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Effect of Coarse Wheat Bran and Crude Protein Level in Nursery Pig Diets Without Pharmacological Levels of Zinc Oxide

Abstract

A total of 360 pigs (200 × 400; DNA, Columbus, NE, initially = 12.4 lb) were used in a 45-d growth trial to evaluate the effects of coarse wheat bran and crude protein level in diets without pharmacological levels of zinc oxide (ZnO) on growth performance of nursery pigs. Upon arrival to the nursery research facility, pigs were randomly assigned to pens with 5 pigs per pen. Pens were allotted to 1 of 6 dietary treatments in a completely randomized design with 12 pens per treatment. Treatment diets were offered in two dietary phases (phase 1 fed from d 0 to 7, and phase 2 from d 7 to 21 post-weaning). A post-treatment period with a common diet was fed from d 21 to 45. Treatment diets included a positive control diet with pharmacological ZnO (3,000 ppm Zn in phase 1 and 2,000 ppm in phase 2); negative control without pharmacological ZnO (110 ppm Zn added from premix); and negative control with 4% coarse wheat bran and formulated to contain 21, 19.5, 18, or 16.5% crude protein (CP). The two control diets and the 21% CP diet contained 1.40% standardized ileal digestible (SID) lysine in phase 1 and 1.35% SID lysine in phase 2, with the 19.5, 18, and 16.5% CP diets containing 1.33, 1.25 and 1.20% lysine, respectively in both phases. Fecal samples were collected from the same three pigs per pen on d 7, 14, 21, and 45 then pooled within pen for each day of collection and dried at 55°C in a forced air oven. All pens were individually scored on d 7, 14, 21, and 45 by the same three individuals to determine visual fecal consistency. Data were analyzed using the lmer function from the lme4 package in R. From d 0 to 21, pigs fed the positive control diet containing ZnO had increased ($P < 0.001$) average daily gain (ADG) and average daily feed intake (ADFI) and improved ($P < 0.050$) feed efficiency (F/G) compared to the negative control and the high CP coarse wheat bran diet. Reducing crude protein levels in diets containing coarse wheat bran resulted in decreased ADG and poorer feed efficiency (linear, $P = 0.002$); however, fecal dry matter percentage was increased (linear, $P = 0.006$), suggesting a greater occurrence of solid feces throughout the experimental period. Overall from d 0 to 45, decreasing crude protein level decreased (linear, $P = 0.012$) ADG, ADFI (linear, $P = 0.038$), and d 45 body weight (linear, $P = 0.010$). Pigs fed the positive control diet with ZnO experienced increased ADG ($P = 0.014$) and increased ADFI ($P = 0.008$) compared to the negative control. There was no evidence for differences in overall growth for the positive control compared with the 21% CP diet with coarse wheat bran. In summary, decreasing crude protein in diets with coarse wheat bran decreased overall ADG and ADFI, resulting in lower body weight throughout the study. The pigs fed these diets had poorer feed efficiency and decreased ADG during the experimental period; however, these pigs had increased fecal dry matter. Further research is warranted to determine if low crude protein diets can be modified to achieve increased fecal dry matter while maintaining growth performance of nursery pigs.

Keywords

crude protein, fecal dry matter, nursery pig, wheat bran, zinc oxide

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Effect of Coarse Wheat Bran and Crude Protein Level in Nursery Pig Diets Without Pharmacological Levels of Zinc Oxide

