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Effects of Bovine Plasma and Pharmacological Zinc Level on Nursery Pig Growth Performance and Fecal Characteristics

Abstract

A total of 300 pigs (241 × 600, DNA; initially 12.9 lb) were used in a 38-d trial to evaluate the effect of Zn level and bovine plasma in nursery pig diets. At the time of placement, pens of pigs were weighed and allotted to 1 of 4 dietary treatments in a randomized complete block design with barn as the blocking factor. There was a total of 60 pens with 5 pigs per pen and 15 replicates per dietary treatment. The treatments were arranged in a 2 × 2 factorial with main effects of Zn level (high and low) and spray-dried bovine plasma inclusion (with or without; APC Inc., Ankeny, IA). Diets with pharmacological levels of Zn had 3,000 and 2,000 ppm of Zn in phase 1 and 2 diets, respectively. Diets with low level of Zn had 110 ppm of Zn in phase 1 and 2 diets. Bovine plasma replaced a portion of a fermented vegetable protein source (MEpro, Prairie Aquatech, Brookings, SD) in diet formulation with bovine plasma included at 5% and 2% in the phase 1 and 2 diets, respectively. Treatment diets were fed in 2 phases (phase 1: d 0 to 9; phase 2: d 9 to 24) with a common diet (110 ppm of Zn without plasma) fed from d 24 to 38. Fecal samples and scores were collected on d 9 and 24 for determination of fecal dry matter. There was no evidence of Zn × plasma interactions ($P > 0.10$) throughout the trial for any growth criteria. From d 0 to 9, pigs fed bovine plasma tended to have improved ADG ($P = 0.066$) and had improved ($P \leq 0.035$) ADFI and BW, while pigs fed high Zn had improved ($P \leq 0.018$) ADG, BW and F/G. From d 9 to 24, pig fed high Zn had improved ($P < 0.001$) ADG and ADFI. During the common period (d 24 to 38), pigs previously fed high Zn had reduced ADFI ($P = 0.046$). Overall (d 0 to 38), pigs fed high Zn had improved ($P \leq 0.029$) BW, ADG, and F/G. For fecal DM, there was a tendency of plasma × Zn interaction ($P = 0.067$) where pigs fed high Zn had increased ($P < 0.05$) fecal DM compared to pigs fed low Zn when bovine plasma was added, while this Zn effect was not significant ($P > 0.05$) when fed in diets without plasma. For fecal score, pigs fed high Zn had higher ($P < 0.001$) frequency of firmer feces. In summary, bovine plasma improved growth performance during the first week after weaning. Feeding pharmacological levels of Zn improved growth performance when fed and overall, as well as improved fecal DM and fecal firmness measured by observational scoring.

Keywords

fecal characteristics, growth, nursery pigs, plasma, zinc

Authors

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Zhong-Xing Rao, Mike D. Tokach, Jason C. Woodworth, Joel M. DeRouchey, Robert D. Goodband, Joy M. Campbell,[1] and Jordan T. Gebhardt[2]

