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Effect of Increasing Manganese from Manganese Hydroxychloride on Growth Performance, Carcass Characteristics, and Economics of Grow-Finish Pigs

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Effect of Increasing Manganese from Manganese Hydroxychloride on Growth Performance, Carcass Characteristics, and Economics of Grow-Finish Pigs

Abstract

A total of 2,025 grow-finish pigs (337 × 1050, PIC; initially 88.0 ± 2.68 lb) were used in a 95-d trial to determine the impact on growth by increasing Mn from Mn hydroxychloride compared to a control diet containing $MnSO_4$. Pigs were housed in mixed gender pens with 27 pigs per pen and 15 pens per treatment. The treatments were structured as a completely randomized design and consisted of a control diet containing 30 ppm of Mn from $MnSO_4$ (Eurochem, Veracruz, Mexico) or 15, 30, 45, or 65 ppm of Mn from Mn hydroxychloride (IBM; IntelliBond M, Micronutrients USA, LLC, Indianapolis, IN). Experimental diets were corn-soybean meal-DDGS-based and were formulated with a premix without Mn and containing 150 ppm of Cu from IntelliBond C (Micronutrients, Indianapolis, IN) and 100 ppm of Zn from IntelliBond Z (Micronutrients, Indianapolis, IN). Diets were fed in four phases from 88 to 110, 110 to 165, 165 to 220, and 220 to 294 lb. In the grower period (d 0 to 43), F/G was improved (quadratic, $P = 0.036$) when IBM level increased up to 45 ppm but then worsened thereafter. Overall (d 0 to 95), there was no evidence of difference for any growth or carcass response criteria when comparing the Mn sources at 30 ppm of Mn or when increasing the level of IBM in diets. In conclusion, no differences were observed in this trial with the exception of an improvement in F/G observed in the grower phase as IBM increased up to 45 ppm.

Keywords

finishing pigs, manganese, growth performance, carcass characteristics

Cover Page Footnote

The authors appreciate Micronutrients USA, LLC, 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.

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Effect of Increasing Manganese from Manganese Hydroxychloride on Growth Performance, Carcass Characteristics, and Economics of Grow-Finish Pigs[1]

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Summary

A total of 2,025 grow-finish pigs (337 × 1050, PIC; initially 88.0 ± 2.68 lb) were used in a 95-d trial to determine the impact on growth by increasing Mn from Mn hydroxychloride compared to a control diet containing $MnSO_4$. Pigs were housed in mixed gender pens with 27 pigs per pen and 15 pens per treatment. The treatments were structured as a completely randomized design and consisted of a control diet containing 30 ppm of Mn from $MnSO_4$ (Eurochem, Veracruz, Mexico) or 15, 30, 45, or 65 ppm of Mn from Mn hydroxychloride (IBM; IntelliBond M, Micronutrients USA, LLC, Indianapolis, IN). Experimental diets were corn-soybean meal-DDGS-based and were formulated with a premix without Mn and containing 150 ppm of Cu from IntelliBond C (Micronutrients, Indianapolis, IN) and 100 ppm of Zn from IntelliBond Z (Micronutrients, Indianapolis, IN). Diets were fed in four phases from 88 to 110, 110 to 165, 165 to 220, and 220 to 294 lb. In the grower period (d 0 to 43), F/G was improved (quadratic, $P = 0.036$) when IBM level increased up to 45 ppm but then worsened thereafter. Overall (d 0 to 95), there was no evidence of difference for any growth or carcass response criteria when comparing the Mn sources at 30 ppm of Mn or when increasing the level of IBM in diets. In conclusion, no differences were observed in this trial with the exception of an improvement in F/G observed in the grower phase as IBM increased up to 45 ppm.

Introduction

Manganese (Mn) is a trace mineral and functions as a component of several enzymes involved in carbohydrate, lipid, and protein metabolism. Manganese is a constituent of mitochondrial superoxide dismutase and is involved in the synthesis of chondroitin sulfate, a component in the organic matrix of bone. The dietary requirements of Mn are not well established. Long-term feeding of a low Mn (0.5 ppm) diet results in abnormal

[1] The authors appreciate Micronutrients USA, LLC, 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.

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skeletal growth and increased fat deposition in growing-finishing pigs. In contrast, when feeding 500 ppm of Mn in growing pigs, a reduction in the growth rates have been observed.[3] A survey by Flohr et al.[4] indicated that many swine nutritionists in the US feed Mn at 5 to 10 times the NRC[5] requirement estimates (2 to 4 ppm) for growing-finishing pigs.

