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Effects of Zinc Source on Growth Performance and Carcass Characteristics of Finishing Pigs[1]

Maxwell L. Corso, Jason C. Woodworth, Mike D. Tokach, Jordan T. Gebhardt,[2] Robert D. Goodband, Joel M. DeRouchey, and Chris van de Ligt[3]

Summary

A total of 3,159 pigs (PIC 337 × 1050; initially 48.2 ± 1.70 lb) were used to determine the effect of Zn source on growth performance, carcass characteristics, and within-pen BW and HCW variation. Pigs were housed in mixed-gender pens with 27 pigs per pen and 39 pens per treatment across three barns. Individual pig weights were taken at allotment, first marketing, and final marketing to calculate within-pen body weight variation. Experimental treatments consisted of diets containing 100 ppm of Zn from: 1) Zn hydroxychloride; 2) $ZnSO_4$, or 3) ZnO. Data were divided into three phases, encompassing three time periods, phase 1 from approximately 50 to 120 lb, phase 2 from 120 to 200 lb, and phase 3 from 200 to 300 lb. During period 1, pigs fed diets with ZnO had improved ($P < 0.05$) ADG and F/G compared to those fed the diet containing Zn hydroxychloride. In period 2, Zn source had no effect on ADG, ADFI, or F/G ($P > 0.10$). During period 3, pigs fed diets containing Zn hydroxychloride had improved ($P < 0.05$) ADG and F/G compared to those fed the diet containing ZnO. Overall, there were no differences ($P > 0.10$) observed for growth performance or carcass characteristics. Furthermore, Zn source did not affect BW or HCW variation. In conclusion, pigs fed the three Zn sources had similar overall growth performance, carcass characteristics, and weight variation.

Introduction

Zinc is a trace mineral that functions as a component of carbohydrate, protein, and lipid metabolism. The Zn sources commonly utilized in swine diets are ZnO and $ZnSO_4$. Recently, Zn hydroxychloride has also become available as an alternative source of Zn. Hydroxychloride-based minerals are inorganic compounds that are manufactured through the reaction of hydrochloric acid. The hydrochloric crystals that are produced through this reaction contain covalent bonds that reduce the ability for minerals to react with other components within the diet, thus having the potential

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to improve bioavailability.[4] Cemin et al.[5] evaluated the effects of Zn source and inclusion level on growth performance of grow-finish pigs and concluded that pigs fed Zn hydroxychloride had improved carcass yield and tended to have a greater HCW than pigs fed $ZnSO_4$. However, this benefit has not consistently been observed and there is little research available to help understand if Zn source will affect within-pen BW variation. Therefore, the objective of this study was to compare the effects of added Zn from Zn hydroxychloride, $ZnSO_4$, and ZnO on growth performance, carcass characteristics, and within-pen body weight and HCW variation of finishing pigs raised in a commercial environment.

Materials and Methods

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 Minnesota. The barns were naturally ventilated and double-curtain-sided with completely 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 of 3,159 pigs (PIC 337 × 1050; initially 48.2 ± 1.70 lb) were used to determine the effects of Zn source on growth performance, carcass characteristics, and within-pen BW and HCW variation. Pigs were housed in mixed-gender pens with 27 pigs per pen and 39 pens per treatment across three barns. Pens were blocked by BW and randomly assigned to one of three treatments in a randomized complete block design. Treatments consisted of diets containing 100 ppm of Zn from: 1) Zn hydroxychloride (IntelliBond Z, Micronutrients USA, LLC, Indianapolis, IN); 2) $ZnSO_4$, or 3) ZnO. Treatment diets were made with three separate vitamin/trace mineral premixes, each containing a separate source of Zn as the only source of supplemental Zn in the diet. The remainder of the premix contained the same sources and levels of other vitamins and trace minerals with the copper supplied by tribasic copper chloride (Intellibond C, Micronutrients USA, LLC, Indianapolis, IN) to provide 150 ppm of Cu and the manganese supplied by manganese hydroxychloride (Intellibond M, Micronutrients USA, LLC, Indianapolis, IN) to provide 30 ppm of Mn. All diets were manufactured at New Horizons feed mill in Pipestone, MN, and were formulated to meet or exceed the NRC requirement estimates for respective weight ranges of growing-finishing pigs (Table 1). Diets were fed in meal form in 4 phases with phase 1 fed from 50 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb and phase 4 from 220 to 290 lb.