Summary

A total of 300 pigs (241 × 600, DNA; initially 12.9 lb) were used in a 38-d trial to evaluate the effect of Zn level and bovine plasma in nursery pig diets. At the time of placement, pens of pigs were weighed and allotted to 1 of 4 dietary treatments in a randomized complete block design with barn as the blocking factor. There was a total of 60 pens with 5 pigs per pen and 15 replicates per dietary treatment. The treatments were arranged in a 2 × 2 factorial with main effects of Zn level (high and low) and spray-dried bovine plasma inclusion (with or without; APC Inc., Ankeny, IA). Diets with pharmacological levels of Zn had 3,000 and 2,000 ppm of Zn in phase 1 and 2 diets, respectively. Diets with low level of Zn had 110 ppm of Zn in phase 1 and 2 diets. Bovine plasma replaced a portion of a fermented vegetable protein source (MEpro, Prairie Aquatech, Brookings, SD) in diet formulation with bovine plasma included at 5% and 2% in the phase 1 and 2 diets, respectively. Treatment diets were fed in 2 phases (phase 1: d 0 to 9; phase 2: d 9 to 24) with a common diet (110 ppm of Zn without plasma) fed from d 24 to 38. Fecal samples and scores were collected on d 9 and 24 for determination of fecal dry matter. There was no evidence of Zn × plasma interactions ($P > 0.10$) throughout the trial for any growth criteria. From d 0 to 9, pigs fed bovine plasma tended to have improved ADG ($P = 0.066$) and had improved ($P \leq 0.035$) ADFI and BW, while pigs fed high Zn had improved ($P \leq 0.018$) ADG, BW and F/G. From d 9 to 24, pig fed high Zn had improved ($P < 0.001$) ADG and ADFI. During the common period (d 24 to 38), pigs previously fed high Zn had reduced ADFI ($P = 0.046$). Overall (d 0 to 38), pigs fed high Zn had improved ($P \leq 0.029$) BW, ADG, and F/G. For fecal DM, there was a tendency of plasma × Zn interaction ($P = 0.067$) where pigs fed high Zn had increased ($P < 0.05$) fecal DM compared to pigs fed low Zn when bovine plasma was added, while this Zn effect was not significant ($P > 0.05$) when fed in diets without plasma. For fecal score, pigs fed high Zn had higher ($P < 0.001$) frequency of firmer feces. In summary, bovine plasma improved growth performance during the first week after weaning. Feeding pharmacological levels of Zn improved

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growth performance when fed and overall, as well as improved fecal DM and fecal firmness measured by observational scoring.

Introduction

Pharmacological levels of Zn between 2,000 to 3,000 ppm in initial nursery diets reduce post-weaning diarrhea and improve growth performance.[3] However, high Zn in manure causes environmental and antimicrobial resistance concerns. Spray-dried animal plasma is often used in swine post-weaning diets to improve growth performance and gastrointestinal development. Spray-dried animal plasma contains protein and minerals. The protein fraction is largely comprised of albumins and globulins (e.g., IgG) which have biological functions in animals, such as maintaining the buffering capacity of the blood and immune function.[4] Including animal plasma in feed has been found to improve the intestinal health and feed intake due to improved diet palatability.[4] These benefits may allow for improved animal health and thus reduce the need to include pharmacological levels of Zn in starter nursery diets. Therefore, the objective of this study was to determine the effects of including spray-dried bovine plasma with or without pharmaceutical level of Zn in phase 1 and 2 nursery diets on growth performance, fecal score, and fecal dry matter during the post-weaning period.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Each pen (4 × 4 ft) was equipped with a 4-hole dry self-feeder, and a nipple waterer to provide *ad libitum* access to feed and water.

Animals and diets

A total of 300 pigs (241 × 600, DNA; initially 12.9 lb) were weaned at approximately 21 d of age and placed in pens of 5 pigs each based on initial BW and gender. Pens of pigs were then randomly allotted to treatment in a randomized complete block design with barn as the blocking factor with 15 replicate pens per treatment. The treatments were structured as a randomized complete block design and arranged in a 2 × 2 factorial with main effects of Zn level (high or low) and bovine plasma inclusion (with or without; APC Inc., Ankeny, IA). Treatment diets were fed in 2 phases (phase 1: d 0 to 9; phase 2: d 9 to 24; Table 1) with a common diet (110 ppm of Zn without plasma) fed from d 24 to 38. High Zn diets had 3,000 and 2,000 ppm of Zn in phase 1 and 2, respectively. Low Zn diets had 110 ppm of Zn in phase 1 and 2 diets. A fermented vegetable protein (MEpro, Prairie Aquatech, Brookings, SD) was included in phase 1 and 2 diets at 7 and 2%, respectively. In order to maintain a constant soybean meal level in all diets, bovine plasma replaced the fermented vegetable protein on an equal lysine basis at 5 and 2% in the phase 1 and 2 diets, respectively. Nutrient loading values for the 2 protein sources were obtained from the manufacturers and used in diet formulation