Trace minerals can be supplemented in animal diets in many forms including inorganic salts and organic chelates or complexes. Hydroxy forms of minerals are inorganic but may have greater bioavailability compared to the normal sulfate or oxide forms commonly used. Kerkaert et al.[6] evaluated increasing levels of dietary Mn provided at 8, 16, or 32 ppm from Mn hydroxychloride or manganese sulfate on growth performance of growing-finishing pigs and did not find differences for ADG, ADFI, and F/G. Moreover, Sawyer et al.[7] did not observe evidence for differences in carcass characteristics when 0 or 350 ppm of Mn from manganese sulfate or a complexed organic manganese were fed.

Consequently, additional research could be beneficial to help swine nutritionists understand how source and level of Mn influences performance. Therefore, the objective of this study was to test the effects of increasing levels of Mn from Mn-hydroxychloride compared to a diet formulated to contain commercial levels of Mn from $MnSO_4$ on the performance, carcass characteristics, and economics of growing-finishing pigs.

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

Two groups of pigs (total 2,025 pigs; 337 × 1050, PIC; initially 88.0 ± 2.68 lb) were used in a 95-d growth trial. Pigs were housed in mixed gender pens with 27 pigs per pen and 15 pens per treatment. The treatments were structured as a completely randomized

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[3] Grummer, R. H., O. G. Bentley, P. H. Phillips, and G. Bohstedt. 1950. The role of manganese in growth, reproduction, and lactation of swine. J. Anim. Sci. 37:948-956. doi: 10.2527/jas1950.92170x.

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[7] Sawyer, J. T., Tittor, A.W., Apple, J. K., Morgan, J. B., Maxwell, C. V., Rakes, L. K. and Fakler, T. M. 2007. Effects of supplemental manganese on performance of growing finishing pigs and pork quality during retail display. J. Anim. Sci. 2007. 85:1046–1053. doi:10.2527/jas.2006-262.

design and consisted of a control diet containing 30 ppm of Mn from $MnSO_4$ (Eurochem, Veracruz, Mexico) or 15, 30, 45, or 65 ppm of Mn from Mn hydroxychloride (IBM; IntelliBond M, Micronutrients USA, LLC, 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[5] requirement estimates for growing-finishing pigs for their respective weight ranges (Table 1). Diets were fed in meal form with phase 1 fed from 88 to 110 lb, phase 2 from 110 to 165 lb, phase 3 from 165 to 220 lb, and phase 4 from 220 to 294 lb. Experimental diets were corn-soybean meal-DDGS-based and were formulated with premix without Mn and containing 150 ppm of Cu from IntelliBond C (Micronutrients, Indianapolis, IN) and 100 ppm of Zn from IntelliBond Z (Micronutrients, Indianapolis, IN). Manganese sources were added to the diet by hand-made premixes, which were added in place of corn.

Pigs were weighed approximately every 14 days to determine ADG, ADFI, and F/G. On d 78, all the pigs were individually weighed to determine body weight variation. The same day, the three heaviest pigs in each pen were selected and marketed, but not included in the final pen carcass data. 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 a U.S. Department of Agriculture-inspected packing plant (JBS Swift, Worthington, MN) 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 pen average final live weight obtained 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) with pen considered the experimental unit, and treatment as fixed effect. Contrast coefficients were used to evaluate linear and quadratic effects of Mn level within IBM and pairwise comparison of Mn sources at 30 ppm. Pig individual weight data on d 78 were used to calculate within-pen coefficient of variation which was analyzed in a similar manner to growth data. Additionally, individual weight 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

As expected, chemical analysis of complete diets indicated that Mn increased in the dietary treatments as planned (Table 2).

In the grower period (d 0 to 43), F/G was improved (quadratic, $P = 0.036$) when IBM level increased up to 45 ppm but then worsened thereafter (Table 3). There was no evidence for difference ($P \geq 0.10$) from increasing IBM for any other growth response criteria for the finishing phase (d 43 to 95) and overall (d 0 to 95). When comparing Mn sources at 30 ppm added Mn, there was no evidence of differences ($P \geq 0.10$) in growth in either period or overall. For pig body weight variability at d 78, there was no evidence of difference ($P \geq 0.10$) between treatments (Figure 1).

For carcass characteristics, no evidence of difference ($P \geq 0.10$) was observed for any parameter when comparing both Mn sources included in diets at 30 ppm or from increasing the level of IBM.