Pens of pigs were weighed and feed disappearance measured approximately every 14 days to determine ADG, ADFI, and F/G. Due to differences in initial BW and

[4] Kerkaert, H. R., Woodworth, J. C., DeRouchey, J. M., Dritz, S. S., Tokach, M. D., Goodband, R. D., Manzke, N. E. 2021. Determining growing–finishing pigs. Transl. Anim. Sci. 5:1-9. doi:10.1093/tas/txab067.

[5] Cemin, H. S., Carpenter, C. B., Woodworth, J. C., Tokach, M. D., Dritz, S. S., DeReouchey, J. M., Goodband, R. D., Usry, J. L. 2019. Effects of zinc source and level on growth performance and carcass characteristics of finishing pigs. Transl. Anim. Sci. 3:742–748. doi:10.1093/tas/txz071.

length of weigh periods between barns, data were divided into three periods. Period 1 was from day 0 to 55 for barn one, day 0 to 41 for barn two, and day 0 to 32 for barn three. Period 2 was day 55 to 98 for barn one, day 41 to 83 for barn two, and day 32 to 74 for barn three. Period 3 from day 98 to 146 for barn one, day 83 to 130 for barn two, and day 74 to 124 for barn three. At allotment, first marketing, and final marketing, all pigs were individually weighed to determine within-pen body weight variation. At first marketing, the heaviest six pigs were selected from each pen, tattooed with a pen identification number, and were marketed and transported to a USDA inspected packing plant (JBS Swift, Worthington, MN) for carcass data collection. At final marketing, the remaining pigs in the pen followed the same procedure. Carcass measurements collected for both marketing events included hot carcass weight (HCW), yield percentage, percentage lean, loin depth, and backfat. Carcass yield was calculated by dividing marketed pig average HCW by the marketed pig average final live weight recorded at the farm.

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). Pen was considered the experimental unit and treatment was considered a fixed effect in the statistical model. Carcass data were analyzed using individual carcass observations and the statistical model included pen as a random intercept to account for subsampling. For analysis of backfat, percentage lean, and loin depth, HCW was used as a covariate. Individual weight data collected at the first and final marketing events were used to calculate within-pen coefficient of variation at each time point, which was analyzed on a pen-basis like other growth performance responses. Additionally, individual 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

In period 1, pigs fed diets containing ZnO had improved ($P < 0.05$; Table 2) ADG and F/G compared to those fed the diet containing Zn hydroxychloride, with those fed $ZnSO_4$ intermediate. No differences in ADFI were observed during this period. In period 2, Zn source had no effect on ADG, ADFI, or F/G ($P > 0.10$). During period 3, pigs fed diets including Zn hydroxychloride had improved ($P < 0.05$) ADG and F/G compared to pigs fed diets containing ZnO; with those fed $ZnSO_4$ intermediate. During this period there were no differences in ADFI between the treatments ($P > 0.10$). For the overall study, Zn source had no affect ($P > 0.10$) on ADG, ADFI, F/G, removals or mortalities. Within-pen pig BW or HCW coefficient of variation was not influenced by treatment at either the first or final marketing event (Figures 1, 2, 3, 4, 5, and 6). Carcass characteristics at the first or final marketing event were not affected by Zn source (Table 3) In conclusion, this study suggests that Zn source had no effect on overall growth performance, carcass characteristics, in-pen BW or HCW variation, or removals and mortality.