[3] Shelton, N., M. Tokach, J. Nelssen, R. Goodband, S. Dritz, J. DeRouchey, and G. Hill. Effects of copper sulfate, tri-basic copper chloride, and zinc oxide on weanling pig performance. J Anim Sci. 2011 Aug;89(8):2440-51. doi: 10.2527/jas.2010-3432.
[4] Balan, P., M. Staincliffe, and P. Moughan. Effects of spray-dried animal plasma on the growth performance of weaned piglets—A review. J Anim Physiol Anim Nutr. 2021; 105: 699– 714. doi: 10.1111/jpn.13435.

while all other ingredient values were obtained from the NRC.[5] For phase 3, all pigs were fed a common corn and soybean meal-based diet for 14 d. Diets were fed in pellet form in phase 1, and meal form in phases 2 and 3. Pen weights and feed disappearance were measured on d 0, 9, 17, 24, 31, and 38 to determine ADG, ADFI, and F/G.

Fecal samples for the determination of fecal dry matter and scores were collected on d 9 and 24. Fecal samples were collected from the same three medium weight pigs from each pen. After collection, fecal samples were dried at 55°C (131°F) in a forced air oven for 48 h and the ratio of dried to wet fecal weight determined the fecal dry matter. Fecal scores were assigned to each pen by the same three observers. Fecal scores were assigned based on a 5-point scale, with 1 = watery feces; 2 = soft unformed feces; 3 = soft moist feces; 4 = firm formed feces; and 5 = hard feces.

Phase 1 and 2 basal diets were manufactured at Hubbard Feeds, Beloit, KS. The basal diets were mixed with remaining ingredients (e.g., AAs, specialty protein sources, ZnO) at the Kansas State University O.H. Kruse Feed Technology Innovation Center (Manhattan, KS) to make the 4 treatment diets. The phase 3 common diet was manufactured at Hubbard Feeds, Beloit, KS. All diets met or exceeded the NRC[5] nutrient requirement estimates. Diet samples were collected and thoroughly mixed within treatment before analysis for dry matter and crude protein (Kansas State University Swine Laboratory, Manhattan, KS).

Statistical analysis

Data were analyzed as a randomized complete block design for two-way ANOVA. Pen was considered the experimental unit. Barn was the blocking factor. Treatments were used as the fixed effect. Interactive and main effects of Zn level (high or low) and bovine plasma (with or without) were tested. For growth performance and fecal DM, data were analyzed using the lmer function from the lme4 package (R Core Team, 2019). Fecal dry matter and fecal score were analyzed as repeated measures representing multiple observations in each pen over time, and pens were included in the model as random intercepts to account for subsampling attributed to the multiple observations on each day. Plasma, Zn, day, and the associated interactions were considered fixed effects within the statistical model. For fecal score, data were analyzed as categorical outcomes using a generalized linear mixed model with a multinomial response distribution using a cumulative logit link function. Data were fit using the GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Inc., Cary, NC), and are summarized using the FREQ procedure and reported as percentage of observations within each fecal score category by treatment and day. For all growth and fecal data, Tukey adjustment was used for multiple comparisons. All results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Growth performance

There was no evidence of Zn × plasma interactions ($P > 0.10$) throughout the trial (d 0 to 38; Table 2).

[5] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

From d 0 to 9, pigs fed bovine plasma had improved d 9 BW ($P = 0.035$; Table 3), and ADFI ($P < 0.001$) and tended to have improved ADG ($P = 0.066$) compared to pigs fed diets without bovine plasma. Also, pigs fed high Zn had improved ($P \leq 0.018$) d 9 BW, ADG, and F/G compared to pigs fed low Zn diets.

From d 9 to 24, pig fed high Zn had improved ($P < 0.001$) d 24 BW, ADG, and ADFI. There was no evidence of difference ($P > 0.10$) in d 24 BW, ADG, ADFI, and F/G between pigs fed diets with or without bovine plasma.

