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Effects of a Gluco-oligosaccharide on Growth Performance of Nursery Pigs

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Effects of a Gluco-oligosaccharide on Growth Performance of Nursery Pigs

Abstract

A total of 3,456 nursery pigs (PIC L337 × 1050, initially 12.4 lb BW) were housed in 3 commercial research rooms and used in a 42-d growth study to determine the effects of gluco-oligosaccharide (Midori USA, Inc., Cambridge, MA) on growth performance. In each room, pens of pigs (27 pigs/pen) were blocked (6, 5, and 5 blocks in rooms 1, 2, and 3, respectively) by initial pen BW. Within blocks, pens were allotted randomly to 1 of 8 dietary treatments in a 2-phase feeding program (d 0 to 14 and d 14 to 42). Dietary treatments were arranged in a 2 × 3 factorial, with or without antibiotic (0 or 55 ppm, Carbadox, Phibro Pro, Teaneck, NJ) and 4 concentrations of gluco-oligosaccharide (0, 200, 400, and 600 ppm). Gluco-oligosaccharide product used in rooms 1 and 2 originated from a different batch than that used in room 3. For the overall feeding period, no room × antibiotic × gluco-oligosaccharide or antibiotic × glucooligosaccharide interactions were observed for any growth responses, but tendencies were found ($P < 0.10$) for room × gluco-oligosaccharide interaction for final BW and ADG. In rooms 1 and 2, antibiotic treatment increased ADG and ADFI in all feeding periods and improved F/G from d 14 to 28 and d 28 to 42. Increasing gluco-oligosaccharide improved (linear, $P < 0.05$) ADG and F/G from d 0 to 14. It also increased ($P = 0.047$) ADG and tended ($P = 0.087$) to increase ADFI from d 14 to 28, but did not alter the growth responses from d 28 to 42. For the overall period (d 0 to 42), adding an antibiotic to the diet increased ($P < 0.01$) ADG and ADFI, but did not affect F/G. Increasing gluco-oligosaccharide improved (linear, $P < 0.01$) ADG and F/G and tended ($P = 0.063$) to linearly increase ADFI. In room 3, a much smaller response was observed for antibiotic inclusion with only improved ($P = 0.005$) F/G from d 14 to 28 and increased ($P < 0.05$) ADG and ADFI from d 28 to 42. Pigs fed increasing glucooligosaccharide tended (linear, $P < 0.10$) to have reduced ADG and ADFI; however, the overall growth performance was not affected by antibiotic or gluco-oligosaccharide treatments. In conclusion, feeding gluco-oligosaccharide may improve growth performance in nursery pigs, and this effect appears to be independent of the use of antibiotic and more prominent during the early nursery phase. However, due to some room × gluco-oligosaccharide interactions, further research is required to confirm the consistency of the responses to the gluco-oligosaccharide used in this study.

Keywords

antibiotic, gluco-oligosaccharide, growth, nursery pig

Cover Page Footnote

Appreciation is expressed to Midori USA, Inc. (Cambridge, MA) for partial funding and New Horizon Farms (Pipestone, MN) for providing the animals, research facilities, and technical support.

Authors

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K-STATE Research and Extension

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Effects of a Gluco-oligosaccharide on Growth Performance of Nursery Pigs[1]

