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# Evaluation of Cellulose in Diets with and without Added ZnO on Nursery Pig Performance


## Abstract

A total of 1,296 pigs (L337 × 1050; PIC, Hendersonville, TN; initially 10.6 lb) were used in a 42-d study to evaluate the addition of cellulose in diets with and without the inclusion of pharmacological levels of Zn on nursery pig growth performance. Pigs were weaned at approximately 20 d of age and randomly allotted to pens in a randomized complete block design by body weight (BW). Pens of pigs were allotted to 1 of 4 dietary treatments with 27 pigs per pen and 12 replications per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of cellulose (0 vs. 1%; J. Rettenmaier USA LP, Schoolcraft, MI) and Zn (200 ppm vs. 3,000 ppm in phase 1 diets and 110 ppm vs. 2,000 ppm in phase 2 diets with added zinc provided by zinc oxide). Treatment diets were formulated in two dietary phases which were fed from approximately d 0 to 7 and 7 to 21 with a common phase 3 diet fed from d 21 to 42 post-weaning. Pig weights and feed disappearance were collected weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). On day 16 or 17, fecal samples were collected from 3 pigs per pen to determine fecal DM, and all pens were visually evaluated for fecal consistency. There were no Zn × cellulose interactions observed. For the experimental period (d 0 to 21), pigs fed diets containing added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G while those that were fed cellulose had decreased ($P = 0.011$) ADG. For fecal dry matter, there was no evidence for difference ($P > 0.10$) between any of the four dietary treatments but those fed added ZnO had visually firmer feces ($P < 0.001$). When pigs were fed a common diet (d 21 to 42), pigs previously fed diets containing added ZnO had increased ($P < 0.001$) ADG and ADFI. For the overall period (d 0 to 42), pigs that had been fed added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G, while those that had been fed cellulose had decreased ($P = 0.023$) ADG. In conclusion, there were no interactive effects between added cellulose and Zn. The addition of cellulose reduced ADG, but did not affect F/G, while the inclusion of pharmacological levels of Zn improved all growth criteria.



## Keywords

cellulose, fecal dry matter, growth, nursery pigs, zinc



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KANSAS STATE UNIVERSITY SWINE INDUSTRY DAY 2020

# Evaluation of Cellulose in Diets with and without Added ZnO on Nursery Pig Performance

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## Summary

A total of 1,296 pigs (L337 × 1050; PIC, Hendersonville, TN; initially 10.6 lb) were used in a 42-d study to evaluate the addition of cellulose in diets with and without the inclusion of pharmacological levels of Zn on nursery pig growth performance. Pigs were weaned at approximately 20 d of age and randomly allotted to pens in a randomized complete block design by body weight (BW). Pens of pigs were allotted to 1 of 4 dietary treatments with 27 pigs per pen and 12 replications per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of cellulose (0 vs. 1%; J. Rettenmaier USA LP, Schoolcraft, MI) and Zn (200 ppm vs. 3,000 ppm in phase 1 diets and 110 ppm vs. 2,000 ppm in phase 2 diets with added zinc provided by zinc oxide). Treatment diets were formulated in two dietary phases which were fed from approximately d 0 to 7 and 7 to 21 with a common phase 3 diet fed from d 21 to 42 post-weaning. Pig weights and feed disappearance were collected weekly to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G). On day 16 or 17, fecal samples were collected from 3 pigs per pen to determine fecal DM, and all pens were visually evaluated for fecal consistency. There were no Zn × cellulose interactions observed. For the experimental period (d 0 to 21), pigs fed diets containing added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G while those that were fed cellulose had decreased ($P = 0.011$) ADG. For fecal dry matter, there was no evidence for difference ($P > 0.10$) between any of the four dietary treatments but those fed added ZnO had visually firmer feces ($P < 0.001$). When pigs were fed a common diet (d 21 to 42), pigs previously fed diets containing added ZnO had increased ($P < 0.001$) ADG and ADFI. For the overall period (d 0 to 42), pigs that had been fed added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G, while those that had been fed cellulose had decreased ($P = 0.023$) ADG. In conclusion, there were no interactive effects between added cellulose and Zn. The addition of cellulose reduced ADG, but did not affect F/G, while the inclusion of pharmacological levels of Zn improved all growth criteria.