During the overall treatment period (d 0 to 24), pigs fed high Zn had improved ($P \leq 0.009$) d 24 BW, ADG, ADFI, and F/G compared to pigs fed low Zn. There was no evidence of difference ($P > 0.10$) in d 24 BW, ADG, ADFI, and F/G between pigs fed diets with or without bovine plasma.

From d 24 to 38 when pigs were fed a common diet, pigs previously fed high Zn from d 0 to 24 had reduced ADFI ($P = 0.046$) compared to pigs fed low Zn diets. There was no evidence of difference ($P > 0.10$) in ADG, ADFI, and F/G between pigs previously fed diets with or without bovine plasma.

For the overall period (d 0 to 38), pigs fed high Zn from d 0 to 24 had improved ($P \leq 0.029$) final BW, ADG, and F/G compared to pigs fed low Zn. There was no evidence of difference ($P > 0.10$) in ADG, ADFI, and F/G between pigs fed diets with or without bovine plasma.

Fecal dry matter and fecal score

For fecal DM, there was no plasma × Zn × day interaction ($P = 0.829$; Table 4). There was a tendency for a plasma × Zn interaction ($P = 0.067$; Table 5) to be observed, where pigs fed high Zn had increased ($P < 0.05$) fecal DM compared to pigs fed low Zn when bovine plasma was added in the diets, while this Zn effect was not significant ($P > 0.05$) when fed in diets without plasma. Moreover, there was a significant Zn × day interaction ($P = 0.032$; Table 6) observed where pigs fed low Zn had increased ($P < 0.05$) fecal DM on d 24 compared to d 9, while fecal DM of pigs fed high Zn had no evidence of difference ($P > 0.05$) between d 9 and 24. Fecal DM of the high Zn diets was higher than those observed in low Zn diets for both days.

For fecal score (Figure 1), there was no evidence of plasma × Zn × day interaction; plasma × Zn interaction; plasma × day interaction; or plasma main effect ($P > 0.10$). There was a tendency for a Zn × day interaction ($P = 0.085$) to be observed where pigs fed low Zn had increased frequency of scores with firmer feces on d 24 compared to d 9, while pigs fed high Zn diets had similar fecal frequency on d 9 and 24. Pigs fed high Zn had higher ($P < 0.001$) frequency of scores with firmer feces.

In summary, pigs fed pharmacological levels of Zn had improved nursery performance whereas pigs fed bovine plasma had improved performance for the first 9 days post-weaning. Moreover, high Zn improved fecal characteristics, while bovine plasma had negative effects on fecal DM when fed in low Zn diets. The results of this study indicate that the benefits of pharmacological levels of zinc could not be replaced by bovine plasma alone.

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

	Phase 1				Phase 2				
	Without plasma		With plasma		Without plasma		With plasma		
Item	Low Zn	High Zn	Low Zn	High Zn	Low Zn	High Zn	Low Zn	High Zn	Phase 3
Ingredient, %									
Corn	41.38	40.98	42.19	41.79	54.14	53.88	54.48	54.22	67.82
Soybean meal (46.5% CP)	21.25	21.25	21.25	21.25	29.90	29.90	29.90	29.90	28.13
MEpro[2]	7.00	7.00	2.00	2.00	2.00	2.00	---	---	---
Spray dried bovine plasma[3]	---	---	5.00	5.00	---	---	2.00	2.00	---
Dried whey	12.50	12.50	12.50	12.50	---	---	---	---	---
Dried whey permeate (80% lactose)	11.25	11.25	11.25	11.25	9.00	9.00	9.00	9.00	---
Corn oil	3.00	3.00	3.00	3.00	1.00	1.00	1.00	1.00	---
Calcium carbonate	0.60	0.60	0.78	0.78	0.70	0.70	0.78	0.78	0.75
Monocalcium phosphate	1.08	1.08	0.75	0.75	1.20	1.20	1.05	1.05	1.00
Sodium chloride	0.40	0.40	0.13	0.13	0.58	0.58	0.45	0.45	0.60
L-Lys-HCl	0.48	0.48	0.30	0.30	0.47	0.47	0.40	0.40	0.55
DL-Met	0.27	0.27	0.29	0.29	0.23	0.23	0.24	0.24	0.22
L-Thr	0.22	0.22	0.14	0.14	0.23	0.23	0.20	0.20	0.23
L-Trp	0.04	0.04	0.00	0.00	0.03	0.03	0.02	0.02	0.05
L-Val	0.14	0.14	0.04	0.04	0.13	0.13	0.09	0.09	0.16
Vitamin premix with phytase[4]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[5]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Zinc oxide	---	0.40	---	0.40	---	0.26	---	0.26	---
Copper sulfate	---	---	---	---	---	---	---	---	0.07
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