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Summary

A total of 360 pigs (200 × 400; DNA, Columbus, NE, initially = 12.4 lb) were used in a 45-d growth trial to evaluate the effects of coarse wheat bran and crude protein level in diets without pharmacological levels of zinc oxide (ZnO) on growth performance of nursery pigs. Upon arrival to the nursery research facility, pigs were randomly assigned to pens with 5 pigs per pen. Pens were allotted to 1 of 6 dietary treatments in a completely randomized design with 12 pens per treatment. Treatment diets were offered in two dietary phases (phase 1 fed from d 0 to 7, and phase 2 from d 7 to 21 post-weaning). A post-treatment period with a common diet was fed from d 21 to 45. Treatment diets included a positive control diet with pharmacological ZnO (3,000 ppm Zn in phase 1 and 2,000 ppm in phase 2); negative control without pharmacological ZnO (110 ppm Zn added from premix); and negative control with 4% coarse wheat bran and formulated to contain 21, 19.5, 18, or 16.5% crude protein (CP). The two control diets and the 21% CP diet contained 1.40% standardized ileal digestible (SID) lysine in phase 1 and 1.35% SID lysine in phase 2, with the 19.5, 18, and 16.5% CP diets containing 1.33, 1.25 and 1.20% lysine, respectively in both phases. Fecal samples were collected from the same three pigs per pen on d 7, 14, 21, and 45 then pooled within pen for each day of collection and dried at 55°C in a forced air oven. All pens were individually scored on d 7, 14, 21, and 45 by the same three individuals to determine visual fecal consistency. Data were analyzed using the lmer function from the lme4 package in R. From d 0 to 21, pigs fed the positive control diet containing ZnO had increased ($P < 0.001$) average daily gain (ADG) and average daily feed intake (ADFI) and improved ($P < 0.050$) feed efficiency (F/G) compared to the negative control and the high CP coarse wheat bran diet. Reducing crude protein levels in diets containing coarse wheat bran resulted in decreased ADG and poorer feed efficiency (linear, $P = 0.002$); however, fecal dry matter percentage was increased (linear, $P = 0.006$), suggesting a greater occurrence of solid feces throughout the experimental period. Overall from d 0 to 45, decreasing crude protein level decreased (linear, $P = 0.012$) ADG, ADFI (linear, $P = 0.038$), and d 45 body weight (linear, $P = 0.010$). Pigs fed the positive control diet with ZnO experienced increased ADG ($P = 0.014$)

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and increased ADFI ($P = 0.008$) compared to the negative control. There was no evidence for differences in overall growth for the positive control compared with the 21% CP diet with coarse wheat bran. In summary, decreasing crude protein in diets with coarse wheat bran decreased overall ADG and ADFI, resulting in lower body weight throughout the study. The pigs fed these diets had poorer feed efficiency and decreased ADG during the experimental period; however, these pigs had increased fecal dry matter. Further research is warranted to determine if low crude protein diets can be modified to achieve increased fecal dry matter while maintaining growth performance of nursery pigs.

Introduction

Weaning is a stressful transition for young pigs, generally initiating the occurrence of gastrointestinal issues and enteric diseases such as post-weaning diarrhea (PWD). Nursery swine diets commonly include pharmacological levels of ZnO; however, the inclusion of high ZnO levels in swine diets has been banned in some EU countries. Due to concerns of similar regulations being enforced on ZnO in the US, an alternative offering similar growth and physiological benefits to nursery pigs is of concern to the swine industry.

High protein diets can exacerbate PWD in the weaned pig because of an increase in undigested protein, ammonia production, and microbial fermentation in the hindgut.³ Coarse wheat bran decreases the ability of *Escherichia coli* to attach to intestinal mucosa and has been hypothesized to offer similar antimicrobial properties to ZnO.⁴ Therefore, the objective of this experiment was to determine the effect of coarse wheat bran with decreasing crude protein levels on the growth performance of nursery pigs in diets without pharmacological levels of zinc oxide.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan, KS. The facility has two identical barns that are completely enclosed, environmentally controlled, and mechanically ventilated. Treatments were equally represented in each barn. Each pen contained a 4-hole, dry self-feeder and a cup waterer to provide *ad libitum* access to feed and water. Pens (4×4 ft) had metal tri-bar floors and allowed approximately 2.7 ft²/pig.

Following arrival to the research facility, 360 pigs (200×400 ; DNA, Columbus, NE; initially 12.4 lb) were used in a 45-d study with 5 pigs per pen and 12 pens per treatment. Upon arrival, pigs were randomly assigned to pens and then pens were allotted to 1 of 6 dietary treatments in a completely randomized design. Treatment diets were offered in two dietary phases (phase 1 fed from d 0 to 7 and phase 2 from d 7 to 21 post-

³ Heo, J.M., F. O. Opapeju, J. R. Pluske, J. C. Kim, D. J. Hampson, and C. M. Nyachoti. 2013. Gastrointestinal health and function in weaned pigs: a review of feeding strategies to control post-weaning diarrhea without using in-feed antimicrobial compounds. *J. Anim. Physiol. Anim. Nutr.* 97(2):207-237. doi: 10.1111/j.1439-0396.2012.01284.x.

⁴ Molist, F., R. G. Hermes, A. G. de Segura, S. M. Martín-Orúe, J. Gasa, E. G. Manzanilla, and J. F. Pérez. 2011. Effect and interaction between wheat bran and zinc oxide on productive performance and intestinal health in post-weaning piglets. *Br. J. Nutr.* 105(11):1592-1600. doi: 10.1017/S0007114510004575.

weaning). A post-treatment period with a common diet (1.35% SID Lys) was fed from d 21 to 45.