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

Ingredients, %	Phase 1	Phase 2	Phase 3	Phase 4
Corn	54.63	60.98	65.87	68.37
Soybean meal (46.5% CP)	17.34	11.19	6.67	4.22
DDGS[2]	25.00	25.00	25.00	25.00
Limestone	1.45	1.40	1.30	1.25
Monocalcium phosphate (21% P)	0.30	0.20	---	---
Salt	0.40	0.40	0.40	0.40
L-Lys HCl	0.48	0.45	0.43	0.43
DL- Met	0.02	---	---	---
ThrPro	0.11	0.10	0.08	0.08
L-Trp	0.03	0.03	0.03	0.04
Phytase[3]	0.05	0.05	0.03	0.02
VTM premix[4]	0.20	0.20	0.20	0.20
Total	100	100	100	100
Calculated analysis				
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	63	64	65
Trp:Lys	18.4	18.1	18	18.3
Val:Lys	71	73	76	77
Lys:NE, g/Mcal	4.62	3.82	3.26	3.05
NE, kcal/lb	1,082	1,100	1,116	1,123
CP, %	20.40	17.90	16.10	15.20
Ca, %	0.65	0.60	0.51	0.49
STTD P, %	0.43	0.39	0.33	0.31

[1] Phases 1, 2, 3, and 4 were fed from 50 to 110, 110 to 165, 165 to 220, and 220 lb to marketing, respectively.
[2] DDGS = dried distiller's grains with solubles.
[3] Optiphos 2500 (Huvepharma Inc. Peachtree City, GA) provided 389.6 units of phytase FTY/lb of diet with an assumed release of 0.12% available P.
[4] Treatments formed by including the VTM that contains Zinc hydroxychloride (IntelliBond Z, Micronutrients USA, LLC, Indianapolis, IN), Zinc sulfate, or ZnO to provide 100 ppm Zn with the same source and concentrations of all other added minerals and vitamin. The VTM provided 150 ppm Cu from Intellibond C and 30 ppm Mn from Intellibond M.

Table 2. Effects of zinc source on finishing pig performance[1,2]

Item[3]	Zn Hydroxychloride[4]	$ZnSO_4$	ZnO	SEM	P =
BW, lb					
Initial	48.2	48.1	48.2	1.70	0.919
End period 1	116.2	116.5	117.5	1.46	0.327
End period 2	201.8	200.8	203.1	1.54	0.111
First marketing event					
Marketed pigs	284.4	282.8	283.8	2.12	0.810
All pigs	262.5	260.0	261.9	1.86	0.239
Final marketing event	304.6	301.7	301.9	2.31	0.218
Average market weight[5]	299.9	297.1	296.9	2.01	0.102
Period 1[6]					
ADG, lb	1.57[b]	1.59[ab]	1.62[a]	0.019	0.024
ADFI, lb	3.33	3.29	3.31	0.048	0.427
F/G	2.12[a]	2.06[b]	2.04[b]	0.014	0.001
Period 2[7]					
ADG, lb	2.01	1.98	2.01	0.030	0.194
ADFI, lb	5.31	5.25	5.35	0.074	0.106
F/G	2.65	2.66	2.67	0.017	0.467
Period 3[8]					
ADG, lb	2.25[a]	2.21[ab]	2.17[b]	0.034	0.003
ADFI, lb	7.61	7.51	7.48	0.059	0.129
F/G	3.39[b]	3.41[ab]	3.48[a]	0.036	0.005
Overall					
ADG, lb	1.94	1.92	1.93	0.016	0.199
ADFI, lb	5.38	5.33	5.36	0.065	0.309
F/G	2.77	2.77	2.78	0.014	0.556
Removals, %	7.6	6.1	5.4	0.94	0.100
Mortality, %	0.6	0.6	0.6	0.27	0.700
Total removals, %	8.3	6.9	5.9	0.99	0.100

continued

Table 2. Effects of zinc source on finishing pig performance[1,2]

Item[3]	Zn Hydroxychloride[4]	$ZnSO_4$	ZnO	SEM	*P* =
Coefficient of variation, %[9]					
Allotment	17.9	17.9	17.9	0.69	0.999
First marketing event[10]					
Marketed pigs[11]	5.4	5.2	5.7	0.34	0.538
Remaining pigs[12]	10.2	10.5	10.4	0.42	0.844
All pigs	11.6	12.0	11.8	0.44	0.793
Final marketing event	8.9	9.4	9.5	0.34	0.433
All marketed pigs[13]	8.7	8.8	9.1	0.24	0.533