continued

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

Item	Phase 1				Phase 2				Phase 3
	Without plasma		With plasma		Without plasma		With plasma		
	Low Zn	High Zn	Low Zn	High Zn	Low Zn	High Zn	Low Zn	High Zn	
Calculated analysis									
SID AA, %									
Lys	1.40	1.40	1.40	1.40	1.35	1.35	1.35	1.35	1.30
Ile:Lys	57	57	56	56	57	57	56	56	53
Leu:Lys	112	112	119	119	114	114	117	116	113
Met:Lys	39	39	39	39	38	38	38	37	37
Met and Cys:Lys	58	58	64	64	58	58	60	60	58
Thr:Lys	64	64	64	64	65	65	65	65	63
Trp:Lys	19.1	19.1	19.2	19.2	19.3	19.3	19.2	19.2	19.3
Val:Lys	70	70	70	70	70	70	70	70	70
His:Lys	34	34	37	37	36	36	37	37	35
Net energy, kcal/lb	1,209	1,204	1,209	1,204	1,134	1,131	1,134	1,131	1,108
CP, %	21.4	21.3	21.3	21.3	21.3	21.3	21.3	21.3	20.0
Ca, %	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.65
STTD P,[6] %	0.55	0.55	0.55	0.55	0.52	0.52	0.52	0.52	0.47
Added Zn, ppm	110	3,000	110	3,000	110	2,000	110	2,000	110

[1]Phase 1, 2, and 3 diets were fed for 9, 15, and 14 days, respectively.
[2]MEpro is a fermented vegetable protein source (Prairie Aquatech, Brookings, SD).
[3]Spray dried bovine plasma was provided by APC Inc., Ankeny, IA.
[4]Vitamin premix provided per lb of the complete diet: 1,875 IU vitamin A; 750 IU vitamin D; 20 IU vitamin E; 1.5 mg vitamin K; 0.015 mg vitamin B_{12}; 22.5 mg niacin; 12.5 mg pantothenic acid; 3.75 mg riboflavin; and 567 FTU phytase with an expected P release of 0.12% STTD (Ronozyme HiPhos GT 2700; DSM Nutritional Products, Parsippany, NJ).
[5]Trace mineral premix provided per lb of the complete diets: 50 mg Zn, 50 mg Fe, 15 mg Mn, 7.5 mg Cu, 0.13 mg I, and 0.13 mg Se.
[6]STTD P = standardized total tract digestible phosphorus.

Table 2. Effects of bovine plasma and Zn level on nursery pig growth performance[1]