Treatment diets included a positive control diet with pharmacological ZnO (3,000 ppm Zn in phase 1 and 2,000 ppm in phase 2); a negative control without pharmacological ZnO (110 ppm added Zn from premix); and the negative control with 4% coarse wheat bran and formulated to contain 21, 19.5, 18, or 16.5% CP. All diets were formulated to obtain a similar ratio of essential SID amino acids to SID lysine with feed grade amino acids. Standardized ileal digestible lysine was lowered in order to reduce crude protein level for the low CP diets with wheat bran to limit amino acid deficiencies relative to lysine. All diets were formulated to a maximum SID lysine:digestible CP ratio of 6.35%, thus SID lysine was reduced in the 19.5, 18, and 16.5% CP diets. The control diets and the 21% CP diet contained 1.40% SID lysine in phase 1 and 1.35% SID lysine in phase 2, and the diets with 19.5, 18, and 16.5% CP had 1.33, 1.25, and 1.20% lysine, respectively, in both phases. All other nutrients met or exceeded NRC⁵ requirement estimates (Table 1).

The first phase was fed in pellet form and the following phases were fed as meal. Phase 1 diets were pelleted under the following parameters: 123°F average conditioning temperature, 157°F average hot pellet temperature, 3/16 × 1 1/4-inch die size (L/D = 6.0), 1,560 lb/h production rate, and 73°F ambient temperature. Diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS. The average particle size of the coarse wheat bran included in the experimental diets was determined to be 1,061 microns. Pig weight and feed disappearance were measured on d 0, 7, 21, 31, 38, and 45 of the trial to determine ADG, ADFI, and F/G.

Fecal samples were collected from the same three pigs per pen on d 7, 14, 21, and 45 of the study. Sterile cotton-tipped applicators (Fisher Healthcare, Pittsburgh, PA) were inserted into the rectum to stimulate defecation. Fecal samples were collected into clean, single use zipper storage bags and were then stored at -20°C until fecal dry matter analysis. Fecal samples were pooled by pen respective of the day of collection and dried at 55°C in a forced air oven for 48 h. Fecal dry matter was determined as follows: (dried sample weight at 48 h - pan weight) / (initial wet sample weight - pan weight) × 100. In addition, all pens were individually observed and scored on d 7, 14, 21, and 45 of the study by the same three individuals to determine visual fecal consistency based on a numeric scale from 1 to 5: 1) hard, dry pellet-like feces; 2) firmly formed feces; 3) soft, moist feces that retain shape; 4) soft, unformed feces; and 5) watery, liquid feces.

Chemical Analysis

Complete diet samples were taken during manufacturing of each phase and were stored at -20°C until they were homogenized, subsampled, and submitted for analysis. Duplicate composite samples per dietary treatment were analyzed (Ward Laboratories, Kearney, NE) for dry matter, CP, crude fiber, ADF, neutral detergent fiber (NDF), Ca, and P.

⁵ NRC. 2012. Nutrient Requirements of Swine, 11th ed. Natl. Acad. Press, Washington DC.

Statistical Analysis

Statistical analysis was performed using the lmer function from the lme4 package in R (version 3.6.1 (2019-07-05), R Foundation for Statistical Computing, Vienna, Austria). Growth performance data were analyzed as a completely randomized design using pen as the experimental unit and barn as a random effect. Pre-planned linear and quadratic contrast statements were used to evaluate decreasing crude protein levels. Contrast statements were used to evaluate the positive and negative control diets and the positive control vs. the 21% CP diet. A repeated measures statement, with random effect of barn, was used for analyzing fecal dry matter and fecal consistency scores over time. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

The chemical analyses of the experimental diets were similar to formulated values with CP being slightly lower than formulated (Table 4).

From d 0 to 7, there were no differences between the three diets containing 21% CP (positive control, negative control, and wheat bran diet; Table 5). Average daily gain decreased (linear, $P < 0.001$) and feed efficiency became poorer (linear, $P < 0.001$) with decreasing CP level in the diets containing wheat bran. Pigs fed coarse wheat bran with high protein had increased (linear, $P = 0.001$) body weight on d 7 compared to pigs fed lower CP diets. On d 7, there was marginal evidence for differences for pigs fed the positive control to have more solid feces (Table 6) as fecal dry matter was increased compared to pigs fed the 21% CP coarse wheat bran diet ($P = 0.059$).

