Kansas Agricultural Experiment Station Research Reports

Volume 9
Issue 7 *Swine Day*

Article 34

2023

Effect of Sulfate or Hydroxychloride Forms of Zinc, Manganese, and Copper on Growth Performance, Weight Variation, Carcass Characteristics, and Economics of Grow-Finish Pigs

Hilario M. Cordoba
Kansas State University, Manhattan, hcordoba@k-state.edu

Jason C. Woodworth
Kansas State University, Manhattan, jwoodworth@k-state.edu

Robert D. Goodband
Kansas State University, Manhattan, goodband@k-state.edu

See next page for additional authors

Recommended Citation

Cordoba, Hilario M.; Woodworth, Jason C.; Goodband, Robert D.; DeRouchey, Joel M.; Tokach, Mike D.; Gebhardt, Jordan T.; and van de Ligt, Chris P.A. (2023) "Effect of Sulfate or Hydroxychloride Forms of Zinc, Manganese, and Copper on Growth Performance, Weight Variation, Carcass Characteristics, and Economics of Grow-Finish Pigs," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 7. https://doi.org/10.4148/2378-5977.8535

Effect of Sulfate or Hydroxychloride Forms of Zinc, Manganese, and Copper on Growth Performance, Weight Variation, Carcass Characteristics, and Economics of Grow-Finish Pigs

Funding Source

The authors appreciate Selko USA (Indianapolis, IN) for providing partial financial support for these studies. The authors appreciate New Horizon Farms (Pipestone, MN) for providing technical assistance for these studies.

Authors

Hilario M. Cordoba, Jason C. Woodworth, Robert D. Goodband, Joel M. DeRouchey, Mike D. Tokach, Jordan T. Gebhardt, and Chris P.A. van de Ligt

Effect of Sulfate or Hydroxychloride Forms of Zinc, Manganese, and Copper on Growth Performance, Weight Variation, Carcass Characteristics, and Economics of Grow-Finish Pigs[1]

Hilario M. Cordoba, Jason C. Woodworth, Robert D. Goodband, Joel M. DeRouchey, Mike D. Tokach, Jordan T. Gebhardt,[2] and Chris P.A. van de Ligt[3]

Summary

A total of 1,026 grow-finish pigs (337 × 1050 PIC; initially 57.2 ± 0.73 lb) were used in a 124-d trial to compare sulfate and hydroxychloride forms of Zn, Mn, and Cu on growth performance, carcass characteristics, weight variation, and economics of grow-finish pigs. Pigs were housed in mixed gender pens with 27 pigs per pen and 19 pens per treatment. The treatments were structured as a completely randomized design and consisted of a control diet containing 150, 16, and 110 ppm of Cu, Mn, and Zn, respectively, from sulfate sources or the same inclusion provided by hydroxychloride sources. Experimental diets were corn-soybean meal-DDGS-based and fed in meal form in phase 1 from 57 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to 300 lb. In the grower period (57 to 173 lb), there was a tendency ($P = 0.052$) to improve F/G when sulfate Mn, Zn, and Cu were fed. In the finisher period (d 61 to 124), pigs fed hydroxychloride mineral sources had improved ($P = 0.041$) ADG. For pig body weight variability, there was no evidence of differences ($P \geq 0.10$) on the coefficient of variation between treatments. Pigs marketed at the end of the study which were fed hydroxychloride sources tended to have greater HCW ($P = 0.054$) compared to sulfate sources, but no evidence for differences ($P \geq 0.10$) were found in any other carcass trait at any marketing event. There was a tendency ($P = 0.088$) to reduce feed cost per lb of gain when using sulfate sources compared to hydroxychloride forms; however, IOFC was not impacted by mineral source ($P > 0.10$). In conclusion, these data suggest there were no differences in pig weight variability, overall pig growth performance, or carcass characteristics between mineral sources.

---

[1] The authors appreciate Selko USA (Indianapolis, IN) for providing partial financial support for these studies. The authors appreciate New Horizon Farms (Pipestone, MN) for providing technical assistance for these studies.