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## Introduction

The practice of adding pharmacological levels of Zn to nursery pig diets has been accepted widely in the industry to help control diarrhea and subsequently improve growth performance. However, due to environmental and antimicrobial resistance concerns, nutritionists are searching for alternatives to pharmacological additions of Zn to feed nursery pigs immediately after weaning. High insoluble fiber sources have been of interest as they can improve gut microflora and enzymatic activity, minimize stool looseness, reduce the instances of antibiotic injections, and improve growth performance.[2] Yet, some of these sources, particularly cereal grains high in insoluble fiber, can be expensive if not available locally and can pose the risk from mycotoxins or other components that can hinder pig growth. Concentrated cellulose products can mitigate some of these risks while providing insoluble fiber to the diet. In a study comparing pure cellulose (J. Rettenmaier USA LP, Schoolcraft, MI) and dried distillers grains with solubles (DDGS) in nursery pig diets, Cemin et al.[3] observed a slight reduction in pig removal and improved economic variables in pigs fed the cellulose product without DDGS; however, there was no evidence for difference in growth performance. Functional cellulose products derived from plant-based raw materials are thought to improve nutrient digestibility, intestinal villi length, and prevent diarrhea post-weaning in nursery pigs due to the high water absorbency. Thus, the objective of this experiment was to determine the effect of adding cellulose in comparison and in combination with pharmacological levels of Zn on nursery pig growth performance.

## Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This study was conducted at a commercial nursery research site owned and operated by New Horizon Farms (Pipestone, MN). This study was conducted in a single room with 48 pens that was completely enclosed, environmentally controlled, and mechanically ventilated. Each pen (12 × 8 ft) had plastic slatted floors and was equipped with a six-hole stainless steel dry feeder and pan waterer to provide *ad libitum* access to feed and water.

A total of 1,296 pigs (L337 × 1050, PIC, Hendersonville, TN; initially 10.6 ± 0.2 lb initial BW) were used in a 42-d growth study with 27 pigs per pen. The room was filled over the course of two days and all pens were balanced with 14 gilts and 13 barrows. Pigs were assigned to 1 of 4 dietary treatments with 12 replications per treatment in a randomized complete block design with pens blocked by BW and weaning date. Dietary treatments were arranged in a 2 × 2 factorial with main effects of cellulose (0 vs. 1%; J. Rettenmaier USA LP, Schoolcraft, MI) and pharmacological levels of Zn (200 ppm vs. 3,000 ppm in phase 1 diets and 110 ppm vs. 2,000 ppm in phase 2 diets; Tables 1 and 2). Pigs received 4 lb of the phase 1 diet and then were fed phase 2 diets until d 21. A common diet, without added cellulose or ZnO, was offered from d 21

[2] Flis, M., W. Sobotka, and Z. Antoszkiewicz. 2017. Fiber substrates in the nutrition of weaned piglets – a review. Ann. Anim. Sci. 17:627-643.

[3] Cemin, H.S., M. Tokach, S. Dritz, J. Woodworth, J. DeRouchey, R. Goodband, M. Allerson. 2019. PSV-9 Effects of insoluble fiber source (cellulose or distillers dried grains with solubles) on growth performance of nursery pigs. J. Anim. Sci. 97:193-194.

to 42 (Table 2). All diets were formulated to meet or exceed NRC[4] requirement estimates. Phase 1 diets were manufactured by Hubbard Feeds (Worthington, MN) and fed in pellet form, while phases 2 and 3 were manufactured by New Horizon Farms (Pipestone, MN) and fed as a meal. Feed additions were accomplished using a robotic feeding system (FeedPro, FeedLogic Corp., Wilmar, MN) that was able to record daily feed additions for individual pens. Pens of pigs were weighed, and feed disappearance recorded weekly during the course of the study to determine average daily gain (ADG), average daily feed intake (ADFI), and feed efficiency (F/G).