From d 7 to 21, reducing CP in the wheat bran diets decreased (linear, $P = 0.017$) ADG and decreased (linear, $P = 0.003$) body weight on d 21. There was marginal evidence for poorer (linear, $P = 0.073$) feed efficiency as crude protein decreased for pigs fed wheat bran diets. Pigs fed the positive control diet containing ZnO had increased ($P < 0.001$) ADG, ADFI, and body weight on d 21 compared to the negative control and compared to the 21% CP coarse wheat bran diet. Feed efficiency was improved for pigs fed the positive control compared with the negative control ($P = 0.013$) and the high CP wheat bran diet ($P = 0.004$). Evidence for differences in fecal scores by day (Figure 1) from d 7 to 21 were observed with looser feces on the last day of the experimental period compared to more consistent feces on d 7 of the trial.

When both phases of the experimental diet phase are combined (d 0 to 21), pigs fed the positive control diet containing ZnO had increased ($P < 0.001$) ADG and ADFI and improved ($P < 0.050$) F/G compared to the negative control and coarse wheat bran diet with high CP. Pigs fed decreased crude protein in diets containing coarse wheat bran had decreased ADG and poorer feed efficiency (linear, $P = 0.002$); however, fecal dry matter percentage was increased (linear, $P = 0.006$) and visual fecal score (Figure 2) was decreased ($P < 0.001$), which suggests more solid feces and lower instances of loose stool.

Pigs previously fed the wheat bran diet with 21% CP experienced an increase ($P = 0.033$) in ADG during the post-treatment period compared to pigs fed the positive control diet. Feed efficiency was also improved for the wheat bran diet with high

CP ($P = 0.005$) and the negative control diet ($P < 0.001$) compared to the positive control. From d 21 to 45, there was a marginal decrease (linear, $P = 0.058$) in ADFI as crude protein fed in the previous period decreased; however, there was a marginal improvement in feed efficiency in response to the previous feeding of decreasing crude protein levels, suggesting a slight compensatory response in the pigs fed low crude protein during the experimental period. Pigs fed treatment diets with decreasing crude protein level resulted in decreased (linear, $P = 0.010$) body weight on d 45 and pigs fed the positive control diet tended to have greater ($P = 0.056$) BW on d 45 compared to pigs fed the negative control diet.

Overall from d 0 to 45, decreasing crude protein level resulted in decreased (linear, $P = 0.012$) ADG, ADFI (linear, $P = 0.038$), and fecal dry matter percentage on d 45 (linear, $P = 0.002$). Pigs fed the positive control diet experienced increased ADG ($P = 0.014$) and ADFI ($P = 0.008$) compared to the negative control. However, fecal dry matter was increased for the negative control compared to the positive control ($P = 0.004$) and increased for the high CP wheat bran diet vs. the positive control ($P = 0.016$) on d 45 at the conclusion of the trial.

In summary, pigs fed low crude protein diets with coarse wheat bran had decreased overall ADG and ADFI resulting in lower body weight throughout the study. The pigs fed these diets had poorer feed efficiency and decreased ADG during the experimental period; however, these pigs had drier and more consistent feces. The observed decrease in growth performance was driven by a lysine deficiency; however, lysine was reduced to maintain a SID lysine:digestible CP ratio of 6.35%. Pigs consuming diets containing pharmacological ZnO had increased ADG, ADFI, and improved feed efficiency during the experimental phase compared to the negative control and the high CP diet with coarse wheat bran. From d 0 to 45, pigs fed the positive control had increased ADG and ADFI compared to the negative control diet, with no evidence for differences in growth for the positive control vs. the 21% CP diet with coarse wheat bran. Overall, the pigs fed the high protein diet with wheat bran experienced similar performance compared to the positive control; however, due to decreased performance during the experimental period, a 1.2-pound difference in final body weight was observed for the pigs fed the wheat bran diet with high CP compared to pigs fed the positive control diet. Further research is needed to determine if low crude protein diets can be modified to achieve increased fecal dry matter while maintaining growth performance of nursery pigs.

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Table 1. Phase 1 diet composition (as-fed basis)¹

Ingredient, %	Control, 21% CP		CP (%) with coarse wheat bran			
	Added ZnO	No added ZnO	21	19.5	18	16.5
Corn	44.35	44.80	41.45	45.40	48.90	52.30
Soybean meal, 46.5% CP	18.10	18.10	17.45	13.45	9.75	5.45
Fish meal	4.5	4.5	4.5	4.5	4.5	4.5
Dried whey	25.0	25.0	25.0	25.0	25.0	25.0
Coarse wheat bran	---	---	4.0	4.0	4.0	4.0
Soybean oil	1.5	1.5	1.5	1.5	1.5	1.5
Calcium carbonate	0.25	0.25	0.30	0.30	0.35	0.35
Monocalcium phosphate, 21%	0.30	0.30	0.20	0.25	0.30	0.35
Salt	0.30	0.30	0.30	0.30	0.33	0.33
L-Lysine	0.43	0.43	0.44	0.47	0.49	0.56
DL-Methionine	0.23	0.23	0.22	0.21	0.20	0.21
L-Threonine	0.21	0.20	0.20	0.20	0.21	0.24
L-Tryptophan	0.07	0.07	0.07	0.08	0.08	0.10
L-Valine	0.14	0.14	0.14	0.15	0.17	0.20
L-Isoleucine	---	---	---	---	---	0.05
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Phytase ²	0.08	0.08	0.08	0.08	0.08	0.08
Zinc oxide (ZnO)	0.40	---	---	---	---	---
HP 300 ³	3.75	3.75	3.75	3.75	3.75	3.75
Total	100	100	100	100	100	100