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

[3] Selko USA (Indianapolis, IN).

Introduction

Minerals found in grains and oilseeds are low in quantity and availability. Therefore, those minerals that have specific roles for influencing metabolism should be supplemented in the diet. Typically, trace minerals have been supplemented as oxide or sulfate sources due to their low cost. However, the use of organic and hydroxy forms has gained interest due to better stability and bioavailability.[4] Previous research has mainly focused on comparing sources of only one mineral at a time.[5,6,7] However, additive benefits may be observed from replacing all sulfate sources of minerals with the higher availability hydroxy sources of minerals. Therefore, the objective of this study was to compare a feeding program using either sulfate or hydroxychloride mineral forms of Zn, Mn, and Cu on growth performance, carcass characteristics, weight variation, and economics in grow-finish 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 barns were naturally ventilated and double-curtain-sided with totally slatted floors. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) able to record feed deliveries for individual pens.

Animals and diets

A total 1,026 pigs (337 × 1050 PIC; initially 57.2 ± 0.73 lb) were used in a 124-d growth trial. Pigs were housed in mixed gender pens with 27 pigs per pen and 19 pens per treatment. The treatments were structured as a completely randomized design and consisted of a control diet containing 110, 16, and 150 ppm of added Zn, Mn, and Cu, respectively, from sulfate sources or the same inclusion provided by hydroxychloride sources (IntelliBond, Selko USA, Indianapolis, IN). All treatment diets were manufactured at the New Horizon Farms Feed Mill in Pipestone, MN, and were formulated to meet or exceed NRC[8] requirement estimates for growing-finishing pigs for their respective weight ranges (Table 1). Diets were corn-soybean meal-DDGS-based and fed in meal form, with phase 1 fed from 57 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to 300 lb.

[4] Reddy, B. V. V., S. Nayak, A. Khare, R. P. Pal, R. Sharma, A. Chourasiya, S. Namdeo, and S. Thakur. 2021. Role of hydroxy trace minerals on health and production of livestock: a review. J Livestock Sci. 12:279-286.

[5] Cemin, H. S., J. C. Woodworth, M. D. Tokach, S. S. Dritz, J. M. DeRouchey, R. D. Goodband, and J. L. Ursy. 2019. Effects of increasing dietary zinc on growth performance and carcass characteristics of pigs raised under commercial conditions. Transl. Anim. Sci. doi: 10.1093/tas/txz054

[6] Coble, K. F., J. M. DeRouchey, M. D. Tokach, S. S. Dritz, R. D. Goodband, J. C. Woodworth, and J. L. Ursy. 2017. The effects of copper source and concentration on growth performance, carcass characteristics, and pen cleanliness in finishing pigs. J. Anim. Sci. 95:4052-4059.

[7] Kerkaert, H. R., J. C. Woodworth, J. M. DeRouchey, S. S. Dritz, M. D. Tokach, R. D. Goodband, and N. E. Manzke. 2021. Determining effects of manganese source and level on growth performance and carcass characteristics of growing-finishing pigs. Transl. Anim. Sci. doi: 10.1093/tas/txab067.