[1]A total of 3,159 pigs (PIC 337 × 1050; initially 48.2 ± 1.70 lb) were utilized in a 146-d growth trial. with 27 pigs per pen and 39 replications per treatment across three barns.
[2]Zinc was included in the diet at 100 ppm for each of the dietary treatments.
[3]BW=body weight; ADG = average daily gain; ADFI= average daily feed intake; F/G= feed-to-gain ratio.
[4] Intellibond Z (Zn hydroxychloride, Micronutrients, Indianapolis, IN).
[5] Average marketing weight = (first marketing weight + final marketing weight)/total pigs marketed
[6]Period 1 was from day 0 to 55 for barn one, day 0 to 41 for barn two, and day 0 to 32 for barn three.
[7]Period 2 was day 55 to 98 for barn one, day 41 to 83 for barn two, and day 32 to 74 for barn three.
[8]Period 3 was day 98 to 146 for barn one, day 83 to 130 for barn two, and day 74 to 124 for barn three.
[9]Within pen Coefficient of Variation = (SD of individual weights / mean of individual weights) × 100.
[10]First marketing event was on day 119 for barn one, day 112 for barn two, and day 102 for barn three.
[11]The six heaviest pigs were selected, individually weighed, tattooed with a pen identification number, and transported to a USDA inspected packing plant where carcass data were collected.
[12]The remaining pigs that were not removed during the first marketing event.
[13]All marketed pigs CV includes the CV for the marketed pigs at the first marketing and the CV of all pigs marketed at the final marketing event.

Table 3. Effect of zinc source on carcass characteristics[1]

Item	Zn Hydroxychloride[2]	$ZnSO_4$	ZnO	SEM	*P* =
HCW, lb[3]					
First marketing[4]	212.9	211.5	211.8	1.69	0.673
Final marketing	222.2	221.0	220.8	1.56	0.429
Overall	219.9	218.7	218.5	1.36	0.305
Yield, %					
First marketing	74.7	74.7	74.7	0.27	0.986
Final marketing	72.9	73.2	73.3	0.19	0.185
Overall	73.5	73.4	73.6	0.19	0.504
Loin depth, in[5]					
First marketing	2.49	2.47	2.48	0.020	0.797
Final marketing	2.65	2.64	2.65	0.016	0.579
Overall	2.62	2.60	2.61	0.030	0.486
Backfat, in[5]					
First marketing	0.65	0.65	0.64	0.012	0.593
Loadout	0.64	0.64	0.63	0.007	0.331
Overall	0.64	0.64	0.63	0.017	0.437
Lean, %[5]					
First marketing	56.4	56.5	56.6	0.20	0.772
Final marketing	57.1	57.0	57.2	0.13	0.334
Overall	56.9	56.9	57.1	0.31	0.510
Coefficient of variation, %[6]					
First marketing	6.1	5.8	6.4	0.40	0.547
Final marketing	8.9	9.1	9.3	0.31	0.665
All carcasses	8.8	8.8	9.0	2.80	0.849

[1]A total of 3,159 pigs (PIC 337 × 1050; initially 48.2 ± 1.70 lb) were utilized in a 146-d growth trial. with 27 pigs per pen and 39 replications per treatment in three barns.
[2] Intellibond Z (Zn hydroxychloride, Micronutrients, Indianapolis, IN)
[3]HCW = hot carcass weight.
[4]At the first marketing event the six heaviest pigs per pen were selected, individually weighed, tattooed with a pen identification number, and transported to a USDA inspected packing plant where carcass data were collected. At final marketing the remaining pigs in the pen followed the same procedure.
[5]Adjusted using HCW as a covariate.
[6]Coefficient of Variation = (SD of individual HCW / mean of individual HCW) × 100.