Fecal samples were collected from 3 pigs per pen on day 16 or 17 and pooled by pen to form one composite sample. Fecal samples were collected into clean, single use zipper storage bags and were then stored at -4°F until fecal dry matter analysis. Fecal samples were dried at 131°F in a forced air oven for 48 h. On the same days, prior to fecal collection, all pens were also individually observed and scored by two 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 (Figure 1).

### *Statistical Analysis*

Growth performance and fecal dry matter data were analyzed using the nlme package of R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria) as a randomized complete block design with body weight as the blocking factor and pen as the experimental unit. Fecal scores data were analyzed using the Cumulative Link Mixed Model function in the ORDINAL package of R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria). The main effects of cellulose and added ZnO, as well as their interactions, were tested. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

## Results and Discussion

There were no interactions observed between dietary addition of pharmacological levels of Zn and cellulose for any response criteria (Table 3).

From d 0 to 7, pigs fed 3,000 ppm Zn had increased ($P < 0.001$) ADG and BW and improved ($P = 0.031$) F/G compared to pigs that did not receive added ZnO. No evidence was observed for difference ($P > 0.10$) in any of the growth criteria for pigs that were fed diets with or without cellulose.

From d 7 to 21, pigs fed diets with added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G compared to those fed no added ZnO. Those that were fed cellulose had decreased ($P = 0.028$) ADG, but no statistical differences were detected ($P > 0.10$) for ADFI, BW, or F/G compared to those not fed cellulose.

For the overall experimental period (d 0 to 21), pigs fed pharmacological levels of Zn had increased ($P < 0.001$) ADG and ADFI, leading to increased ($P < 0.001$) BW and improved ($P < 0.001$) F/G. Pigs that were fed cellulose had decreased ($P = 0.011$)

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

ADG, but no evidence for difference ($P > 0.10$) in ADFI, BW, or F/G compared to those not fed cellulose. There was no difference ($P > 0.10$) among the pigs fed any dietary treatment for fecal DM; however, there was evidence for difference in fecal scores (Figure 1) with pigs fed added ZnO having firmer feces compared to those not fed added ZnO. Dietary addition of cellulose did not influence fecal scores.

From d 21 to 42, when pigs were fed a common diet, pigs previously fed added ZnO had increased ($P < 0.001$) ADG and ADFI; however, no difference was observed in F/G compared to those not fed added ZnO. There was no evidence for difference ($P > 0.10$) in any of the growth criteria for pigs that were previously fed cellulose.

Similar to the experimental period, during the overall period (d 0 to 42), pigs fed pharmacological levels of added Zn had increased ($P < 0.001$) ADG, ADFI, and BW and improved ($P < 0.001$) F/G. However, pigs fed cellulose had decreased ($P = 0.023$) ADG, but no difference ($P > 0.10$) was observed in ADFI, BW, or F/G.

In summary, the results from this study suggest that added ZnO is an impactful additive for maximizing performance of nursery pigs. Pigs fed pharmacological levels of added Zn had increased ADG and ADFI, resulting in a heavier body weight as well as improved feed efficiency, while those fed cellulose had a negative impact on ADG. While fecal DM was not significantly different among any of the four dietary treatments, pigs fed pharmacological levels of added Zn had visually firmer feces than pigs fed cellulose. Further research is needed to determine how pure cellulose products could be used in conjunction with other ingredients to minimize the use of added Zn in the early nursery period.