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

Pens of pigs were weighed approximately every 14 d to determine ADG, ADFI, and F/G. On d 0 and 102, all the pigs in each pen were individually weighed to determine body weight variation. On d 102, the 6 heaviest pigs in each pen were selected, tattooed with a pen identification number, and transported to a U.S. Department of Agriculture-inspected packing plant (JBS Swift, Worthington, MN) for carcass data collection. On the last day of the trial, final pen weights were obtained, and the remaining pigs were tattooed with a pen identification number and transported to the same packing plant for carcass data collection. Carcass measurements included HCW, loin depth, backfat, and percentage lean. Percentage lean was calculated from a plant proprietary equation. Carcass yield was calculated by dividing the pen average HCW by the total weight of the 6 pigs weighed individually at first marketing event and the pen average final live weight obtained at the farm at the final marketing event. The HCW variation was determined at both marketing events and overall. Feed cost per pig was calculated by diet feed cost times feed intake per phase divided by pigs placed. Feed cost per lb of gain was calculated 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 the low price calculations were: carcass price = $0.59/lb; corn = $3.00/bushel ($107/ton); soybean meal = $300/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; Thr Pro = $0.80/lb; L-Trp = $3.00; L-Val = $2.50/lb; Optiphos Plus 2500 G = $1.18/lb; VTM sulfate sources = $1.50/lb; VTM hydroxychloride sources = $2.00/lb. Prices for the high price calculations were: carcass price = $0.88/lb; corn = $6.00/bushel ($214/ton); soybean meal = $400/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; Thr Pro = $0.80/lb; L-Trp = $5.00; L-Val = $4.00/lb; Optiphos Plus 2500 G = $1.18/lb; VTM sulfate sources = $1.50/lb; VTM hydroxychloride sources = $2.00/lb.

Statistical analysis

Data were analyzed as a completely randomized design for one-way ANOVA using the lmer function from the lme4 package in R (version 4.1.1 (2021-08-10), R Foundation for Statistical Computing, Vienna, Austria) with pen considered the experimental unit, and treatment as fixed effect. Pig individual weight data on d 0 and 102 were used to calculate within-pen coefficient of variation which was analyzed in a similar manner to growth data. Additionally, individual live weight and HCW data were visualized using the ggplot package in R. All results were considered significant at $P \leq 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Chemical analysis of complete diets were consistent with the calculated values used in the diet formulation for Zn, Mn, and Cu (Table 2).

In the grower period (57 to 173 lb), there was a tendency ($P = 0.052$) for improved F/G when sulfate forms of Mn, Zn, and Cu were provided, without any impact on ADG or ADFI ($P > 0.10$). In the finisher period (173 to 300 lb), pigs fed hydroxychloride mineral sources had improved ($P = 0.041$) ADG, with no impact on ADFI or F/G ($P > 0.10$). Overall (57 to 300 lb), there was no evidence for difference ($P > 0.10$) in ADG, ADFI, or F/G when comparing the sulfates and hydroxychloride forms of minerals. For pig body weight variability, there was no evidence of differences ($P > 0.10$) in the coefficient of variation between treatments either on d 0 (Figure 1) or d 102 (Figure 2).

For carcass characteristics, no evidence of difference ($P > 0.10$) was observed for any parameter when comparing sulfates and hydroxychloride mineral sources in pigs evaluated on the first marketing event. However, for pigs in the final marketing event, there was a tendency ($P = 0.054$) for increased HCW when pigs were fed hydroxychloride forms of minerals during the study. When both marketing events were combined, no evidence of differences ($P > 0.10$) was observed for any carcass characteristics trait. For HCW variability, no evidence of difference ($P > 0.10$) was observed when comparing sulfates and hydroxychloride mineral sources in pigs evaluated on the first (Figure 3), final (Figure 4), and combined (Figure 5) marketing events.

For economics, there was a trend ($P = 0.088$) for reduced feed cost per lb of gain in the low-price scenario when pigs were fed sulfate mineral forms compared to those fed hydroxychloride forms, but it did not impact IOFC and there was no difference in economics when considering a high price scenario ($P > 0.10$).

In conclusion, these data suggest there were no differences in pig weight variability, overall pig growth performance, and carcass characteristics between pigs fed sulfate or hydroxychloride forms of Cu, Zn, and Mn.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