	Without plasma		With plasma			Probability, *P* =		
Item	Low Zn	High Zn	Low Zn	High Zn	SEM	Plasma × Zn	Plasma	Zn
BW, lb								
d 0	12.9	12.9	12.9	12.9	0.02	0.309	0.610	0.610
d 9	15.9	16.4	16.3	16.8	0.19	0.905	0.035	0.007
d 24	27.3	29.3	27.6	29.8	0.62	0.791	0.401	< 0.001
d 38	45.2	46.3	45.6	47.8	0.96	0.432	0.180	0.029
d 0 to 9								
ADG, lb	0.34	0.40	0.39	0.43	0.021	0.616	0.066	0.018
ADFI, lb	0.37	0.39	0.44	0.43	0.017	0.369	0.001	0.809
F/G	1.11	0.99	1.16	1.03	0.049	0.849	0.130	< 0.001
d 9 to 24								
ADG, lb	0.75	0.85	0.74	0.86	0.044	0.565	0.963	< 0.001
ADFI, lb	0.98	1.10	0.99	1.13	0.036	0.649	0.545	< 0.001
F/G	1.31	1.30	1.34	1.31	0.037	0.630	0.196	0.272
d 0 to 24 (treatment period)								
ADG, lb	0.60	0.68	0.61	0.70	0.027	0.836	0.525	< 0.001
ADFI, lb	0.75	0.83	0.78	0.87	0.026	0.955	0.164	< 0.001
F/G	1.26	1.23	1.29	1.25	0.018	0.641	0.105	0.009
d 24 to 38 (common period)								
ADG, lb	1.27	1.21	1.29	1.27	0.028	0.435	0.101	0.189
ADFI, lb	1.90	1.79	1.91	1.86	0.038	0.405	0.253	0.046
F/G	1.50	1.48	1.48	1.46	0.015	0.980	0.278	0.183
d 0 to 38 (overall period)								
ADG, lb	0.84	0.88	0.86	0.90	0.026	0.727	0.227	0.028
ADFI, lb	1.17	1.18	1.19	1.23	0.029	0.786	0.163	0.296
F/G	1.39	1.36	1.40	1.36	0.013	0.798	0.732	0.001

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 15 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively.

Table 3. Main effects of bovine plasma and Zn level on nursery pig growth performance[1]

	Plasma				Zn			
Item	Without	With	SEM	*P* =	Low	High	SEM	*P* =
BW, lb								
d 0	12.9	12.9	0.01	0.610	12.9	12.9	0.01	0.610
d 9	16.2	16.6	0.15	0.035	16.1	16.6	0.15	0.007
d 24	28.3	28.7	0.52	0.401	27.4	29.5	0.52	< 0.001
d 38	45.7	46.7	0.81	0.180	45.4	47.0	0.81	0.029
d 0 to 9								
ADG, lb	0.37	0.41	0.015	0.066	0.36	0.41	0.015	0.018
ADFI, lb	0.38	0.44	0.012	0.001	0.41	0.41	0.012	0.809
F/G	1.05	1.09	0.043	0.130	1.13	1.01	0.043	< 0.001
d 9 to 24								
ADG, lb	0.80	0.80	0.041	0.963	0.74	0.85	0.041	< 0.001
ADFI, lb	1.04	1.06	0.030	0.545	0.98	1.12	0.030	< 0.001
F/G	1.31	1.33	0.034	0.196	1.33	1.31	0.034	0.272
d 0 to 24 (treatment period)								
ADG, lb	0.64	0.65	0.023	0.525	0.60	0.69	0.023	< 0.001
ADFI, lb	0.79	0.82	0.021	0.164	0.76	0.85	0.021	< 0.001
F/G	1.25	1.27	0.015	0.105	1.28	1.24	0.015	0.009
d 24 to 38 (common period)								
ADG, lb	1.24	1.28	0.022	0.101	1.28	1.24	0.022	0.189
ADFI, lb	1.84	1.89	0.028	0.253	1.90	1.83	0.028	0.046
F/G	1.49	1.47	0.010	0.278	1.49	1.47	0.010	0.183
d 0 to 38 (overall period)								
ADG, lb	0.86	0.88	0.023	0.227	0.85	0.89	0.023	0.028
ADFI, lb	1.17	1.21	0.024	0.163	1.18	1.20	0.024	0.296
F/G	1.37	1.38	0.011	0.732	1.40	1.36	0.011	0.001

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 30 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively.