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

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

| | Cellulose[2] | | No cellulose | |
|---|---|---|---|---|
| | No ZnO | ZnO | No ZnO | ZnO |
| Ingredients, % | | | | |
| Corn | 39.35 | 38.94 | 40.35 | 39.93 |
| Soybean meal | 27.36 | 27.35 | 27.37 | 27.36 |
| Blood plasma | 2.50 | 2.50 | 2.50 | 2.50 |
| Whey powder | 12.50 | 12.50 | 12.50 | 12.50 |
| Whey permeate, 80% lactose | 11.25 | 11.25 | 11.25 | 11.25 |
| Corn oil | 3.00 | 3.00 | 3.00 | 3.00 |
| Calcium carbonate | 0.85 | 0.85 | 0.85 | 0.85 |
| Monocalcium phosphate | 0.85 | 0.85 | 0.85 | 0.85 |
| Sodium chloride | 0.25 | 0.25 | 0.25 | 0.25 |
| L-Lysine-HCl | 0.35 | 0.35 | 0.35 | 0.35 |
| DL-Methionine | 0.21 | 0.21 | 0.21 | 0.21 |
| L-Threonine | 0.18 | 0.18 | 0.18 | 0.18 |
| L-Tryptophan | 0.005 | 0.005 | 0.005 | 0.005 |
| L-Valine | 0.10 | 0.10 | 0.10 | 0.10 |
| Phytase[3] | 0.02 | 0.02 | 0.02 | 0.02 |
| Trace mineral premix[4] | 0.13 | 0.13 | 0.13 | 0.13 |
| Vitamin premix[5] | 0.05 | 0.05 | 0.05 | 0.05 |
| Selenium premix (0.06%) | 0.05 | 0.05 | 0.05 | 0.05 |
| Zinc oxide[6] | --- | 0.42 | --- | 0.42 |
| Cellulose | 1.00 | 1.00 | --- | --- |
| Total | 100 | 100 | 100 | 100 |

*continued*

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

| | Cellulose[2] | | No cellulose | |
|---|---|---|---|---|
| | No ZnO | ZnO | No ZnO | ZnO |
| Calculated analysis | | | | |
| Standardized ileal digestible (SID) amino acids, % | | | | |
| Lysine | 1.35 | 1.35 | 1.35 | 1.35 |
| Isoleucine:lysine | 56 | 56 | 56 | 56 |
| Leucine:lysine | 113 | 113 | 113 | 113 |
| Methionine:lysine | 35 | 35 | 35 | 35 |
| Methionine and cysteine:lysine | 58 | 58 | 58 | 58 |
| Threonine:lysine | 65 | 65 | 65 | 65 |
| Tryptophan:lysine | 19.2 | 19.2 | 19.2 | 19.2 |
| Valine:lysine | 70 | 70 | 70 | 70 |
| SID lysine:net energy, g/Mcal | 5.17 | 5.19 | 5.12 | 5.14 |
| Net energy, kcal/lb | 1,183 | 1,178 | 1,195 | 1,190 |
| Crude protein, % | 20.7 | 20.6 | 20.8 | 20.7 |
| Calcium, % | 0.69 | 0.69 | 0.69 | 0.69 |
| STTD P, %[7] | 0.56 | 0.56 | 0.56 | 0.56 |
| Zinc, ppm | 200 | 3,224 | 200 | 3,224 |

[1]Phase 1 diets were fed at a rate of 4 lb per pig and manufactured by Hubbard Feeds (Worthington, MN).
[2]J. Rettenmaier USA, Schoolcraft, MI.
[3]Quantum Blue 5G (AB Vista, Plantation, FL) provided 1,959 FTU/kg.
[4]Provided per kg of premix: 160,090 mg Zn from zinc sulfate; 134,000 mg Fe from ferrous sulfate; 40,000 mg Mn from manganese oxide; 13,340 mg Cu from copper sulfate; and 666 mg I from calcium iodate.
[5]Provided per kg of premix: 11,100,196 IU vitamin A; 2,000,360 IU vitamin D; 59,996 IU vitamin E; 6000 mg vitamin K; 50 mg vitamin B12; 8,001 mg riboflavin; 41,000 mg pantothenic acid; 45,002 mg niacin; 1,200 mg folic acid; and 200 mg biotin.
[6]ZnO was fed to supply 3,000 ppm of Zn for the duration of phase 1.
[7]Standardized total tract digestible phosphorus.