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

Item	Phase 1	Phase 2	Phase 3	Phase 4
Ingredients, %				
Corn	54.63	60.98	65.87	68.37
Soybean meal, 46.5% CP[2]	17.34	11.20	6.68	4.22
DDGS	25.00	25.00	25.00	25.00
Limestone	1.45	1.40	1.30	1.25
Monocalcium P, 21% P	0.30	0.20	0.00	0.00
Salt	0.40	0.40	0.40	0.40
L-Lys-HCl	0.48	0.45	0.43	0.43
DL-Met	0.02	0.00	0.00	0.00
L-Trp	0.03	0.03	0.03	0.04
Thr[3]	0.11	0.08	0.07	0.08
Vitamin-trace mineral premix[4]	0.20	0.20	0.20	0.20
Phytase[5]	0.05	0.05	0.03	0.02
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.08	0.91	0.78	0.72
Ile:Lys	60	60	60	60
Leu:Lys	155	168	183	190
Met:Lys	29	30	33	34
Met and Cys:Lys	56	59	64	66
Thr:Lys	62	62	63	65
Trp:Lys	18	18	18	18
Val:Lys	71	73	76	77
His:Lys	42	44	46	47
Total Lys, %	1.27	1.08	0.94	0.87
NE, kcal/lb	1,081	1,099	1,115	1,122
SID Lys:NE, g/Mcal	4.53	3.76	3.17	2.91
CP, %	20.4	17.9	16.1	15.2
Ca, %	0.67	0.62	0.53	0.50
STTD P, %	0.43	0.39	0.33	0.31

[1]Phases 1, 2, 3, and 4 were fed from approximately 57 to 110 lb, 110 to 165 lb, 165 to 220 lb and 220 to market, respectively.
[2]CP = crude protein.
[3]Thr Pro; CJ America-Bio, Downers Grove, IL.
[4]Vitamin trace mineral premix containing 110 ppm of Zn, 16 ppm of Mn, and 150 ppm of Cu provided by sulfate sources or hydroxychloride sources (IntelliBond, Selko USA, Indianapolis, IN) were added to form the experimental treatments.
[5]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 1,250 FTU/kg on phases 1 and 2, 625 FTU/kg on phase 3, and 500 FTU/kg on phase 4 providing an estimated release of 0.13% STTD P in phases 1 and 2, 0.11% STTD P in phase 3, and 0.10% STTD P in phase 4.

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

	Mineral source[2]	
	Sulfate	Hydroxychloride
Calculated, ppm (added basis)		
Zn	110	110
Mn	16	16
Cu	150	150
Analyzed, ppm (total basis)		
Zn	211	220
Mn	30	36
Cu	168	151

[1] Values represent the means from 8 composite samples (4 samples per treatment). For each treatment, samples were collected from multiple feeders from the two groups, blended, subsampled, ground, and analyzed (Cumberland Valley Analytical Services, Waynesboro, PA).

[2] Sulfate or hydroxychloride sources of Zn, Mn, and Cu were used for the 2 treatments.

Table 3. Effect of sulfate or hydroxychloride forms of zinc, manganese, and copper on growth performance, weight variation, carcass characteristics, and economics of grow-finish pigs[1]

	Mineral source			
Item	Sulfates[2]	Hydroxychloride[3]	SEM	*P* =
BW, lb				
d 0	57.0	57.2	0.73	0.865
d 61	173.2	173.0	1.09	0.886
d 124	298.7	301.6	1.50	0.192
Grower (d 0 to 61)				
ADG, lb	1.89	1.89	0.010	0.656
ADFI, lb	4.37	4.42	0.032	0.269
F/G	2.31	2.35	0.012	0.052
Finisher (d 61 to 124)				
ADG, lb	2.06	2.12	0.019	0.041
ADFI, lb	6.56	6.66	0.049	0.188
F/G	3.19	3.15	0.026	0.308
Overall (d 0 to 124)				
ADG, lb	1.97	2.00	0.010	0.115
ADFI, lb	5.44	5.50	0.035	0.203
F/G	2.75	2.75	0.016	0.957
CV, %[4]				
d 0	15.6	15.5	0.59	0.919
d 102	9.8	9.2	0.37	0.226
Carcass characteristics				
First marketing event				
HCW, lb	204.6	204.5	1.61	0.948
HCW CV, %[6]	5.5	4.9	0.35	0.294
Yield, %	73.1	73.3	0.27	0.655
Backfat, in.[5]	0.64	0.63	0.012	0.842
Loin depth, in.[5]	2.39	2.39	0.024	0.830
Lean, %[5]	56.3	56.4	0.21	0.818
Final marketing event				
HCW, lb	216.1	219.7	1.28	0.054
HCW CV, %[6]	8.2	7.7	0.35	0.291
Yield, %	72.1	72.4	0.26	0.467
Backfat, in.[5]	0.62	0.63	0.008	0.176
Loin depth, in.[5]	2.49	2.48	0.015	0.900
Lean, %[5]	56.9	56.7	0.14	0.208

