8[b] | 0.10 | <0.018 | — | — | — |

[1]A total of 1,206 pigs (PIC 337 × 1050; PIC, Hendersonville, TN; initial BW 48.9 kg) were used in an 84-d study with a four-phase feeding program with 27 pigs per pen and 15 replications per treatment.

[2]Cr (Cr propionate; Kemin Industries Inc., Des Moines, IA).

[3]Dietary phase 1 and 2 fed from day 0 to 48.

[4]Dietary phase 3 and 4 fed from day 48 to 84.

[5]Carcass characteristics other than yield were adjusted to a common HCW by using HCW as a covariate in the statistical model.

[6]Yield was calculated by dividing average pen HCW by average pen live weight collected at the research barn before transport to processing facility.

[a,b]Means lacking common superscripts differ ($P < 0.05$).

but in general analyzed Cr concentrations increased as the level of added Cr increased.

Cr propionate was granted permission by the U.S. Food and Drug Administration in 2000 to be marketed without objection for inclusion in swine diets at inclusion levels up to 200 µg/kg (Lindeman, 2007), and similar bioavailibity to Cr picolinate has been observed (Matthews et al., 2001). However, evaluation of different sources of Cr provides evidence that when added at very high levels, tissue concentration of Cr differed among the various sources (Lindemann et al., 2008). Additional investigation into added Cr propionate in finishing pig diets has observed variable effects on growth performance and carcass characteristics (Shelton et al., 2003; Matthews et al., 2005, Jackson et al., 2009). Therefore, because Cr propionate has been shown to be a bioavailable source of Cr in swine, further investigation into the effects of supplementation under commercial conditions was the primary objective of the current series of experiments.

In addition to a large degree of variability in Cr composition of feed ingredients and questionable bioavailability, the historical influence of added Cr on growth outcomes and carcass composition is also quite variable (Lindeman, 2007). A number of peer-reviewed publications show both benefits and no response when adding Cr on both growth performance and carcass characteristics. Greater detail regarding the mixed results of these studies is provided in NRC (2012). To summarize the body of published evidence, a meta-analysis on added dietary Cr on carcass characteristics and growth performance of finishing swine was conducted by Sales and Jancik (2011). Their evaluation included studies that added Cr in the form of Cr-methionine chelate, Cr-nanocomposite, Cr-nicotinate, Cr-propionate, Cr-tripicolinate, and Cr-yeast. Cumulative findings of the 31 studies analyzed observed a reduction in backfat thickness, and an increase in percentage carcass lean and loin muscle area with added Cr. In the series of experiments herein, the only carcass characteristic that was influenced by added Cr was a reduction in percentage carcass yield and only in Exp. 2. In the review by Sales and Jancik (2011), they observed that the later in the finishing period when Cr supplementation was initiated, the greater the magnitude of decreased fat and increased carcass lean. Boleman et al. (1995) found that supplementation of 200 μg/kg Cr-picolinate only in the finisher period resulted in greater carcass percentage muscle, lower 10th rib backfat, and lower total carcass fat percentage compared with both control and pigs fed 200 μg/kg added Cr-picolinate in both the grower and finisher periods.

In conclusion, growth performance was moderately influenced with the addition of Cr propionate in swine diets. Carcass composition was largely unaffected by added Cr with the exception of reducing percentage carcass yield in Exp. 2. The specific dosage in which ADG and G:F was maximized varied from 100 μg/kg in Exp. 1 to 200 μg/kg added Cr in Exp. 2. The results of these trials do not provide evidence that different feeding regimens will consistently result in improved performance. Under commercial swine production conditions in the current series of experiments, addition of Cr propionate in finishing pig diets has the potential to modestly influence growth performance; however, it did not lead to positive impacts on carcass characteristics.

*Conflict of interest statement*. None declared

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