F. Wu, M.D. Tokach, J.M. DeRouchey, S.S. Dritz,[2] J.C. Woodworth, and R.D. Goodband

Summary

A total of 3,456 nursery pigs (PIC L337 × 1050, initially 12.4 lb BW) were housed in 3 commercial research rooms and used in a 42-d growth study to determine the effects of gluco-oligosaccharide (Midori USA, Inc., Cambridge, MA) on growth performance. In each room, pens of pigs (27 pigs/pen) were blocked (6, 5, and 5 blocks in rooms 1, 2, and 3, respectively) by initial pen BW. Within blocks, pens were allotted randomly to 1 of 8 dietary treatments in a 2-phase feeding program (d 0 to 14 and d 14 to 42). Dietary treatments were arranged in a 2 × 3 factorial, with or without antibiotic (0 or 55 ppm, Carbadox, Phibro Pro, Teaneck, NJ) and 4 concentrations of gluco-oligosaccharide (0, 200, 400, and 600 ppm). Gluco-oligosaccharide product used in rooms 1 and 2 originated from a different batch than that used in room 3. For the overall feeding period, no room × antibiotic × gluco-oligosaccharide or antibiotic × gluco-oligosaccharide interactions were observed for any growth responses, but tendencies were found ($P < 0.10$) for room × gluco-oligosaccharide interaction for final BW and ADG. In rooms 1 and 2, antibiotic treatment increased ADG and ADFI in all feeding periods and improved F/G from d 14 to 28 and d 28 to 42. Increasing gluco-oligosaccharide improved (linear, $P < 0.05$) ADG and F/G from d 0 to 14. It also increased ($P = 0.047$) ADG and tended ($P = 0.087$) to increase ADFI from d 14 to 28, but did not alter the growth responses from d 28 to 42. For the overall period (d 0 to 42), adding an antibiotic to the diet increased ($P < 0.01$) ADG and ADFI, but did not affect F/G. Increasing gluco-oligosaccharide improved (linear, $P < 0.01$) ADG and F/G and tended ($P = 0.063$) to linearly increase ADFI. In room 3, a much smaller response was observed for antibiotic inclusion with only improved ($P = 0.005$) F/G from d 14 to 28 and increased ($P < 0.05$) ADG and ADFI from d 28 to 42. Pigs fed increasing gluco-oligosaccharide tended (linear, $P < 0.10$) to have reduced ADG and ADFI; however, the overall growth performance was not affected by antibiotic or gluco-oligosaccharide treatments. In conclusion, feeding gluco-oligosaccharide may improve growth performance in nursery pigs, and this effect appears to be independent of the use of antibiotic and more prominent during the early nursery phase. However, due to some room × gluco-oligosaccharide interactions, further research is required to confirm the consistency of the responses to the gluco-oligosaccharide used in this study.

[1] Appreciation is expressed to Midori USA, Inc. (Cambridge, MA) for partial funding and New Horizon Farms (Pipestone, MN) for providing the animals, research facilities, and technical support.

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Key words: antibiotic, gluco-oligosaccharide, growth, nursery pig

Introduction

Oligosaccharides are a group of carbohydrate polymers containing 3 to 10 simple sugars that can be fed to pigs as prebiotics. Mannan- (Davis et al., 2002;[3] Rozeboom et al., 2005[4]), chito- (Liu et al., 2008[5]), and fructo-oligosaccharides (Gebbink et al., 1999[6]), have been shown to improve growth performance in young pigs. Possible mechanisms by which oligosaccharides benefit growth performance have been proposed and center on improving health status of the pig. For example, oligosaccharide may interact with intestinal mucosa and prevent pathogens, e.g., *E. coli* and *Salmonella,* from colonizing and proliferating at the mucosal surface (Miguel et al., 2004[7]). Oligosaccharide may also enhance the immune system of pigs by increasing antibody titers, immunoglobulins, and macrophage activities (Davis et al., 2004[8]). In addition, antibiotics have been widely fed to nursery pigs as growth promoters; however, concerns with antibiotic resistance have led to a ban on the use of growth promoting antibiotics that are medically important for human use (FDA, 2015[9]) in swine diets. Therefore, oligosaccharide products have been proposed as the alternatives to antibiotics in nursery pig diets. The objective of this study was to determine the effects of feeding a gluco-oligosaccharide with or without a feed grade antibiotic on growth performance of nursery pigs.

Procedures

The Kansas State University Institutional Animal Care Committee approved the protocol used in the experiment. The study was conducted at a commercial nursery research facility in southwest Minnesota. The barn was mechanically ventilated and temperature was maintained at approximately 80°F. Each pen (12.1 × 7.5 ft^2) had completely slatted plastic floors and was equipped with a 6-hole, stainless-steel, dry self-feeder and a pan waterer. Pigs were allowed ad libitum access to feed and water throughout the experiment. Diets were manufactured at a local feed mill (New Horizon Farms, Pipestone, MN). Feed additions to each individual pen were delivered and recorded by a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN).

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[3] Davis, M. E., C. V. Maxwell, D. C. Brown, B. Z. De Rodas, Z. B. Johnson, E. B. Kegley, D. H. Hellwig, and R. A. Dvorak. 2002. Effect of dietary mannan oligosaccharides and(or) pharmacological additions of copper sulfate on growth performance and immunocompetence of weanling and growing/finishing pigs. J. Anim. Sci. 80:2887–2894.

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[5] Liu, P., X. S. Piao, S. W. Kim, L. Wang, Y. B. Shen, H. S. Lee, and S. Y. Li. 2008. Effects of chito-oligosaccharide supplementation on the growth performance, nutrient digestibility, intestinal morphology, and fecal shedding of *Escherichia coli* and *Lactobacillus* in weaning pigs. J. Anim. Sci. 86:2609-2618.

[6] Gebbink, G. A. R., A. L. Sutton, B. T. Richert, J. A. Patterson, J. Nielsen, D. T. Kelly, M. W. A. Verstegen, B. A. Williams, M. Bosch, M. Cobb, D. C. Kendall, S. DeCamp, and K. Bowers. 1999. Effects of addition of fructooligosaccharide (FOS) and sugar beet pulp to weanling pig diets on performance, microflora and intestinal health. Swine Day, vol. 31. Purdue University, pp. 53–59.