continued

Table 3. Effect of sulfate or hydroxychloride forms of zinc, manganese, and copper on growth performance, weight variation, carcass characteristics, and economics of grow-finish pigs[1]

	Mineral source			
Item	Sulfates[2]	Hydroxychloride[3]	SEM	*P* =
Overall				
HCW, lb	213.3	215.6	1.21	0.189
HCW CV, %[6]	7.5	6.9	0.28	0.170
Yield, %	72.4	72.7	0.01	0.353
Backfat, in.[5]	0.62	0.63	0.007	0.208
Loin depth, in.[5]	2.46	2.46	0.012	0.809
Lean, %[5]	56.8	56.6	0.12	0.252
Total removals, %	3.7	5.3	0.99	0.226
Economics, $/pig placed				
Low price scenario[7]				
Feed cost	46.46	47.36	0.408	0.128
Feed cost/lb gain[8]	0.202	0.205	0.0012	0.088
Revenue[9]	98.37	99.22	0.857	0.490
IOFC[10]	51.91	51.86	0.574	0.946
High price scenario[11]				
Feed cost	79.59	80.67	0.699	0.281
Feed cost/lb gain[7]	0.346	0.349	0.0020	0.299
Revenue[8]	146.72	147.98	1.277	0.490
IOFC[9]	67.14	67.31	0.812	0.877

[1] A total of 1,026 pigs (initial BW of 57.2 lb ± 0.73 lb) were used with 27 pigs per pen and 19 replicates per treatment. Treatments were assigned in a completely randomized design to compare the effect of sulfates and hydroxychloride (IntelliBond, Selko USA, Indianapolis, IN) forms of Zn, Mn, and Cu on growth performance, weight distribution, and carcass characteristics of grow-finish pigs.

[2] Added Zn, Mn, and Cu were provided by sulfate sources at 110, 16, and 150 ppm, respectively.

[3] Added Zn, Mn, and Cu were provided by hydroxychloride sources at 110, 16, and 150 ppm, respectively.

[4] Pigs were weighed individually to calculate variation of final BW. Coefficient of variation of individual pig weight was calculated for each pen and analyzed to determine the effect of dietary treatment with pen as the experimental unit.

[5] Adjusted using HCW as covariate.

[6] HCW was collected at the packing plant and used to calculate variation of final HCW for each marking event. Coefficient of variation of individual pig HCW was calculated for each pen and analyzed to determine the effect of dietary treatment with pen as the experimental unit.

[6] Market price for the low price calculation: carcass price = $0.59/lb; corn = $3.00/bushel ($107/ton); soybean meal = $300/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; Thr Pro = $0.80/lb; L-Trp = $3.00; L-Val = $2.50/lb; Optiphos Plus 2500 G = $1.18/lb; VTM sulfate sources = $1.50/lb; VTM hydroxychloride sources = $2.00/lb.

[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.

[10] Market price for the high price calculation: carcass price = $0.88/lb; corn = $6.00/bushel ($214/ton); soybean meal = $400/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; Thr Pro = $0.80/lb; L-Trp = $5.00; L-Val = $4.00/lb; Optiphos Plus 2500 G = $1.18/lb; VTM sulfate sources = $1.50/lb; VTM hydroxychloride sources = $2.00/lb.