**Table 2. Composition of phase 2 and phase 3 diets (as-fed basis)[1]**

| | Phase 2 | | | | Phase 3 |
|---|---|---|---|---|---|
| | Cellulose[2] | | No cellulose | | Common diet |
| | No ZnO | ZnO | No ZnO | ZnO | |
| Ingredients, % | | | | | |
| Corn | 52.23 | 52.98 | 54.22 | 53.98 | 65.19 |
| Soybean meal | 31.81 | 31.79 | 31.82 | 31.8 | 29.81 |
| Whey permeate, 80% lactose | 9.00 | 9.00 | 9.00 | 9.00 | --- |
| Choice white grease | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Calcium carbonate | 0.90 | 0.90 | 0.90 | 0.90 | 1.10 |
| Monocalcium phosphate | 1.10 | 1.10 | 1.10 | 1.10 | 0.95 |
| Sodium chloride | 0.60 | 0.60 | 0.60 | 0.60 | 0.60 |
| L-Lysine-HCl | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| DL-Methionine | 0.24 | 0.24 | 0.24 | 0.24 | 0.21 |
| L-Threonine | 0.25 | 0.25 | 0.25 | 0.25 | 0.24 |
| L-Tryptophan | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 |
| L-Valine | 0.15 | 0.15 | 0.15 | 0.15 | 0.14 |
| Phytase[3] | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Vitamin trace mineral premix[4] | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Zinc oxide[5] | --- | 0.27 | --- | 0.27 | --- |
| Cellulose | 1.00 | 1.00 | --- | --- | --- |
| TBBC[6] | --- | --- | --- | --- | 0.03 |
| Total | 100 | 100 | 100 | 100 | 100 |

*continued*

**Table 2. Composition of phase 2 and phase 3 diets (as-fed basis)[1]**

| | Phase 2 | | | | Phase 3 |
|---|---|---|---|---|---|
| | Cellulose[2] | | No cellulose | | Common diet |
| | No ZnO | ZnO | No ZnO | ZnO | |
| Calculated analysis | | | | | |
| Standardized ileal digestible (SID) amino acids, % | | | | | |
| Lysine | 1.35 | 1.35 | 1.35 | 1.35 | 1.30 |
| Isoleucine:lysine | 55 | 55 | 55 | 55 | 55 |
| Leucine:lysine | 110 | 110 | 110 | 110 | 115 |
| Methionine:lysine | 37 | 37 | 37 | 37 | 37 |
| Methionine and cysteine:lysine | 58 | 58 | 58 | 58 | 58 |
| Threonine:lysine | 64 | 64 | 64 | 64 | 65 |
| Tryptophan:lysine | 19.1 | 19.1 | 19.1 | 19.1 | 19.2 |
| Valine:lysine | 70 | 70 | 70 | 70 | 71 |
| SID lysine:net energy, g/Mcal | 5.47 | 5.49 | 5.42 | 5.44 | 5.25 |
| Net energy, kcal/lb | 1,117 | 1,114 | 1,129 | 1,126 | 1,123 |
| Crude protein, % | 20.8 | 20.7 | 20.8 | 20.8 | 20.5 |
| Calcium, % | 0.69 | 0.69 | 0.69 | 0.69 | 0.71 |
| STTD P, %[7] | 0.52 | 0.52 | 0.52 | 0.52 | 0.46 |
| Zinc, ppm | 110 | 2,018 | 110 | 2,018 | 110 |

[1]Phase 2 diets were fed from the completion of Phase 1 until d 21 (approximately 21.1 lb BW) and phase 3 diets were fed from d 21 to 42 (approximately 21.1 to 45.5 lb BW). Both phase 2 and 3 diets were manufactured by New Horizon Farms (Pipestone, MN).

[2]J. Rettenmaier USA, Schoolcraft, MI.

[3]Optiphos 2000 (Huvepharma, Peachtree City, GA) provided 1,742 FTU/kg.