[7] Miguel, J. C., S. L. Rodriguez-Zas, and J. E. Pettigrew. 2004. Efficacy of a mannan oligosaccharide (Bio-Mos®) for improving nursery pig performance. J. Swine Health Prod. 12:296–307.

[8] Davis, M. E., D. C. Brown, C. V. Maxwell, Z. B. Johnson, E. B. Kegley, and R. A. Dvorak. 2004. Effect of phosphorylated mannans and pharmacological additions of zinc oxide on growth and immunocometence of weanling pigs. J. Anim. Sci. 82:581–587.

[9] FDA. 2015. Federal register. 80: No. 106.

This experiment was replicated twice. In replicate 1, pigs (n = 2,376; initial BW = 11.9 lb; PIC L337 × 1050) were housed in two rooms (48 pens in room 1 and 40 pens in room 2). Replicate 2 was conducted with the next group of pigs placed into room 1, but will be referred to as room 3 for ease of clarification. In room 3, pigs (n = 1,080; initial BW = 13.5 lb; PIC L337 × 1050) were housed in 40 pens. In each room, pens of pigs (27 pigs/pen) were blocked (6, 5, and 5 blocks in rooms 1, 2, and 3, respectively) by initial pen BW and allotted randomly to 1 of 8 dietary treatments. The dietary treatments were arranged in a 2 × 3 factorial, with or without antibiotic (0 or 55 ppm Carbadox, Phibro Animal Health Corp., Teaneck, NJ), and 4 levels of gluco-oligosaccharide (0, 200, 400, and 600 ppm; Midori USA, Inc., Cambridge, MA). The basal diets used in the study are provided in Table 1. Antibiotic and/or gluco-oligosaccharide were added to the basal diets at the expense of corn. The 0 and 600 ppm gluco-oligosaccharide diets were manufactured and used to blend in the robotic feeding system to provide diets with 200 and 400 ppm gluco-oligosaccharide (Table 2). Gluco-oligosaccharide product used in rooms 1 and 2 originated from a different batch from that of product used in room 3. Pigs were fed in 2 phases from d 0 to 14 and d 14 to 42. Pens were weighed and feed disappearance was measured every 7 d to determine ADG, ADFI, and F/G. Diet samples were taken from six feeders per dietary treatment, delivered to Kansas State University Swine Laboratory, and stored at -20°C. Diet samples were submitted to Ward Laboratories, Inc. (Kearney, NE) for analysis of DM, CP, crude fat, Ca, and P. Diet samples were also sent to Phibro Animal Health Corp. Feed Laboratory (State College, PA) for the analysis of Carbadox concentrations.

Data were analyzed using the GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. The statistical model included fixed effects of room, antibiotic, gluco-oligosaccharide, and their interactions, with block as a random effect. The statistical model was simplified by removing the room × antibiotic × gluco-oligosaccharide interaction ($P > 0.10$), and the degrees of freedom of non-significant interactions were pooled to test the remaining fixed effects. Linear and quadratic contrasts were conducted among the gluco-oligosaccharide concentrations and a single degree of freedom contrast was used to compare the treatments with and without antibiotic. Results were considered significant at $P < 0.05$ and a tendency at $0.05 < P < 0.10$.

Results and Discussion

Analyzed chemical composition of dietary treatments generally matched formulated nutrient levels. Analyzed CP and antibiotic concentrations were slightly lower than the formulated levels, but were consistent across treatments, phases, and rooms.

The *P* values for the fixed effects on ADG, ADFI, F/G, and BW are shown in Table 3. No room × antibiotic × gluco-oligosaccharide interactions were significant ($P > 0.10$) for any of the growth responses and, therefore, were removed from the statistical model. Tendencies for room × gluco-oligosaccharide interactions were observed for final BW ($P = 0.059$; Figure 1) and overall ADG ($P = 0.087$; Figure 2). Pigs from rooms 1 and 2 had similar response trends to the gluco-oligosaccharide but shared different patterns than that of pigs in room 3 (Figure 1 and 2). Pigs from the first (room 1 and 2) and second (room 3) replicates of the experiment were from different batches, raised in different time points, and fed a different batch of the gluco-oligosaccharide, which might

explain the discrepancy in pig performance between experimental replicates. Therefore, data from room 1 and 2 were pooled to test the treatment effects of gluco-oligosaccharide and antibiotic separately from room 3.