Table 4. Interactive effects of bovine plasma, Zn level, and day on nursery pig fecal dry matter[1]

	Without plasma		With plasma			Probability, P =[2]				
Item[2]	Low Zn	High Zn	Low Zn	High Zn	SEM	Inter-action[2]	Plasma × Zn	Plasma × day	Zn × day
Dry matter, %					≤ 0.937	0.829	0.067	0.162	0.032
d 9	17.36	21.46	13.92	20.50	--	--	--	--	--
d 24	18.95	20.32	16.87	21.22	--	--	--	--	--

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 45 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively. Fecal samples were collected from the same three medium weight pigs from each pen. After collection, fecal samples were dried at 55°C (131°F) in a forced air oven for 48 h and the ratio of dried to wet fecal weight determined the fecal dry matter.
[2]Interaction: Plasma × Zn × day. Main effect P-values: Plasma (0.061), Zn (< 0.001), and day (0.074).

Table 5. Interactive effects of bovine plasma and Zn level on nursery pig fecal dry matter[1]

	Low Zn		High Zn			Probability, P =
Item	Without plasma	With plasma	Without plasma	With plasma	SEM	Plasma × Zn
Dry matter, %	18.16[a]	15.39[b]	20.89[a]	20.86[a]	≤ 0.739	0.067

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 90 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively.
[ab]Means with different superscripts differ (P < 0.05).

Table 6. Interactive effects of Zn level and day on nursery pig fecal dry matter[1]

	Low Zn		High Zn			Probability, P =
Item	Day 9	Day 24	Day 9	Day 24	SEM	Zn × day
Dry matter, %	15.64[c]	17.91[b]	20.98[a]	20.77[a]	≤ 0.659	0.032

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 90 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively.
[abc]Means with different superscripts differ (P < 0.05).

Table 7. Main effects of bovine plasma, Zn level, and day on nursery pig growth performance[1]

	Plasma				Zn				Day			
Item	Without	With	SEM	P =	Low	High	SEM	P =	9	24	SEM	P =
Dry matter, %	19.52	18.13	0.521	0.061	16.78	20.88	≤ 0.522	< 0.001	18.31	19.34	0.465	0.074

[1]A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each mean represents 180 observations. Treatment diets were fed from d 0 to 24. Common diet was fed to all pigs from d 24 to 38. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively.