For economics, there were only trends for feed cost per lb of gain in low (quadratic, $P = 0.086$) and high (quadratic, $P = 0.092$) price scenarios where pigs fed 45 ppm of IBM had the lowest feed cost per lb of gain.

In conclusion, these data suggest minimal differences in grow-finish pig performance, carcass traits, and pig weight variability when comparing $MnSO_4$ or IBM included at 30 ppm or from increasing levels of IBM in growing and finishing diets. However, the improvement in F/G observed during the grower period when IBM was increased up to 45 ppm warrants further investigation.

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

Item	Phase 1	Phase 2	Phase 3	Phase 4
Ingredients, %				
Corn	58.41	66.40	72.29	80.38
Soybean meal, 46.5% CP	26.75	19.06	13.41	15.46
DDGS	10.00	10.00	10.00	---
Corn oil	1.50	1.50	1.50	1.50
Limestone, ground	1.23	1.10	1.10	0.90
Monocalcium P, 21% P	1.10	0.95	0.70	0.80
Salt	0.35	0.35	0.35	0.35
L-Lys-HCl	0.37	0.38	0.39	0.30
DL-Met	0.06	0.03	0.01	0.04
L-Trp	0.02	0.02	0.03	0.03
Thr[2]	0.10	0.09	0.10	0.12
Vitamin-trace mineral premix[3]	0.10	0.10	0.10	0.10
Phytase[4]	0.02	0.02	0.02	0.02
Mn source[5]	+/-	+/-	+/-	+/-
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.15	0.97	0.84	0.79
Ile:Lys	63	61	60	61
Leu:Lys	140	148	155	147
Met:Lys	31	29	29	32
Met and Cys:Lys	55	55	56	59
Thr:Lys	62	62	64	65
Trp:Lys	19	19	19	20
Val:Lys	70	70	70	70
His:Lys	42	42	42	43
Total Lys, %	1.31	1.11	0.96	0.89
NE, kcal/lb	1,129	1,153	1,171	1,179
SID Lys:NE, g/Mcal	4.62	3.82	3.25	3.04
CP, %	20.9	17.8	15.6	14.4
Ca, %	0.73	0.63	0.57	0.53
STTD P, %	0.52	0.47	0.41	0.39

[1]Phases 1, 2, 3, and 4 were fed from approximately 88 to 110 lb, 110 to 165 lb, 165 to 220 lb, and 220 to market, respectively.
[2]Thr Pro; CJ America Bio, Downers Grove, IL.
[3]Vitamin trace mineral premix without Mn and containing 150 ppm of Cu from IntelliBond C (Micronutrients, Indianapolis, IN) and 100 ppm of Zn from IntelliBond Z (Micronutrients, Indianapolis, IN).
[4]Optiphos (Huevepharma, Sofia, Bulgaria) was included at 500 FTU/kg providing an estimated release of 0.10% STTD P for all the diets.
[5]Manganese sources were hand-made and added to contribute the desired $MnSO_4$ or IBM (Micronutrients, Indianapolis, IN), and Mn level (15, 30, 45, or 65 ppm) to the appropriate treatment.

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

	$MnSO_4$, ppm	Mn hydroxychloride, ppm			
Calculated Mn	30	15	30	45	65
Analyzed Mn	46	32	41	57	65

[1]Values represent means from 20 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).

Table 3. Effect of increasing Mn hydroxychloride on grow-finish pigs growth performance, carcass characteristics, and economics[1]