No interactive effects among room, antibiotic, and gluco-oligosaccharide were observed for removal rate ($P > 0.42$). Percentage of pigs removed from the experiment was not affected by the antibiotic or gluco-oligosaccharide treatments, but tended ($P = 0.064$) to vary among rooms. Removal rate in room 3 (4.2%) was greater ($P < 0.05$) than in room 2 (1.9%), but was not statistically different from that in room 1 (2.8%); no differences were observed between removal rates in room 1 and 2.

No antibiotic × gluco-oligosaccharide interactions were observed in the analyses of growth responses. In a review of 29 studies, Miguel et al. (2004[7]) concluded that the effects of feeding mannan-oligosaccharide on growth performance of nursery pigs were independent to the application of an antibiotic in the diet, and the effects are additive. Growth performance of pigs fed in rooms 1 and 2 is presented in Table 4. Body weight of pigs fed antibiotic was greater ($P = 0.073$) at d 14 and ($P < 0.01$) at d 28 and 42. Feeding an antibiotic improved ($P = 0.026$) ADG, tended to increase ($P = 0.067$) ADFI, but did not affect F/G of pigs from d 0 to 14. Pigs fed diets containing antibiotic had improved ($P < 0.05$) ADG, ADFI, and F/G compared with those fed diets without antibiotic from d 14 to 28 and 28 to 42. For the overall feeding period (d 0 to 42), ADG and ADFI were improved ($P < 0.01$), but F/G was unaffected by addition of a dietary antibiotic.

In rooms 1 and 2, increasing gluco-oligosaccaride increased (linear, $P < 0.01$) BW on d 14, 28, and 42. Increasing gluco-oligosaccharide improved (linear, $P < 0.01$) ADG and F/G, but did not affect ADFI from d 0 to 14. From d 14 to 28, increasing gluco-oligosaccharide increased (linear, $P = 0.047$) ADG and tended to increase (linear, $P = 0.087$) ADFI, but had no effect on F/G. Growth performance of pigs from d 28 to 42 were not affected by added gluco-oligosaccharide. For the overall period (d 0 to 42), increasing gluco-oligosaccharide improved (linear, $P < 0.01$) ADG and F/G and tended to increase (linear, $P = 0.063$) ADFI. Improved pig growth performance during nursery phases has been reported in other studies (Davis et al., 2002;[3] Rozeboom et al., 2005;[4] Liu et al., 2008[5]) when mannan- or chito-oligosaccharides were added in the diets. Miguel et al. (2004[7]) suggested that pigs in the first 1 to 2 weeks post-weaning with relatively slow growth rate had more prominent response to oligosaccharide products than older nursery pigs, which supported our findings that gluco-oligosaccharide treatment promoted ADG and F/G during d 0 to 14 and increased ADG and ADFI from d 14 to 28 but did not affect growth responses from d 28 to 42.

Growth performance of pigs in room 3 is presented in Table 5. Neither the antibiotic nor gluco-oligosaccharide treatments affected the BW of pigs. In contrast to the observations in rooms 1 and 2, a much smaller response was observed for dietary antibiotic addition in room 3, with the only improved ($P = 0.005$) F/G from d 14 to 28 and increased ($P < 0.05$) ADG and ADFI from d 28 to 42. No response was observed for added gluco-oligosaccharide, except that pigs tended (linear, $P < 0.10$) to have decreased ADG and ADFI from d 14 to 28 with increasing gluco-oligosaccharides. Discrepancies in pigs' responses to gluco-oligosaccharide treatment between experimen-

tal replicates might be attributed to the environment, health status of pigs, quality of dietary ingredients, as well as many other factors (Miguel et al., 2004[7]). Rozeboom et al. (2005[4]) also reported inconsistent responses of pigs to dietary mannan-oligosaccharide in an experiment where improved ADG, ADFI, and F/G were observed in one research farm, but these responses were not able to be replicated in another two farms during the same feeding period; likewise, antibiotics were reported to enhance pig growth performance in two out of the three farms, but no effect was observed in the third farm.

In summary, these results suggest that the gluco-oligosaccharide used in these studies may improve growth performance of nursery pigs, especially during the early post-weaning period, and the magnitude of these effects may be related to the concentration of gluco-oligosaccharide and independent to the use of antibiotic in the diets. However, further research is required to confirm the consistency of pigs' responses to antibiotic and gluco-oligosaccharide treatments.