continued

Table 1. Phase 1 diet composition (as-fed basis)¹

Ingredient, %	Control, 21% CP		CP (%) with coarse wheat bran			
	Added ZnO	No added ZnO	21	19.5	18	16.5
Calculated analysis						
Standardized digestible (SID) amino acids, %						
Lysine	1.40	1.40	1.40	1.33	1.25	1.20
Isoleucine:lysine	56	56	56	54	52	52
Leucine:lysine	109	110	108	107	106	102
Methionine:lysine	38	38	37	37	38	38
Methionine and cysteine:lysine	58	58	58	58	58	58
Threonine:lysine	65	64	64	64	64	64
Tryptophan:lysine	21.0	21.0	21.1	21.0	21.0	21.1
Valine:lysine	70	70	70	70	70	70
Total lysine, %	1.54	1.54	1.54	1.45	1.37	1.31
ME, kcal/lb	1,555	1,561	1,542	1,544	1,544	1,547
NE, kcal/lb	1,172	1,177	1,160	1,170	1,179	1,191
SID lysine:NE, g/Mcal	5.42	5.40	5.47	5.13	4.81	4.57
Crude protein, %	21.0	21.0	21.0	19.5	18.0	16.5
Calcium, %	0.65	0.65	0.65	0.65	0.66	0.66
Phosphorus, %	0.64	0.64	0.65	0.64	0.63	0.63
Available phosphorus, %	0.55	0.55	0.54	0.55	0.55	0.56
STTD P, %	0.56	0.56	0.56	0.56	0.56	0.56

¹Phase 1 diets were fed from approximately 12 to 15 lb.

²HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.

³HP 300 (Hamlet Protein, Findlay, OH).

CP = crude protein. ME = metabolizable energy. NE = net energy. STTD P = Standardized total tract digestible phosphorus.

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Table 2. Phase 2 diet composition (as-fed basis)¹

Ingredient, %	Control, 21% CP		CP (%) with coarse wheat bran			
	Added ZnO	No added ZnO	21	19.5	18	16.5
Corn	55.65	55.90	52.75	56.55	60.40	64.35
Soybean meal, 46.5% CP	30.20	30.15	29.35	25.30	21.30	17.00
Dried whey	10.0	10.0	10.0	10.0	10.0	10.0
Coarse wheat bran	---	---	4.0	4.0	4.0	4.0
Calcium carbonate	0.93	0.93	0.98	0.98	0.98	0.98
Monocalcium phosphate, 21%	0.90	0.90	0.80	0.85	0.90	1.0
Salt	0.55	0.55	0.55	0.55	0.58	0.58
L-Lysine	0.47	0.47	0.48	0.58	0.61	0.68
DL-Methionine	0.22	0.22	0.21	0.23	0.23	0.23
L-Threonine	0.20	0.21	0.21	0.25	0.26	0.28
L-Tryptophan	0.06	0.06	0.06	0.08	0.08	0.10
L-Valine	0.13	0.13	0.13	0.18	0.20	0.23
L-Isoleucine	---	---	---	---	0.03	0.08
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Phytase ²	0.08	0.08	0.08	0.08	0.08	0.08
Zinc oxide (ZnO)	0.27	---	---	---	---	---
Total	100	100	100	100	100	100