[4] Provided per kg of premix: 73,300 mg Zn from zinc oxide; 66,700 mg Fe from ferrous sulfate; 26,700 mg Mn from manganese oxide; 10,000 mg Cu from copper sulfate; 500 mg I from calcium iodate; 200 mg Se; 7,272,726 IU vitamin A; 1,818,183 IU vitamin D; 136,365 IU vitamin E; 2,274 mg vitamin K; 29 mg vitamin B12; 5,454 mg riboflavin; 20,910 mg pantothenic acid; 39,546 mg niacin; 909 mg folic acid; and 91 mg biotin.

[5]ZnO was fed to supply 2,000 ppm of Zn for the duration of phase 2.

[6]Tribasic copper chloride (TBBC; Intellibond C; Micronutrients Inc., Indianapolis, IN) provided 150 ppm copper in phase 3.

[7]Standardized total tract digestible phosphorus.

**Table 3. Interactive effects of cellulose and added ZnO on nursery pig performance[1,2,3]**

| | Cellulose | | No cellulose | | | Probability, *P* = | | |
|---|---|---|---|---|---|---|---|---|
| Item | No ZnO | ZnO | No ZnO | ZnO | SEM | Cellu-lose | ZnO | Cellulose × ZnO |
| BW, lb | | | | | | | | |
| d 0 | 10.6 | 10.6 | 10.6 | 10.6 | 0.18 | 0.384 | 0.861 | 0.953 |
| d 7 | 11.2 | 11.5 | 11.2 | 11.6 | 0.21 | 0.419 | <0.001 | 0.869 |
| d 21 | 18.3 | 20.7 | 18.6 | 21.1 | 0.35 | 0.125 | <0.001 | 0.890 |
| d 42 | 41.3 | 45.0 | 42.2 | 45.4 | 0.58 | 0.155 | <0.001 | 0.510 |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | 0.07 | 0.12 | 0.08 | 0.14 | 0.012 | 0.341 | <0.001 | 0.986 |
| ADFI, lb | 0.37 | 0.38 | 0.39 | 0.39 | 0.008 | 0.384 | 0.557 | 0.691 |
| F/G | 6.47 | 3.46 | 5.40 | 4.32 | 0.909 | 0.913 | 0.031 | 0.297 |
| Day 7 to 21 | | | | | | | | |
| ADG, lb | 0.47 | 0.62 | 0.50 | 0.65 | 0.015 | 0.028 | <0.001 | 0.767 |
| ADFI, lb | 0.80 | 0.90 | 0.84 | 0.91 | 0.021 | 0.313 | <0.001 | 0.491 |
| F/G | 1.72 | 1.45 | 1.69 | 1.39 | 0.035 | 0.274 | <0.001 | 0.619 |
| Day 0 to 21 experimental period | | | | | | | | |
| ADG, lb | 0.33 | 0.44 | 0.35 | 0.47 | 0.012 | 0.011 | <0.001 | 0.715 |
| ADFI, lb | 0.65 | 0.72 | 0.68 | 0.72 | 0.014 | 0.161 | <0.001 | 0.490 |
| F/G | 2.00 | 1.61 | 1.94 | 1.53 | 0.049 | 0.160 | <0.001 | 0.807 |
| Day 21 to 42 common diet | | | | | | | | |
| ADG, lb | 1.09 | 1.15 | 1.12 | 1.15 | 0.014 | 0.297 | 0.001 | 0.269 |
| ADFI, lb | 1.52 | 1.62 | 1.55 | 1.62 | 0.025 | 0.481 | <0.001 | 0.452 |
| F/G | 1.40 | 1.40 | 1.38 | 1.40 | 0.010 | 0.501 | 0.139 | 0.488 |
| Day 0 to 42 overall period | | | | | | | | |
| ADG, lb | 0.70 | 0.79 | 0.73 | 0.81 | 0.012 | 0.023 | <0.001 | 0.621 |
| ADFI, lb | 1.07 | 1.15 | 1.10 | 1.16 | 0.017 | 0.138 | <0.001 | 0.412 |
| F/G | 1.54 | 1.46 | 1.52 | 1.44 | 0.013 | 0.120 | <0.001 | 0.900 |
| Fecal dry matter, %[4] | 20.72 | 19.01 | 20.10 | 19.91 | 0.951 | 0.883 | 0.316 | 0.426 |
| Fecal score, avg.[5] | 3.46 | 3.06 | 3.78 | 3.03 | 0.139 | 0.268 | <0.001 | 0.192 |