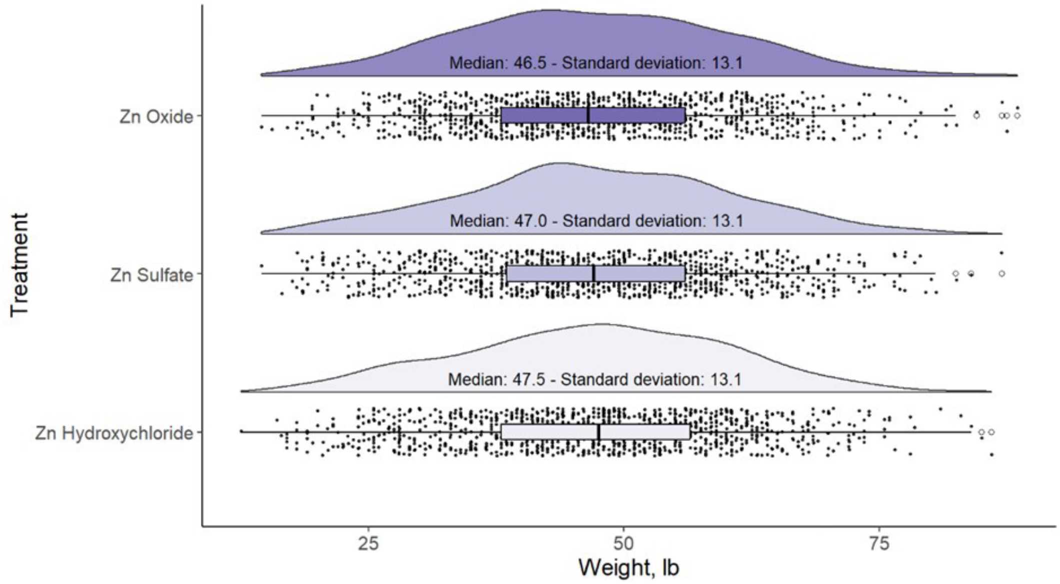

Figure 1. At allotment, all pigs were individually weighed to determine pen BW variability.

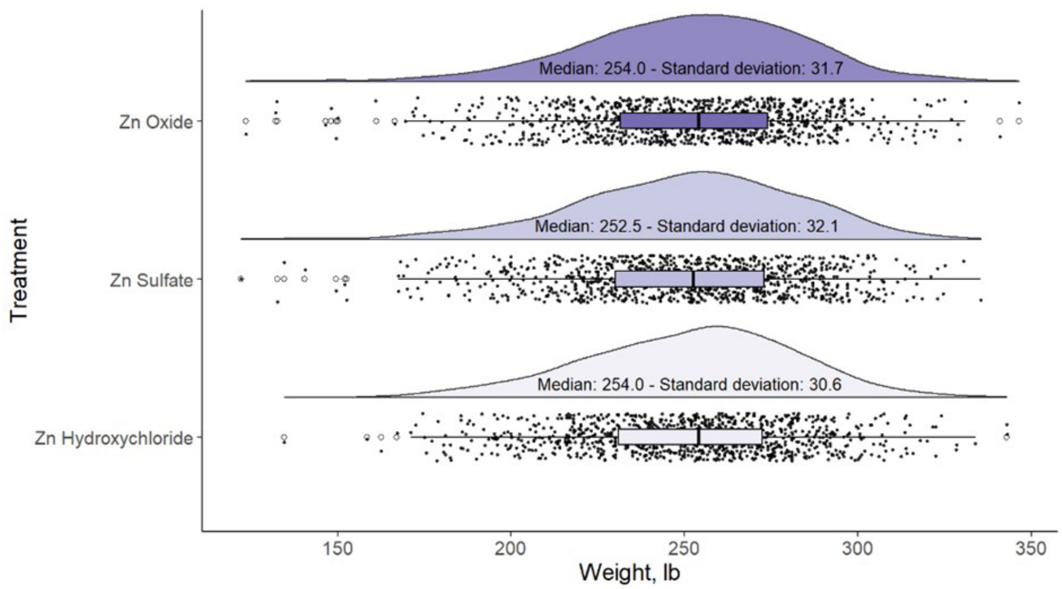

Figure 2. At first marketing, all pigs were individually weighed to determine pen BW variability.