continued

Table 2. Phase 2 diet composition (as-fed basis)¹

Ingredient, %	Control, 21% CP		CP (%) with coarse wheat bran			
	Added ZnO	No added ZnO	21	19.5	18	16.5
Calculated analysis						
Standardized digestible (SID) amino acids, %						
Lysine	1.35	1.35	1.35	1.33	1.25	1.20
Isoleucine:lysine	57	57	56	52	52	52
Leucine:lysine	114	114	112	106	105	101
Methionine:lysine	37	37	36	37	37	37
Methionine and cysteine:lysine	58	58	58	58	58	58
Threonine:lysine	64	64	64	64	64	64
Tryptophan:lysine	21.2	21.2	21.3	21.1	21.0	21.1
Valine:lysine	70	70	70	70	70	70
Total lysine, %	1.49	1.49	1.49	1.45	1.37	1.31
ME, kcal/lb	1,485	1,489	1,471	1,474	1,475	1,477
NE, kcal/lb	1,100	1,104	1,088	1,099	1,109	1,120
SID lysine:NE, g/Mcal	5.57	5.55	5.63	5.47	5.11	4.86
Crude protein, %	21.0	21.0	21.0	19.5	18.0	16.5
Calcium, %	0.75	0.75	0.76	0.75	0.75	0.75
Phosphorus, %	0.62	0.62	0.63	0.62	0.61	0.61
Available phosphorus, %	0.47	0.47	0.46	0.46	0.47	0.48
STTD P, %	0.51	0.51	0.51	0.51	0.51	0.51

¹Phase 2 diets were fed from approximately 15 to 24 lb.

²HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.

CP = crude protein. ME = metabolizable energy. NE = net energy. STTD P = Standardized total tract digestible phosphorus.

Table 3. Phase 3 common diet composition (as-fed basis)¹

Ingredient, %	Common diet
Corn	65.55
Soybean meal, 46.5% CP	30.20
Calcium carbonate	1.0
Monocalcium phosphate, 21%	0.95
Salt	0.60
L-Lysine	0.55
DL-Methionine	0.23
L-Threonine	0.25
L-Tryptophan	0.08
L-Valine	0.15
Trace mineral premix	0.15
Vitamin premix	0.25
Phytase ²	0.08
Total	100
Calculated analysis	
Standardized digestible (SID) amino acids, %	
Lysine	1.35
Isoleucine:lysine	54
Leucine:lysine	112
Methionine:lysine	37
Methionine and cysteine:lysine	58
Threonine:lysine	64
Tryptophan:lysine	21.3
Valine:lysine	70
Total lysine, %	1.49
ME, kcal/lb	1,487
NE, kcal/lb	1,101
SID lysine:NE, g/Mcal	5.56
Crude protein, %	20.8
Calcium, %	0.73
Phosphorus, %	0.59
Available phosphorus, %	0.42
STTD P, %	0.46

¹A common diet was fed from approximately 24 to 57 lb during phase 3 from d 21 to 45.

²HiPhos 2700 (DSM Nutritional Products, Parsippany, NJ) provided an estimated release of 0.10% STTD P.

CP = crude protein. ME = metabolizable energy. NE = net energy. STTD P = Standardized total tract digestible phosphorus.

Table 4. Analyzed diet composition (as-fed basis)^{1,2}

Analyzed composition, %	Control, 21% CP		CP (%) with coarse wheat bran ³			
	Added ZnO	No added ZnO	21	19.5	18	16.5
Phase 1						
Dry matter	91.1	91.0	91.0	91.1	90.9	90.8
Crude fiber	1.6	1.6	2.2	2.1	1.9	2.4
Acid detergent fiber	2.1	2.3	2.7	2.8	2.6	2.4
Neutral detergent fiber	4.6	4.6	6.0	5.9	5.6	5.6
Crude protein (CP)	20.3	20.3	20.6	18.6	17.2	15.7
Zinc oxide	2,526	164	126	169	125	145
Ca	0.89	0.91	0.91	0.86	0.88	0.97
P	0.61	0.64	0.63	0.61	0.62	0.60
Phase 2						
Dry matter	89.2	89.0	89.2	88.9	89.1	89.1
Crude fiber	2.1	2.1	2.3	2.1	2.0	2.1
Acid detergent fiber	3.1	2.7	3.1	3.3	3.0	2.6
Neutral detergent fiber	6.1	6.0	7.2	6.9	6.6	6.2
Crude protein	20.8	20.3	21.0	20.3	17.9	15.7
Zinc oxide	1,575	105	187	115	153	156
Ca	0.90	0.97	0.88	0.79	0.88	0.93
P	0.57	0.58	0.61	0.60	0.59	0.58

¹Diets were fed in 2 phases from d 0 to 7, d 7 to 21, for phases 1 and 2, respectively.

²Complete diet samples were taken at the manufacturer. Samples were stored at -20°C until they were homogenized and subsampled. Duplicate samples per treatment were submitted to Ward Laboratories, Inc. (Kearney, NE) for proximate analysis.

³Coarse wheat bran was included in the diet at 4% from d 0 to d 21.