[1]A total of 1,296 pigs (initial BW of 10.6 ± 0.2 lb) were used in a 42-d growth study with 27 pigs per pen and 12 pens per treatment.
[2]Cellulose (J. Rettenmaier USA LP, Schoolcraft, MI) was added at 1% from d 0 to 21.
[3]ZnO was included to supply 3,000 ppm Zn in phase 1 diets and 2,000 ppm Zn in phase 2 diets.
[4]Fecal samples from 3 pigs/pen were collected on d 16 or 17 prior to the end of the experimental period (d 21).
[5]Fecal scores were assessed on d 16 or 17 prior to the end of the experimental period (d 21) according to a 1-5 scale: 1) hard feces, 2) firm formed feces, 3) soft moist feces, 4) soft unformed feces, 5) watery feces.
BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. SEM = standard error of mean.

**Table 4. Main effects of cellulose and added ZnO on nursery pig performance[1,2,3]**

| | Cellulose | | | | ZnO | | | |
|---|---|---|---|---|---|---|---|---|
| Item | No cellulose | Cellulose | SEM | *P*-value | No ZnO | ZnO | SEM | *P*-value |
| BW, lb | | | | | | | | |
| d 0 | 10.6 | 10.6 | 0.18 | 0.384 | 10.6 | 10.6 | 0.18 | 0.861 |
| d 7 | 11.4 | 11.3 | 0.20 | 0.419 | 11.2 | 11.5 | 0.20 | <0.001 |
| d 21 | 19.8 | 19.5 | 0.32 | 0.665 | 18.5 | 20.9 | 0.32 | <0.001 |
| d 42 | 43.8 | 43.2 | 0.49 | 0.125 | 41.8 | 45.19 | 0.49 | <0.001 |
| Day 0 to 7 | | | | | | | | |
| ADG, lb | 0.11 | 0.10 | 0.008 | 0.341 | 0.08 | 0.13 | 0.008 | <0.001 |
| ADFI, lb | 0.39 | 0.38 | 0.006 | 0.384 | 0.38 | 0.38 | 0.006 | 0.557 |
| F/G | 4.86 | 4.96 | 0.642 | 0.913 | 5.93 | 3.89 | 0.642 | 0.031 |
| Day 7 to 21 | | | | | | | | |
| ADG, lb | 0.58 | 0.55 | 0.011 | 0.028 | 0.49 | 0.64 | 0.011 | <0.001 |
| ADFI, lb | 0.87 | 0.85 | 0.015 | 0.313 | 0.82 | 0.90 | 0.015 | <0.001 |
| F/G | 1.54 | 1.58 | 0.025 | 0.262 | 1.70 | 1.42 | 0.030 | <0.001 |
| Day 0 to 21 experimental period | | | | | | | | |
| ADG, lb | 0.41 | 0.39 | 0.009 | 0.011 | 0.34 | 0.46 | 0.009 | <0.001 |
| ADFI, lb | 0.70 | 0.68 | 0.011 | 0.161 | 0.67 | 0.72 | 0.011 | <0.001 |
| F/G | 1.74 | 1.81 | 0.036 | 0.160 | 1.97 | 1.57 | 0.036 | <0.001 |
| Day 21 to 42 common diet | | | | | | | | |
| ADG, lb | 1.14 | 1.12 | 0.011 | 0.297 | 1.11 | 1.15 | 0.011 | 0.001 |
| ADFI, lb | 1.58 | 1.57 | 0.020 | 0.481 | 1.54 | 1.62 | 0.020 | <0.001 |
| F/G | 1.39 | 1.40 | 0.008 | 0.501 | 1.39 | 1.40 | 0.008 | 0.139 |
| Day 0 to 42 overall period | | | | | | | | |
| ADG, lb | 0.77 | 0.74 | 0.010 | 0.023 | 0.71 | 0.80 | 0.010 | <0.001 |
| ADFI, lb | 1.13 | 1.11 | 0.014 | 0.138 | 1.09 | 1.16 | 0.014 | <0.001 |
| F/G | 1.48 | 1.50 | 0.009 | 0.120 | 1.53 | 1.45 | 0.009 | <0.001 |
| Fecal dry matter, %[4] | 19.87 | 20.01 | 0.685 | 0.883 | 20.41 | 19.46 | 0.685 | 0.316 |
| Fecal score, avg.[5] | 3.40 | 3.26 | 0.105 | 0.268 | 3.62 | 3.04 | 0.105 | <0.001 |