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

Items	Phase 1[1]	Phase 2[1]
Ingredients, %		
Corn	50.53	56.85
Soybean meal (48% CP)	25.35	29.81
Corn DDGS, 6-9% oil	7.50	10.00
Fish meal	3.75	0.00
Dried whey	10.00	0.00
Calcium carbonate	0.90	1.15
Monocalcium phosphate (22% P)	0.35	0.80
Sodium chloride	0.35	0.35
L-Lys HCl	0.40	0.45
DL-Met	0.15	0.13
L-Thr	0.16	0.15
L-Trp	0.03	0.02
Phytase[2]	0.03	0.03
Zinc oxide	0.26	0.00
Tri-basic copper chloride	0.03	0.03
Trace mineral premix	0.13	0.13
Vitamin premix	0.10	0.10
Antibiotic[3]	---	---
Gluco-oligosaccharide premix[4]	---	---
Total	100.00	100.00

continued

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

Items	Phase 1[1]	Phase 2[1]
Calculated analysis		
Standardized ileal digestible (SID) AA, %		
Lys	1.35	1.30
Ile:Lys	59	60
Leu:Lys	125	131
Met:Lys	36	34
Met and Cys:Lys	57	56
Thr:Lys	64	63
Trp:Lys	18	19
Val:Lys	65	66
Total Lys, %	1.52	1.47
CP, %	22.44	22.28
ME, kcal/lb	1,502	1,490
NE, kcal/lb	1,015	966
SID Lys:ME, g/Mcal	4.08	3.96
Ca, %	0.73	0.70
P, %	0.61	0.59
Available P, %	0.47	0.42

[1] Phase 1 diets were fed from d 0 to 14, and Phase 2 diets were fed from d 14 to 42.
[2] Optiphos 2000 (Enzyvia, Sheridan, IN).
[3] Carbadox (Mecadox, Phibro Animal Health Corp., Teaneck, NJ); product was added to the base diets at 55 ppm to form antibiotic treatments.
[4] Midori USA, Inc. (Cambridge, MA); product was added to the base diets at either 200, 400, or 600 ppm to form gluco-oligosaccharide treatments.

Table 2. Analyzed composition of experimental diets (as-fed basis)[1]

	Phase 1[2]								Phase 2[2]							
Antibiotic,[3] ppm:	0	0	0	0	55	55	55	55	0	0	0	0	55	55	55	55
Gluco-oligosaccharide,[4] ppm:	0	200	400	600	0	200	400	600	0	200	400	600	0	200	400	600
Room 1 and 2																
DM, %	89.4	89.0	89.8	89.4	89.0	89.1	89.6	89.4	88.7	88.9	88.3	88.2	89.0	88.4	88.9	88.5
CP, %	20.2	20.5	21.2	21.4	20.3	21.1	20.7	21.7	19.8	21.0	18.8	19.2	19.7	20.5	20.6	21.4
Fat, %	3.0	2.8	2.8	2.8	2.8	2.7	2.7	2.8	3.3	3.0	2.9	2.9	2.8	2.9	3.1	2.9
Ca, %	0.70	0.81	0.84	0.77	0.90	1.00	1.00	1.02	0.81	0.72	0.65	0.77	0.99	0.88	0.83	0.96
P, %	0.61	0.62	0.60	0.62	0.58	0.63	0.64	0.68	0.59	0.60	0.58	0.62	0.61	0.64	0.63	0.63
Carbadox,[5] ppm	< 1	---	---	< 1	47.0	---	---	45.0	< 1	---	---	1.5	50.0	---	---	41.0
Room 3																
DM, %	89.1	88.4	88.9	88.9	88.5	88.4	88.4	90.1	87.5	87.0	86.9	86.9	87.4	86.9	87.2	86.9
CP, %	20.2	20.7	21.5	21.7	21.2	21.4	21.6	22.2	21.9	19.5	21.6	21.3	20.4	21.1	21.9	21.7
Fat, %	3.1	3.1	3.0	2.9	2.9	3.0	2.8	2.9	2.9	2.7	2.8	2.7	2.5	2.6	2.6	3.2
Ca, %	0.77	0.84	0.80	0.79	0.91	0.94	1.05	0.95	0.74	0.75	0.76	0.80	1.16	1.06	0.97	0.85
P, %	0.57	0.60	0.61	0.63	0.62	0.65	0.64	0.64	0.57	0.60	0.63	0.60	0.59	0.62	0.60	0.60
Carbadox,[5] ppm	< 1	---	---	< 1	41.0	---	---	51.0	< 1	---	---	< 1	42.0	---	---	45.0

[1] Multiple samples of each diet were collected, blended and subsampled, and analyzed (Ward Laboratories, Inc., Kearney, NE).
[2] Phase 1 diets were fed from d 0 to 14, and Phase 2 diets were fed from d 14 to 42.
[3] Carbadox (Mecadox, Phibro Animal Health Corp., Teaneck, NJ).
[4] Gluco-oligosaccharide (Midori USA, Inc., Cambridge, MA).
[5] The diets with lowest and highest oligosaccharide content were tested for Carbadox as they were blended for the intermediate treatments.