Table 5. Effect of crude protein (CP) level with coarse wheat bran as an alternative for zinc oxide (ZnO) on growth performance of nursery pigs¹

Item	Control, 21% CP		CP (%) with 4% coarse wheat bran					Probability, <i>P</i> =			
	Added ZnO ²	No added ZnO ³	21	19.5	18	16.5	SEM	Linear	Quadratic	+ vs. -	+ Con. vs. 21% CP
BW, lb											
d 0	12.4	12.4	12.4	12.4	12.4	12.4	0.33	0.202	0.461	0.954	0.908
d 7	15.1	15.0	15.0	15.0	14.5	14.2	0.39	0.001	0.275	0.256	0.572
d 21	26.9	23.9	24.1	24.0	22.7	22.7	1.23	0.003	0.957	<0.001	<0.001
d 45	59.3	57.3	58.1	57.1	56.2	55.6	1.45	0.010	0.751	0.056	0.236
d 0 to 7											
ADG, lb	0.39	0.36	0.38	0.34	0.30	0.30	0.016	<0.001	0.226	0.258	0.557
ADFI, lb	0.38	0.37	0.37	0.37	0.34	0.35	0.019	0.158	0.703	0.747	0.653
F/G	0.98	1.04	0.99	1.11	1.18	1.19	0.046	<0.001	0.142	0.297	0.921
d 7 to 21											
ADG, lb	0.84	0.64	0.65	0.65	0.59	0.58	0.061	0.017	0.823	<0.001	<0.001
ADFI, lb	1.03	0.84	0.87	0.88	0.80	0.83	0.043	0.102	0.705	<0.001	<0.001
F/G	1.23	1.34	1.36	1.37	1.38	1.44	0.071	0.073	0.417	0.013	0.004
Experimental period (d 0 to 21)											
ADG, lb	0.69	0.55	0.56	0.54	0.49	0.48	0.043	0.002	0.830	<0.001	<0.001
ADFI, lb	0.81	0.69	0.70	0.71	0.65	0.67	0.033	0.065	0.634	<0.001	<0.001
F/G	1.18	1.27	1.27	1.31	1.33	1.38	0.046	0.002	0.694	0.018	0.011
Post-test period (d 21 to 45) ⁴											
ADG, lb	1.35	1.38	1.41	1.38	1.39	1.37	0.020	0.263	0.788	0.338	0.033
ADFI, lb	2.10	2.05	2.12	2.07	2.05	2.04	0.043	0.058	0.565	0.281	0.572
F/G	1.56	1.49	1.51	1.50	1.47	1.49	0.022	0.085	0.519	<0.001	0.005
d 0 to 45											
ADG, lb	1.04	0.99	1.01	0.99	0.97	0.96	0.024	0.012	0.838	0.014	0.124
ADFI, lb	1.50	1.41	1.45	1.43	1.39	1.40	0.037	0.038	0.606	0.008	0.187
F/G	1.44	1.43	1.44	1.45	1.43	1.46	0.010	0.446	0.410	0.498	0.707

¹A total of 360 pigs (initial BW of 12.4 lb) were used in a 45-d growth study with 5 pigs per pen and 12 pens per treatment. BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.

²ZnO was included in the diet to provide 3,000 ppm of Zn from d 0 to 7; 2,000 ppm of Zn from d 7 to 21; and no additional Zn other than that from the trace mineral premix (110 ppm Zn) from d 21 to 45.

³The negative control diet contained 110 ppm added Zn from the premix for the entire study.

⁴A common diet was fed from d 21 to 45 in phase 3.

Table 6. Effect of crude protein (CP) level with coarse wheat bran in nursery pig diets on fecal dry matter, %¹

Item	Control, 21% CP		CP (%) with 4% coarse wheat bran					Probability, <i>P</i> =			
	Added ZnO ²	No added ZnO ³	21	19.5	18	16.5	SEM	Linear	Quadratic	+ vs. -	+ vs. 21% CP
Day of collection ⁴											
d 7	28.8	26.8	26.5	27.7	29.3	28.9	0.88	0.029	0.349	0.108	0.059
d 21	21.7	20.8	21.3	23.2	24.4	24.4	0.84	0.006	0.282	0.488	0.779
d 45	24.1	27.0	26.5	24.9	24.0	23.5	0.70	0.002	0.433	0.004	0.016

¹Values represent the mean of 3 pigs per pen and 12 pens per treatment. Three pigs per pen were randomly selected and sampled. Fecal samples were then pooled by pen respective of day of collection and dried at 55°C in a forced air oven.

²ZnO was included in the diet to provide 3,000 ppm of Zn from d 0 to 7; 2,000 ppm of Zn from d 7 to 21; and no additional Zn other than that from the trace mineral premix (110 ppm Zn) from d 21 to 45.