[1]A total of 1,296 pigs (initial BW of 10.6 ± 0.2 lb) were used in a 42-d growth study with 27 pigs per pen and 12 pens per treatment.
[2]Cellulose (J. Rettenmaier USA LP, Schoolcraft, MI) was added at 1% from d 0 to 21.
[3]ZnO was included to supply 3,000 ppm Zn in phase 1 and 2,000 ppm Zn in phase 2 diets.
[4]Fecal samples from 3 pigs/pen were collected on d 16 or 17 prior to the end of the experimental period (d 21).
[5]Fecal scores were assessed on d 16 or 17 prior to the end of the experimental period (d 21) according to a 1-5 scale: 1) hard feces, 2) firm formed feces, 3) soft moist feces, 4) soft unformed feces, 5) watery feces.
BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency. SEM = standard error of mean.

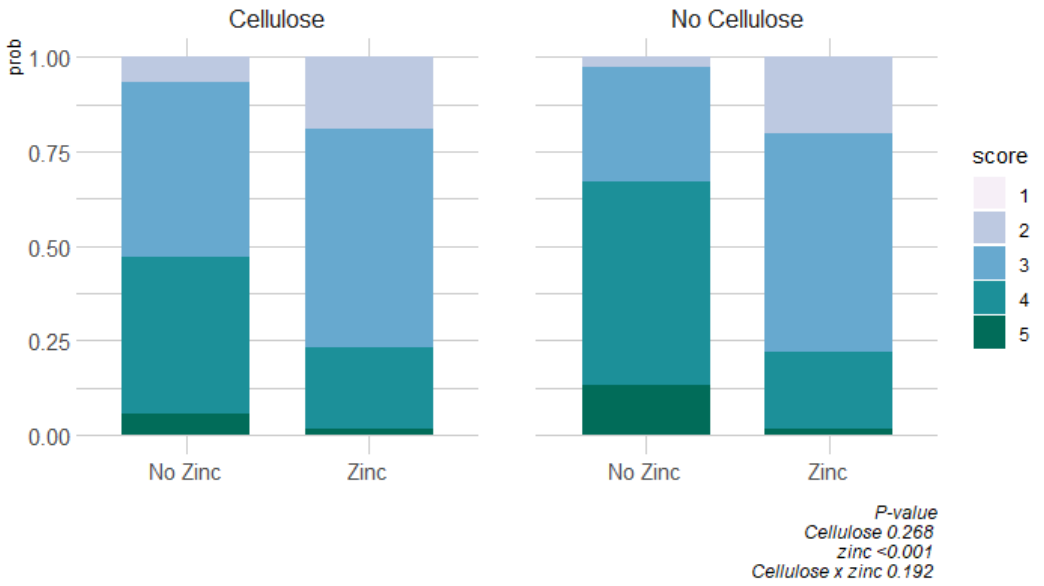


**Figure 1. Frequency distribution of fecal score in nursery pigs on d 16 or 17 of the experimental period for cellulose and ZnO. 1-5 Scale: 1) hard feces, 2) firm formed feces, 3) soft moist feces, 4) soft unformed feces, 5) watery feces.**