Table 3. *P* values for the sources of variation in the analyses of growth performance[1]

Source of variation	d 0 to 14	d 14 to 28	d 28 to 42	d 0 to 42
BW[2,3]				
Antibiotic[4]	0.472	<0.001	<0.001	---
Gluco-oligosaccharide[5]	0.008	0.150	0.195	---
Room	<0.001	0.030	0.188	---
Antibiotic × gluco-oligosaccharide	0.410	0.505	0.603	---
Room × antibiotic	0.143	0.063	0.220	---
Room × gluco-oligosaccharide	0.772	0.168	0.059	---
ADG[3]				
Antibiotic	0.294	<0.001	<0.001	<0.001
Gluco-oligosaccharide	0.006	0.897	0.842	0.304
Room	<0.001	<0.001	0.093	0.002
Antibiotic × gluco-oligosaccharide	0.612	0.417	0.139	0.446
Room × antibiotic	0.083	0.143	0.947	0.243
Room × gluco-oligosaccharide	0.803	0.162	0.033	0.087
ADFI[3]				
Antibiotic	0.308	0.044	<0.001	<0.001
Gluco-oligosaccharide	0.397	0.761	0.591	0.559
Room	0.001	<0.001	0.235	0.065
Antibiotic × gluco-oligosaccharide	0.433	0.523	0.327	0.524
Room × antibiotic	0.244	0.139	0.490	0.201
Room × gluco-oligosaccharide	0.993	0.234	0.188	0.409
F/G[3]				
Antibiotic	0.958	<0.001	0.078	0.054
Gluco-oligosaccharide	0.007	0.724	0.883	0.070
Room	<0.001	0.026	0.666	0.033
Antibiotic × gluco-oligosaccharide	0.937	0.202	0.521	0.486
Room × antibiotic	0.234	0.997	0.085	0.609
Room × gluco-oligosaccharide	0.534	0.744	0.338	0.259

[1] A total of 3,456 pigs (PIC L337 × 1050, initially 12.4 lb BW) were used in a 42-d study. Pigs were housed in 3 commercial research rooms with 27 pigs per pen and a total of 16 pens per treatment.

[2] Body weight of pigs was recorded at the end of a feeding period.

[3] Effects of room × antibiotic × oligosaccharide interaction were not significant ($P > 0.40$) for the overall trial (d 0 to 42) and therefore, were removed from the statistical model.

[4] Carbadox (Mecadox, Phibro Animal Health Corp., Teaneck, NJ).

[5] Gluco-oligosaccharide (Midori USA, Inc., Cambridge, MA).

Table 4. Effects of antibiotic and increasing gluco-oligosaccharide on growth performance of pigs (Rooms 1 and 2)[1]

	Antibiotic,[2] ppm			Gluco-oligosaccharide,[3] ppm					Probability, $P <$		
										Gluco-oligosaccharide	
Item	0	55	SEM	0	200	400	600	SEM	Antibiotic	Linear	Quadratic
Removal, %	2.54	2.16	0.005	3.03	1.32	2.73	2.75	0.008	0.564	0.704	0.161
BW, lb											
d 0	11.9	11.9	0.12	11.8	11.9	11.9	12.0	0.13	0.596	0.115	0.712
d 14	21.1	21.3	0.23	20.8	21.1	21.4	21.5	0.25	0.073	0.001	0.758
d 28	35.0	36.3	0.41	35.0	35.5	35.9	36.2	0.45	<0.001	0.001	0.532
d 42	52.1	54.0	0.46	52.1	52.9	53.2	53.9	0.54	<0.001	0.002	0.985
d 0 to 14											
ADG, lb	0.58	0.60	0.008	0.56	0.58	0.59	0.61	0.010	0.026	0.000	0.901
ADFI, lb	0.79	0.81	0.010	0.79	0.80	0.81	0.80	0.012	0.067	0.224	0.475
F/G	1.37	1.36	0.019	1.41	1.38	1.36	1.32	0.022	0.305	<0.001	0.652
d 14 to 28											
ADG, lb	0.99	1.06	0.015	1.00	1.03	1.03	1.04	0.018	<0.001	0.047	0.403
ADFI, lb	1.41	1.45	0.019	1.40	1.43	1.45	1.44	0.022	0.010	0.087	0.317
F/G	1.42	1.38	0.007	1.40	1.39	1.40	1.39	0.010	<0.001	0.502	0.911
d 28 to 42											
ADG, lb	1.20	1.26	0.012	1.21	1.24	1.22	1.24	0.016	0.001	0.230	0.958
ADFI, lb	1.86	1.97	0.016	1.90	1.91	1.92	1.94	0.022	<0.001	0.146	0.785
F/G	1.55	1.57	0.016	1.56	1.55	1.57	1.56	0.018	0.020	0.712	0.710
d 0 to 42											
ADG, lb	0.92	0.97	0.008	0.92	0.95	0.95	0.96	0.010	<0.001	0.004	0.610
ADFI, lb	1.35	1.41	0.013	1.36	1.38	1.39	1.39	0.016	<0.001	0.063	0.550
F/G	1.46	1.46	0.008	1.47	1.46	1.46	1.45	0.009	0.136	0.007	0.998

[1] A total of 2,376 pigs (PIC L337 × 1050, initially 11.9 lb BW) were housed in rooms 1 and 2 and used in a 42-d study. Room 1 contained 48 pens with 6 pens per treatment and room 2 contained 40 pens with 5 pens per treatment.