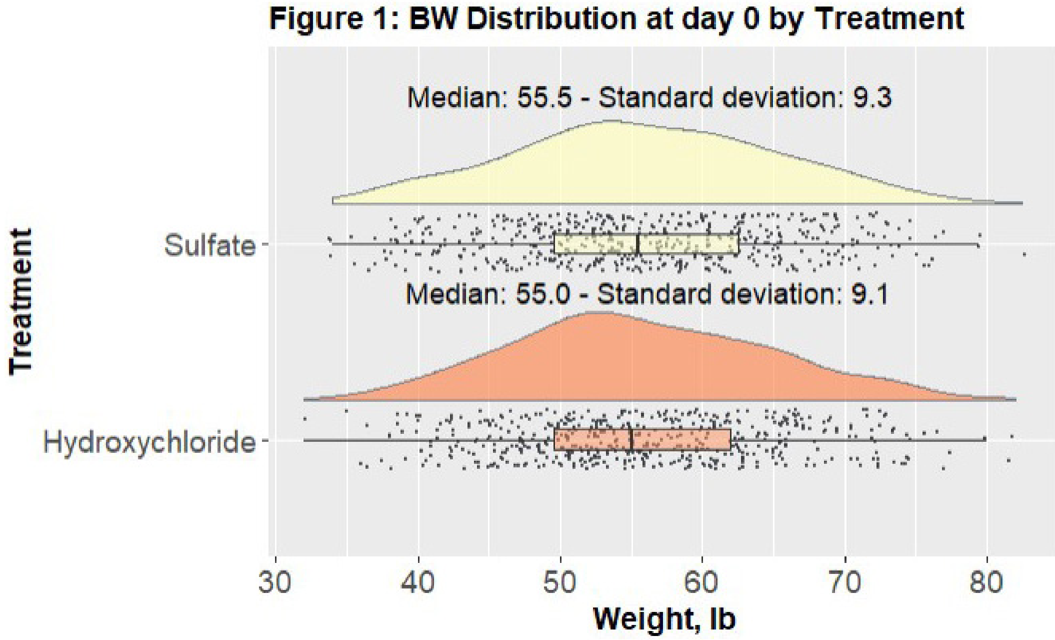

Figure 1. At the beginning of this study (d 0), all pigs (n = 1,026) were individually weighed to determine average pen BW variability. There were no differences (P > 0.10) in the CV between the two treatments. In addition, the median and SD show that treatments had a similar distribution.