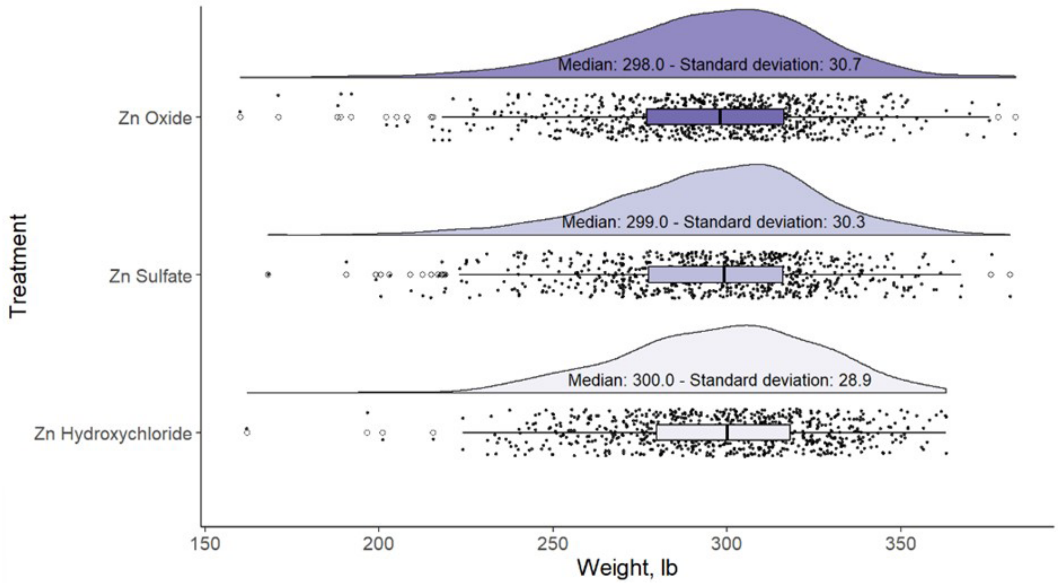

Figure 3. At final marketing, all remaining pigs were individually weighed to determine pen BW variability.

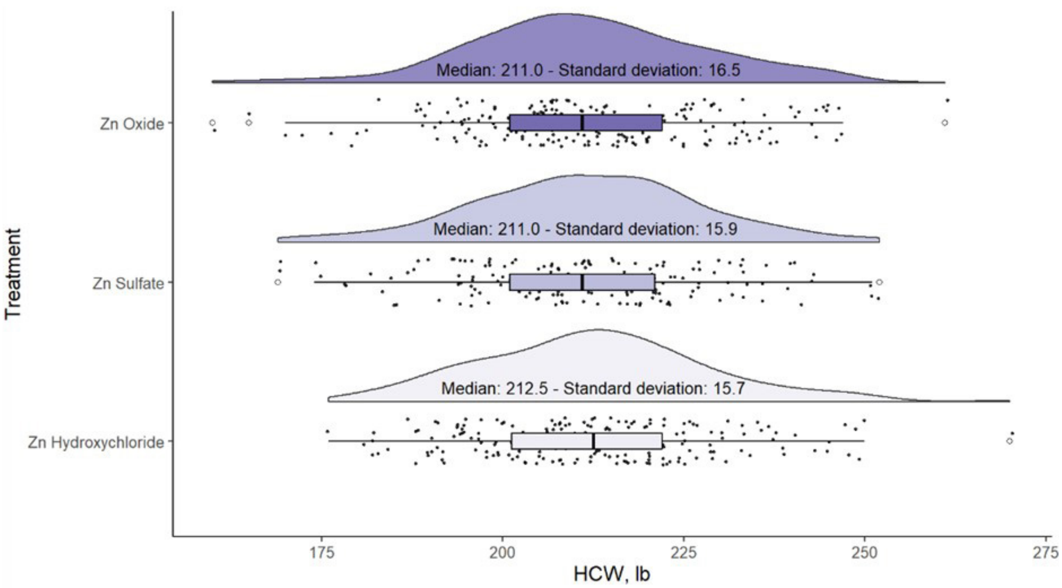

Figure 4. HCW distribution by treatment at first marketing event.