	$MnSO_4$,[2] ppm	Mn Hydroxychloride,[3] ppm					*P* =[4]		
Item	30	15	30	45	65	SEM	Source	Linear	Quadratic
BW, lb									
Initial	88.0	88.0	87.9	88.0	87.9	2.69	0.988	0.977	0.994
Grower	176.4	176.2	177.2	176.5	177.3	6.15	0.839	0.828	0.984
Final	293.1	293.9	294.0	291.5	294.0	8.52	0.832	0.857	0.671
Grower (d 0–43)									
ADG, lb	2.05	2.04	2.05	2.05	2.06	0.093	0.949	0.468	0.940
ADFI, lb	4.64	4.69	4.69	4.58	4.77	0.201	0.627	0.693	0.207
F/G	2.26	2.30	2.29	2.23	2.31	0.022	0.446	0.960	0.036
Finisher (d 43–95)									
ADG, lb	2.29	2.27	2.29	2.25	2.25	0.040	0.901	0.430	0.676
ADFI, lb	6.91	6.90	6.94	6.79	6.88	0.105	0.821	0.579	0.782
F/G	3.02	3.05	3.04	3.02	3.06	0.082	0.619	0.874	0.338
Overall									
ADG, lb	2.18	2.16	2.18	2.16	2.16	0.029	0.930	0.876	0.689
ADFI, lb	5.86	5.86	5.87	5.76	5.89	0.150	0.753	0.874	0.467
F/G	2.69	2.71	2.70	2.67	2.72	0.037	0.560	0.940	0.116
Individual weights (d 78)[5]									
CV, %	10.6	10.7	11.5	10.6	11.3	0.92	0.186	0.634	0.927
Carcass characteristics									
HCW, lb	218.1	219.1	218.0	215.2	218.4	5.73	0.985	0.566	0.283
Carcass yield, %	73.6	74.3	74.2	73.6	73.8	0.50	0.407	0.368	0.746
Backfat, in.[6]	0.70	0.71	0.71	0.70	0.70	0.038	0.551	0.424	0.706
Loin depth, in.[6]	2.55	2.56	2.56	2.59	2.58	0.051	0.514	0.411	0.654
Lean, %[6]	55.8	55.6	55.7	55.9	55.8	0.45	0.764	0.284	0.605
Mortality and removals, %	3.21	6.17	5.68	3.46	6.67	6.441	0.746	0.955	0.739

continued

Table 3. Effect of increasing Mn hydroxychloride on grow-finish pigs growth performance, carcass characteristics, and economics[1]

	$MnSO_4$,[2] ppm	Mn Hydroxychloride,[3] ppm					*P* =[4]		
Item	**30**	**15**	**30**	**45**	**65**	**SEM**	**Source**	**Linear**	**Quadratic**
Economics, $/pig marketed									
Low ingredients prices[7]									
Feed cost	43.52	43.17	43.42	42.87	43.17	1.659	0.895	0.815	0.958
Feed cost/lb gain[8]	0.217	0.219	0.218	0.215	0.221	0.003	0.472	0.726	0.086
Revenue[9]	88.72	87.89	88.52	87.82	86.63	2.532	0.885	0.306	0.354
IOFC[10]	45.21	44.73	45.12	44.96	43.48	1.088	0.943	0.299	0.267
High ingredients prices[11]									
Feed cost	74.60	73.97	74.37	73.42	73.85	2.833	0.862	0.752	0.986
Feed cost/lb gain	0.371	0.375	0.374	0.369	0.377	0.005	0.506	0.826	0.092
Revenue	130.13	128.91	129.83	128.80	127.10	3.713	0.885	0.306	0.354
IOFC	55.55	54.96	55.49	55.40	53.23	1.348	0.970	0.342	0.278

[1]A total of 2,025 pigs (initial BW of 88 lb) were used in two groups with 27 pigs per pen and 15 replicates per treatment.
[2] Erachem, Veracruz, Mexico.
[3] IntelliBond M (IBM), Micronutrients USA, Indianapolis, IN.
[4]Contrast coefficients were used to compare the effect of manganese sources at 30 ppm level and linear and quadratic effect within the increasing levels of IntelliBond M.
[5]At the first marketing event, a total of 1,937 pigs were weighted individually to calculate variation of final BW. Coefficient of variation (CV) of individual pig weight was calculated for each pen and analyzed to determine the effect of dietary treatment with pen as the experimental unit.
[6]Adjusted using HCW as covariate.
[7] Market price for the revenue calculation: corn = $3.00/bushel ($107.14/ton); soybean meal = $300/ton; DDGS = $140/ton; L-Lys HCl = $0.65/lb; DL-Met = $1.70/lb; ThreoPro = $0.80/lb; L-Trp = $3.00; L-Val = $2.50/lb; $MnSO_4$ = $0.675/lb; IBM = $2.15/lb; Optiphos Plus 2500G = $0.947/lb.
[8]Feed cost/lb gain = total feed cost per pig ÷ total gain per pig.
[9]Revenue = (total gain × carcass yield) × carcass price.
[10]Income over feed cost = revenue – feed cost.
[11] Market price for the revenue calculation: corn = $6.00/bushel ($214.29/ton); soybean meal = $400/ton; DDGS = $240/ton; L-Lys HCl = $0.80/lb; DL-Met = $2.50/lb; ThreoPro = $0.80/lb; L-Trp = $5.00; L-Val = $4.00/lb; $MnSO_4$ = $0.675/lb; IBM = $2.15/lb; Optiphos Plus 2500G = $0.947/lb.