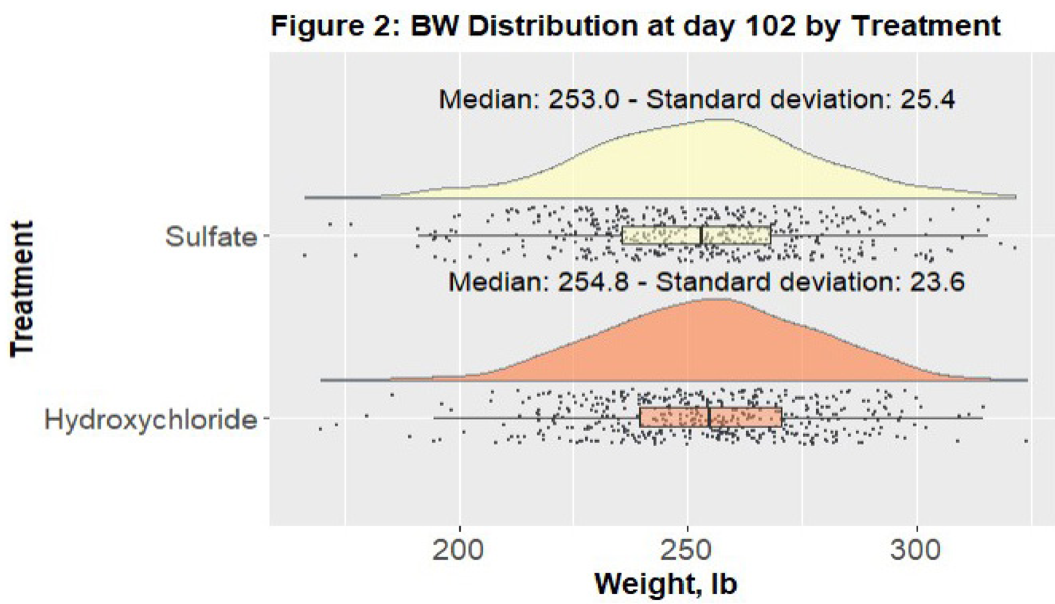

Figure 2. Previous to the first marketing event (d 102), all pigs (n = 986) were individually weighed to determine average pen BW variability. There were no differences (P > 0.10) in the CV between the two treatments.

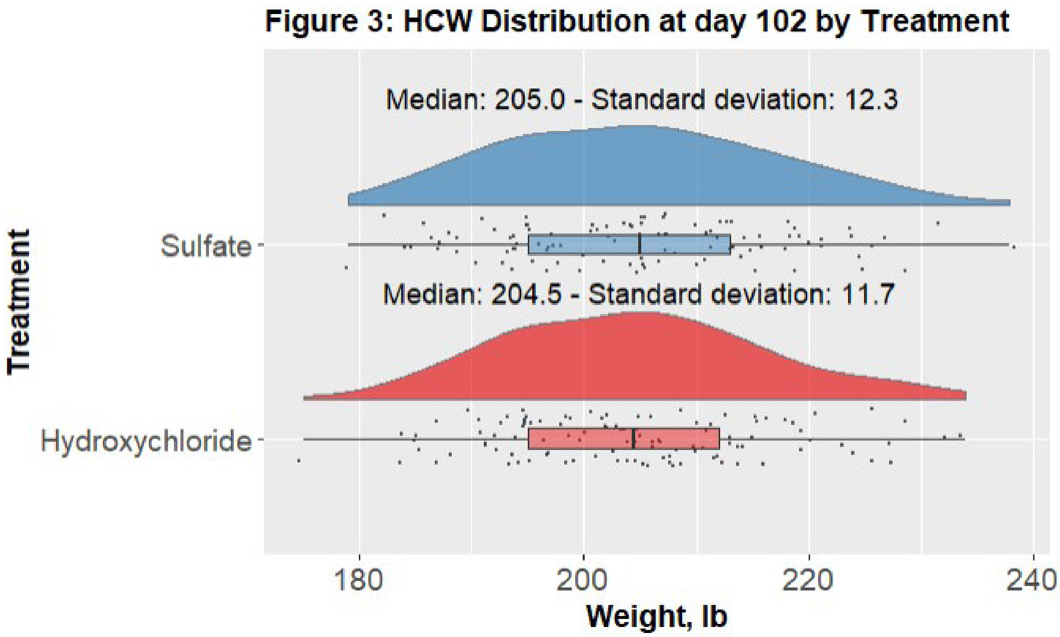

Figure 3. At the first marketing event (d 102), the 6 heaviest pigs per pen were tattooed and marketed. The HCW data was collected at the plant and analyzed to determine HCW variability. There were no differences (*P* > 0.10) in the CV between the two treatments. In addition, the median and SD show that treatments had a similar distribution.