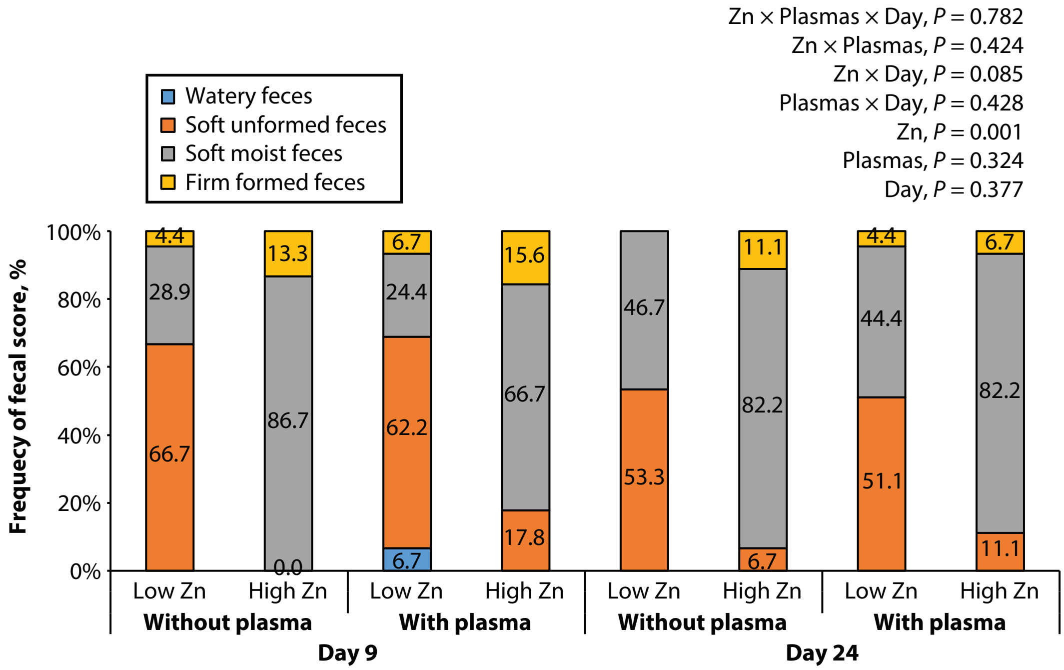

Figure 1. Fecal score frequency on d 9 and 24 by dietary treatment. A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each bar represents 45 observations. Treatment diets were fed from d 0 to 24. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively. Fecal scores were assigned to each pen by the same 3 observers. Fecal scores were assigned based on a 5-point scale, with watery feces, soft unformed feces, soft moist feces, firm formed feces, and hard feces. There were no hard feces observed. Frequency was determined by the number of each fecal score over the total number of observations of each treatment.

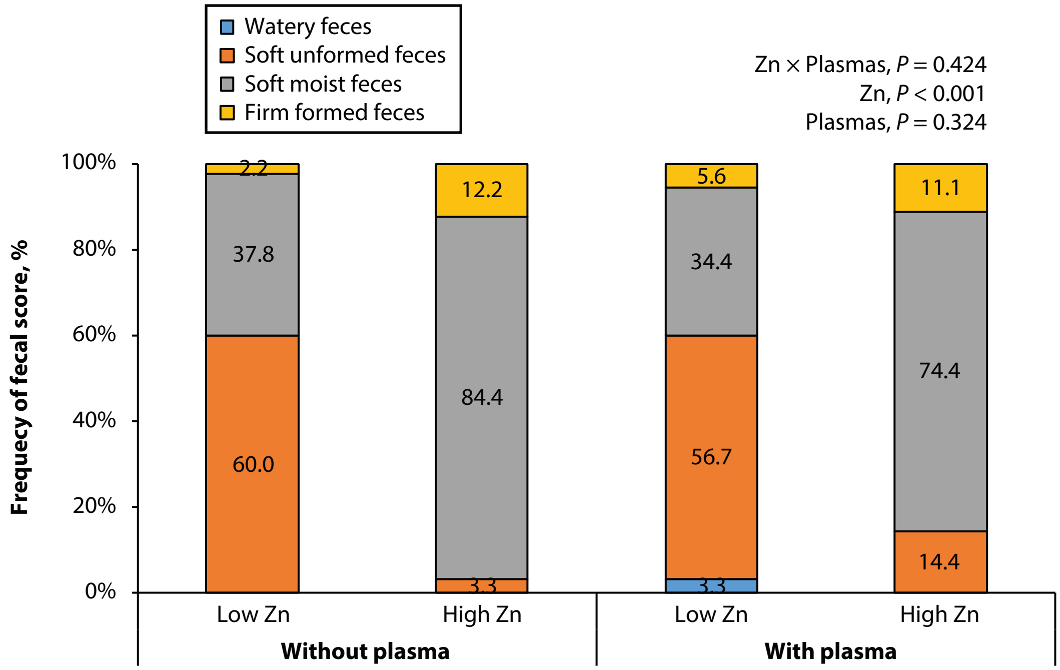

Figure 2. Fecal score frequency by treatment. A total of 300 pigs (initially 12.9 lb) were used with 5 pigs/pen. Each bar represents 90 observations. Treatment diets were fed from d 0 to 24. The inclusion levels of bovine plasma were 5 and 2% in phase 1 and 2 diets, respectively. The inclusion levels of Zn were 3,000 and 2,000 ppm in phase 1 and 2 diets, respectively. Fecal scores were assigned to each pen by the same 3 observers. Fecal scores were assigned based on a 5-point scale, with watery feces, soft unformed feces, soft moist feces, firm formed feces, and hard feces. There were no hard feces observed. Frequency was determined by the number of each fecal score over the total number of observations of each treatment.