³The negative control diet contained 110 ppm added Zn from the premix for the entire study.

⁴Experimental diets were fed from d 0 to 21 and a common diet was fed from d 21 to 45.

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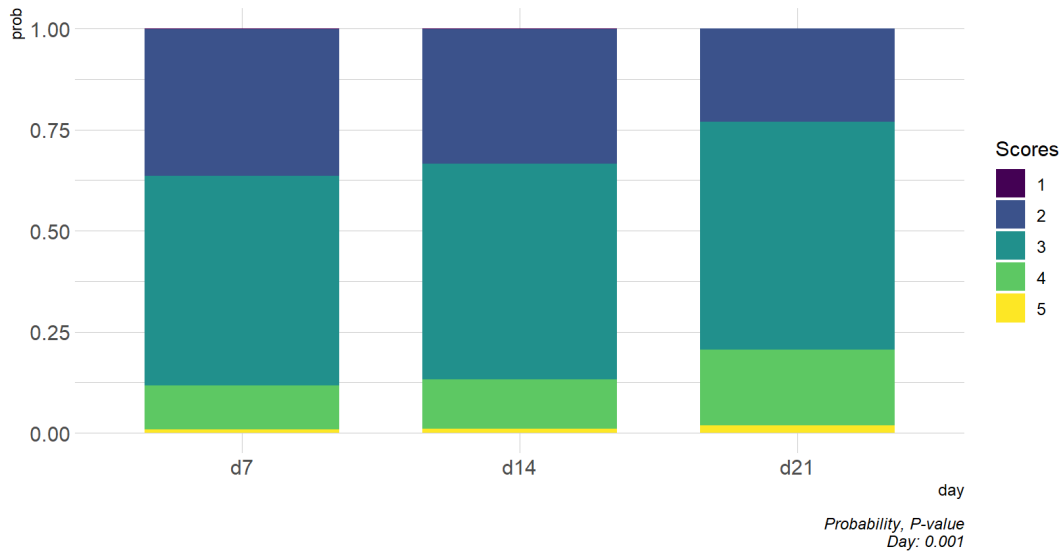


Figure 1. Frequency distribution of fecal score in nursery pigs by day during the experimental period, d 0 to 21 (average of all treatments by day). 1-5 Scale: 1) hard feces; 2) firm formed feces; 3) soft moist feces; 4) soft unformed feces; and 5) watery feces. WB = wheat bran. CP = crude protein.

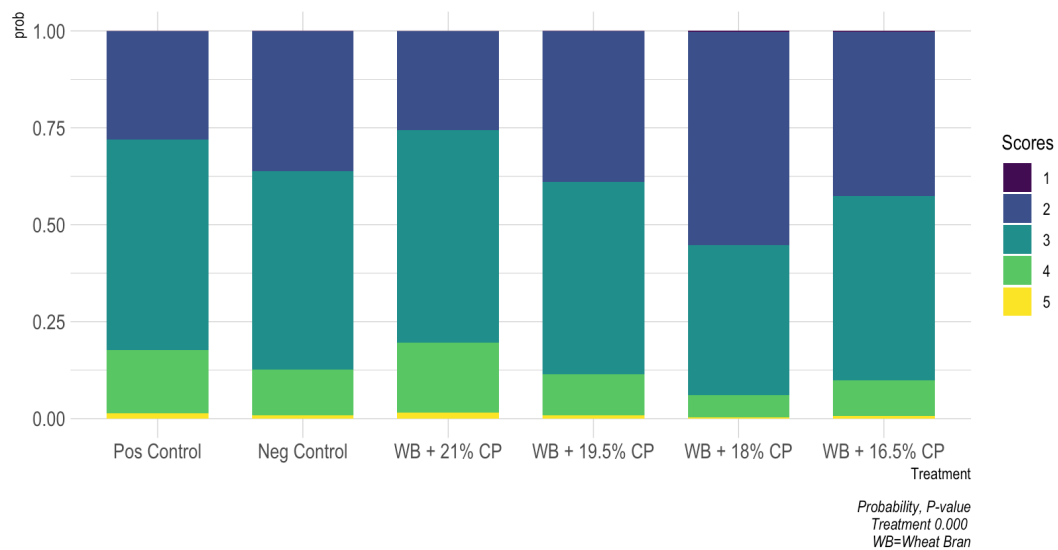


Figure 2. Frequency distribution of fecal score in nursery pigs by treatment (average of the collection days 7 to 21). 1-5 Scale: 1) hard feces; 2) firm formed feces; 3) soft moist feces; 4) soft unformed feces; and 5) watery feces. WB = wheat bran. CP = crude protein.