[2] Carbadox (Mecadox, Phibro Animal Health Corp., Teaneck, NJ).

[3] Midori USA, Inc. (Cambridge, MA).

Table 5. Effects of antibiotic and increasing gluco-oligosaccharide on growth performance of pigs (Room 3)[1]

	Antibiotic,[2] ppm			Gluco-oligosaccharide,[3] ppm					Probability, $P <$		
										Gluco-oligosaccharide	
Item	0	55	SEM	0	200	400	600	SEM	Antibiotic	Linear	Quadratic
Removal, %	4.09	4.22	0.011	3.05	5.49	4.64	3.84	0.016	0.924	0.729	0.231
BW, lb											
d 0	13.5	13.5	0.18	13.4	13.4	13.5	13.6	0.19	0.561	0.079	0.541
d 14	23.2	22.9	0.34	22.8	23.1	23.2	23.1	0.37	0.237	0.333	0.399
d 28	34.4	34.6	0.61	34.6	34.7	34.5	34.1	0.67	0.691	0.370	0.604
d 42	53.4	54.1	0.68	54.1	53.5	54.5	53.0	0.81	0.299	0.389	0.414
d 0 to 14											
ADG, lb	0.54	0.53	0.012	0.53	0.53	0.54	0.54	0.016	0.224	0.427	0.941
ADFI, lb	0.85	0.84	0.015	0.83	0.85	0.84	0.85	0.018	0.461	0.450	0.549
F/G	1.57	1.60	0.028	1.58	1.60	1.59	1.57	0.033	0.208	0.701	0.498
d 14 to 28											
ADG, lb	0.86	0.89	0.023	0.90	0.87	0.87	0.85	0.027	0.250	0.070	0.856
ADFI, lb	1.21	1.20	0.028	1.24	1.21	1.21	1.17	0.034	0.920	0.073	0.777
F/G	1.40	1.36	0.011	1.37	1.39	1.39	1.38	0.015	0.005	0.856	0.322
d 28 to 42											
ADG, lb	1.23	1.27	0.018	1.27	1.22	1.29	1.22	0.024	0.029	0.505	0.707
ADFI, lb	1.89	1.96	0.025	1.95	1.89	1.98	1.88	0.034	0.035	0.495	0.509
F/G	1.54	1.54	0.024	1.54	1.55	1.54	1.54	0.026	0.865	0.926	0.530
d 0 to 42											
ADG, lb	0.88	0.90	0.012	0.90	0.88	0.90	0.88	0.016	0.214	0.396	0.997
ADFI, lb	1.33	1.35	0.020	1.35	1.32	1.36	1.31	0.024	0.350	0.391	0.615
F/G	1.50	1.49	0.011	1.49	1.50	1.50	1.49	0.013	0.215	0.917	0.127

[1] A total of 1,080 pigs (PIC L337 × 1050, initially 13.5 lb BW) were housed in rooms 3 and used in a 42-d study. Room 3 contained 40 pens with 5 pens per treatment.

[2] Carbadox (Mecadox, Phibro Pro, Teaneck, NJ).

[3] Midori USA, Inc. (Cambridge, MA).