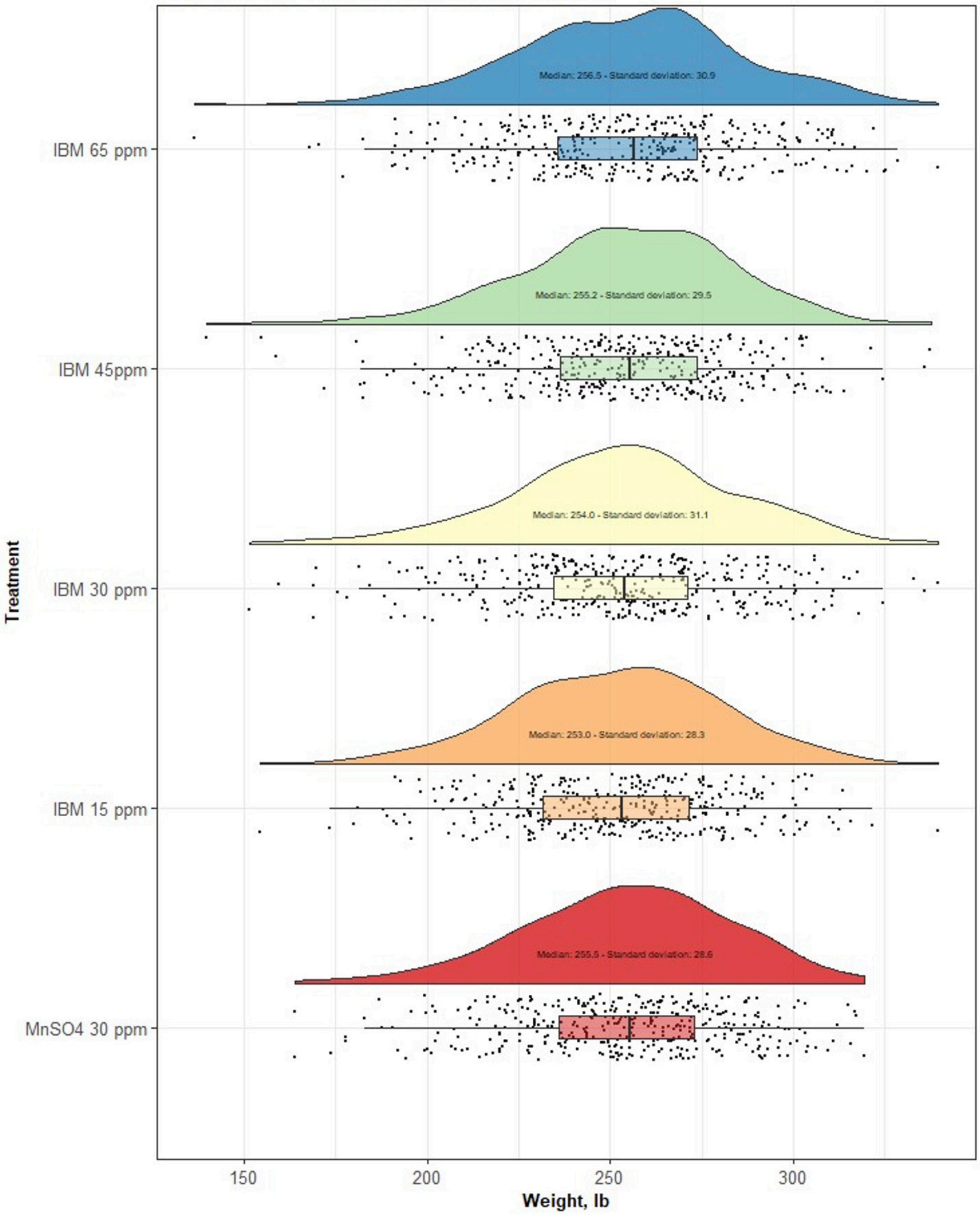

Figure 1. Previous to the first marketing event (d 78), all pigs (n = 1,937) were individually weighed to determine average pen BW variability. There were no differences (*P* > 0.10) in the CV between the five treatments. In addition, the median and SD show that treatments had a similar population distribution.
$MnSO_4$: Median = 255.5 lb and SD = 28.6;
IBM 15 ppm: Median = 253.0 lb and SD= 28.3;
IBM 30 ppm: Median = 254.0 lb and SD = 31.1;
IBM 45 ppm: Median = 255.5 lb and SD = 29.5; and
IBM 65 ppm: Median = 256.5 and SD = 30.9.