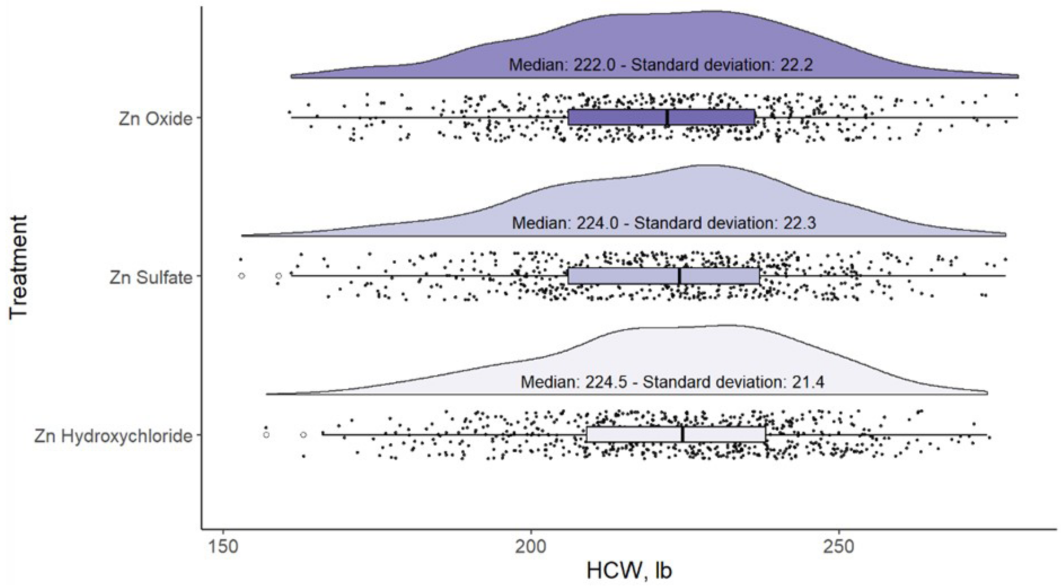

Figure 5. HCW distribution by treatment at the final marketing event.

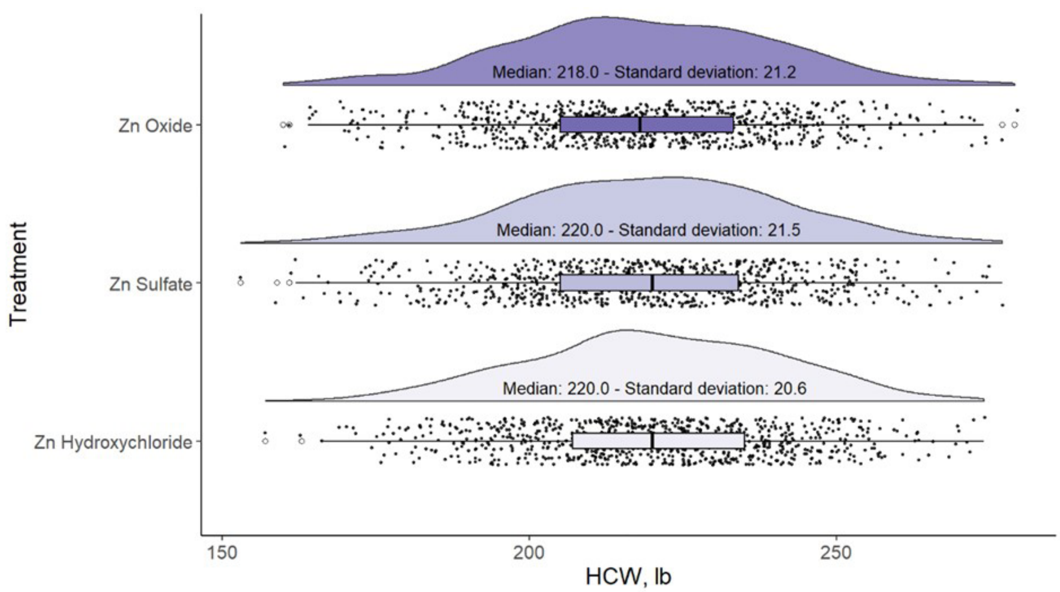

Figure 6. HCW distribution by treatment across both first and final marketing events.