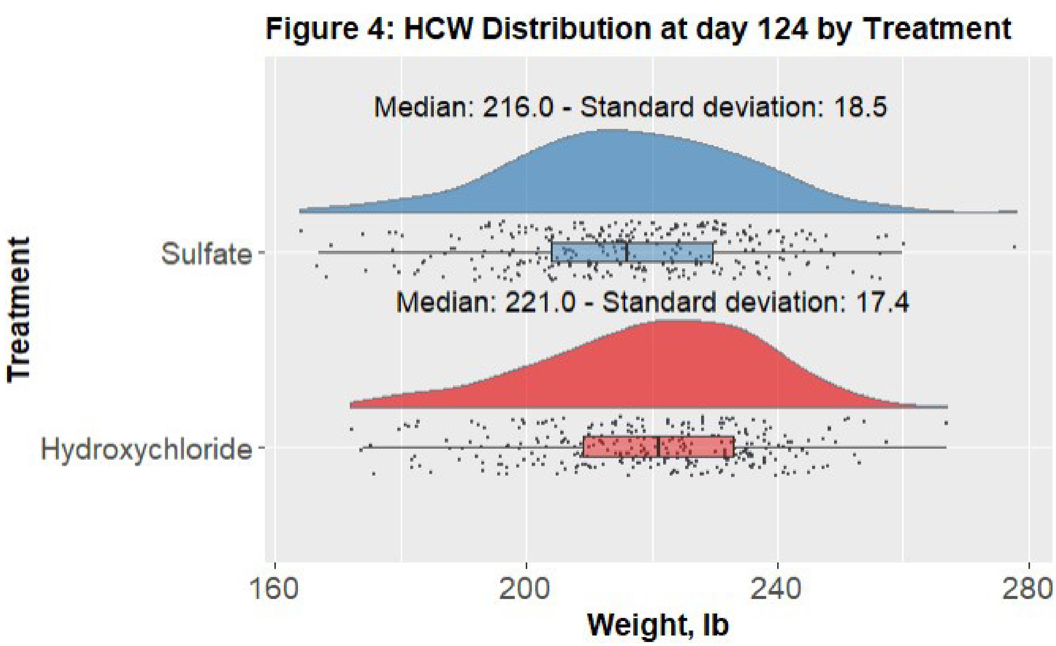

Figure 4. At the final marketing event (d 124), pigs were tattooed and marketed. The HCW data was collected at the plant and analyzed to determine HCW variability. There were no differences (*P* > 0.10) in the CV between the two treatments.

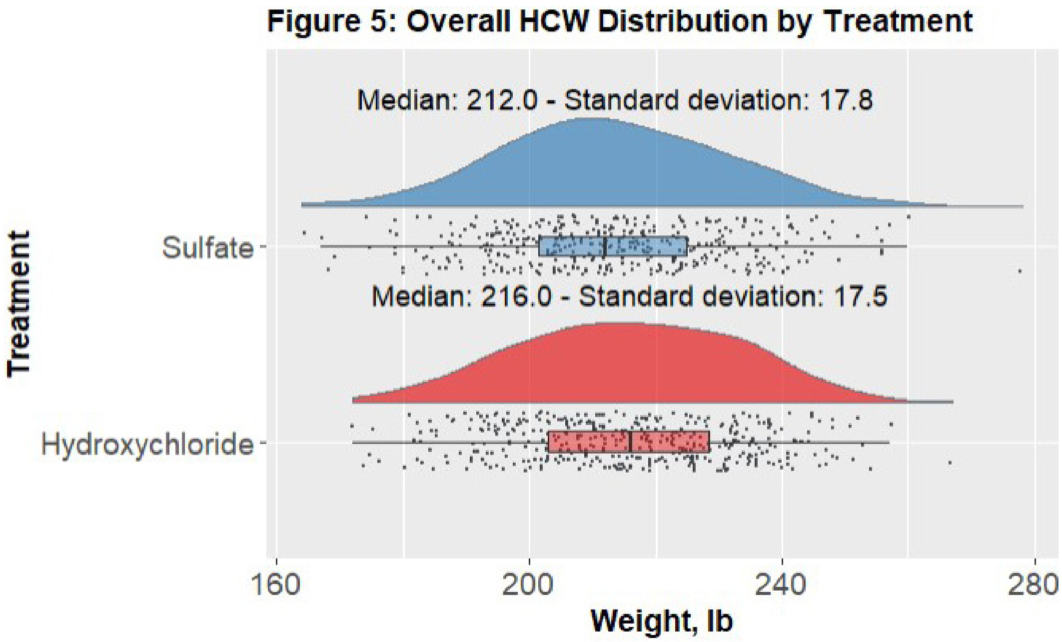

Figure 5. Combined HCW variability from both marketing events. There were no differences (*P* > 0.10) in the CV between the two treatments.