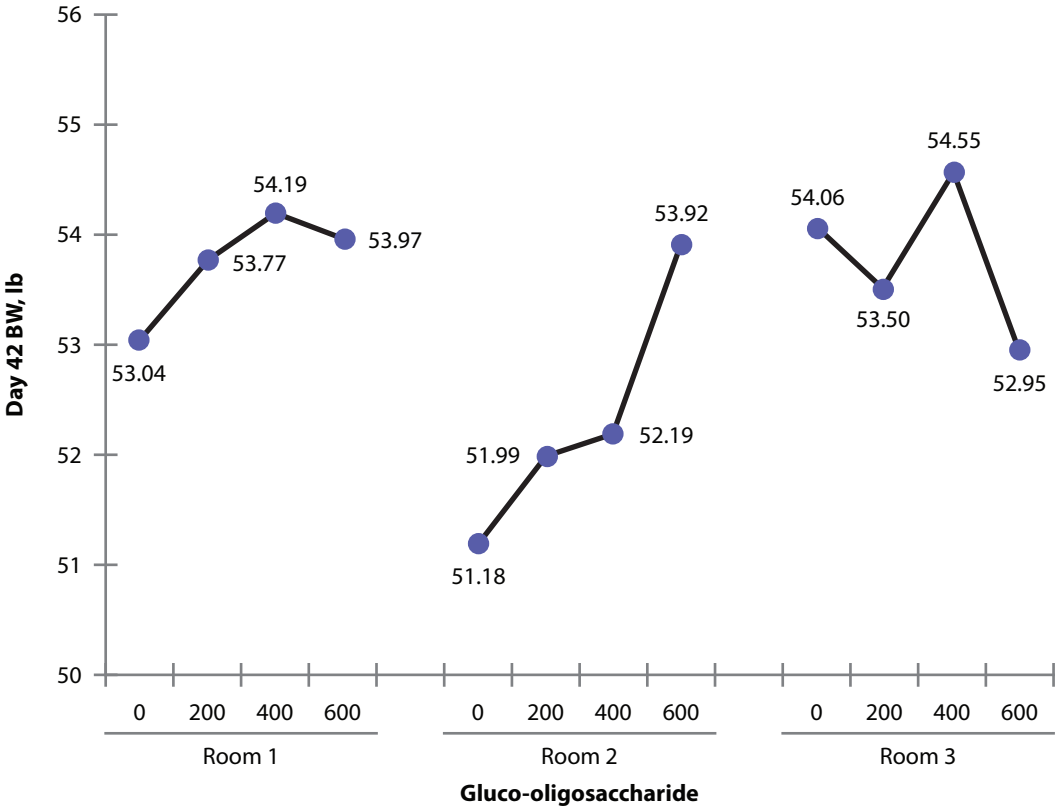

Figure 1. Effects of room × gluco-oligosaccharide interaction on day 42 BW ($P = 0.059$).

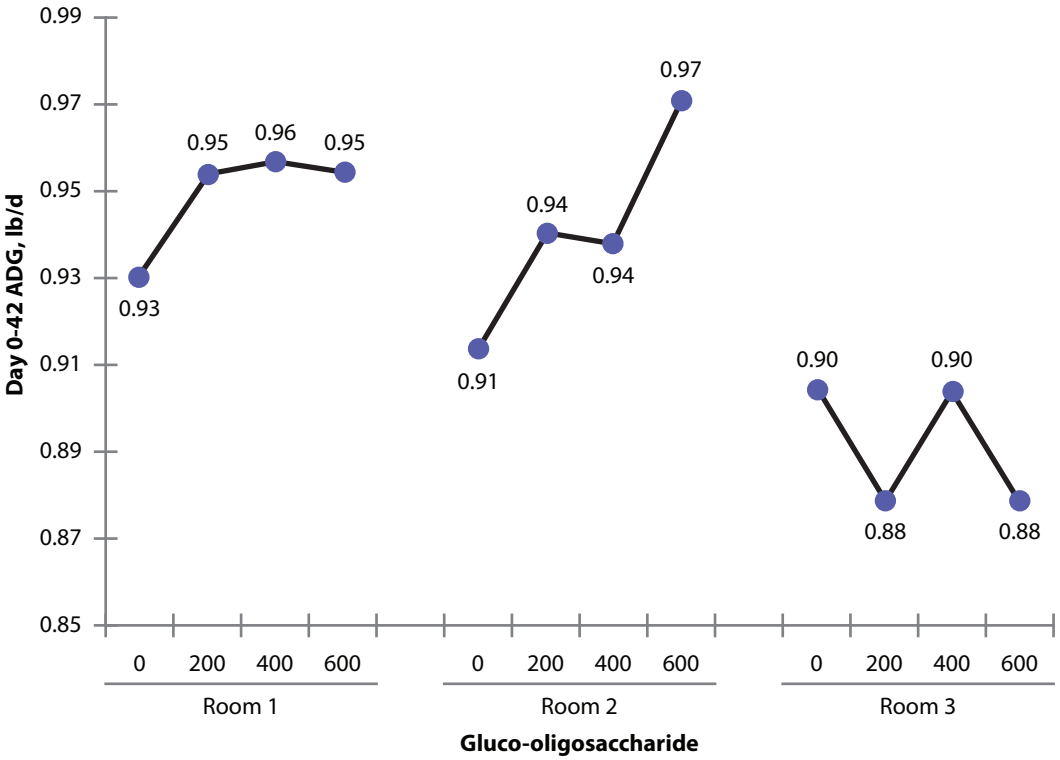

Figure 2. Effects of room × gluco-oligosaccharide interaction on overall ADG ($P = 0.087$).