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Effects of Insoluble Fiber Source (Cellulose or Distillers Dried Grains with Solubles) on Growth Performance of Nursery Pigs

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Abstract

A total of 3,171 weanling pigs (PIC 327 × L42) with an initial body weight (BW) of 12.7 lb were used in a 39-d study with 66 or 67 pigs per fence-line feeder (experimental unit) and 12 replicates per treatment. Pens were blocked by BW and allotted to 1 of 4 dietary treatments in a randomized complete block design. The treatment structure was a 2 × 2 factorial with 0 or 1% cellulose (Arbocel, J. Rettenmaier USA, Schoolcraft, MI) and distillers dried grains with solubles (DDGS; 0 or 5% in Phase 1 and 0 or 15% in Phase 2). Dietary phases 1 and 2 were offered from d 0 to 10 and 10 to 25, respectively. From d 25 to 39, pigs received a common diet with 25% DDGS.

Growth performance, pig removals, and economic variables were evaluated. From d 0 to 25, there was an interaction between cellulose and DDGS ($P = 0.040$) for average daily gain (ADG). Pigs fed diets with DDGS and cellulose had lower ADG than those fed diets without DDGS, with pigs fed diets with DDGS without the addition of cellulose having intermediate ADG. From d 25 to 39, there was a marginally significant interaction ($P = 0.080$) for average daily feed intake (ADFI). Pigs previously fed diets without DDGS and with cellulose had higher ADFI than those fed diets with DDGS and cellulose, and pigs previously fed diets without cellulose had similar ADFI regardless of DDGS inclusion.

In the overall period (d 0 to 39), there was an interaction between cellulose and DDGS ($P = 0.021$) for ADG, similar to d 0 to 25. There was a marginally significant interaction ($P = 0.070$) for pig removals. Adding cellulose to diets without DDGS resulted in numerical decrease in pig removals, but the inclusion of cellulose to diets with DDGS resulted in increased pig removals. For economics, an interaction was observed between cellulose and DDGS for income over feed cost (IOFC; $P = 0.014$). Pigs fed diets without DDGS and with the addition of cellulose had higher IOFC compared to pigs fed diets with DDGS and cellulose, with other treatments being intermediate.

In summary, the addition of cellulose to diets without DDGS resulted in slight improvements in pig removals and economic variables, with no evidence of impact on growth performance. The reduction in performance observed when cellulose was added to diets that contained DDGS may be due to a negative effect of the high fiber level.

Keywords

cellulose, distillers dried grains with solubles, growth, swine

Cover Page Footnote

Appreciation is expressed to Holden Farms Inc. (Northfield, MN) for providing animals and research facilities and to J. Rettenmaier USA (Schoolcraft, MI) for providing cellulose product (Arbocel).

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Effects of Insoluble Fiber Source (Cellulose or Distillers Dried Grains with Solubles) on Growth Performance of Nursery Pigs[1]

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

Summary

A total of 3,171 weanling pigs (PIC 327 × L42) with an initial body weight (BW) of 12.7 lb were used in a 39-d study with 66 or 67 pigs per fence-line feeder (experimental unit) and 12 replicates per treatment. Pens were blocked by BW and allotted to 1 of 4 dietary treatments in a randomized complete block design. The treatment structure was a 2 × 2 factorial with 0 or 1% cellulose (Arbocel, J. Rettenmaier USA, Schoolcraft, MI) and distillers dried grains with solubles (DDGS; 0 or 5% in Phase 1 and 0 or 15% in Phase 2). Dietary phases 1 and 2 were offered from d 0 to 10 and 10 to 25, respectively. From d 25 to 39, pigs received a common diet with 25% DDGS.

Growth performance, pig removals, and economic variables were evaluated. From d 0 to 25, there was an interaction between cellulose and DDGS ($P = 0.040$) for average daily gain (ADG). Pigs fed diets with DDGS and cellulose had lower ADG than those fed diets without DDGS, with pigs fed diets with DDGS without the addition of cellulose having intermediate ADG. From d 25 to 39, there was a marginally significant interaction ($P = 0.080$) for average daily feed intake (ADFI). Pigs previously fed diets without DDGS and with cellulose had higher ADFI than those fed diets with DDGS and cellulose, and pigs previously fed diets without cellulose had similar ADFI regardless of DDGS inclusion.

In the overall period (d 0 to 39), there was an interaction between cellulose and DDGS ($P = 0.021$) for ADG, similar to d 0 to 25. There was a marginally significant interaction ($P = 0.070$) for pig removals. Adding cellulose to diets without DDGS resulted in numerical decrease in pig removals, but the inclusion of cellulose to diets with DDGS resulted in increased pig removals. For economics, an interaction was observed between cellulose and DDGS for income over feed cost (IOFC; $P = 0.014$). Pigs fed diets without DDGS and with the addition of cellulose had higher IOFC compared to pigs fed diets with DDGS and cellulose, with other treatments being intermediate.

[1]Appreciation is expressed to Holden Farms Inc. (Northfield, MN) for providing animals and research facilities and to J. Rettenmaier USA (Schoolcraft, MI) for providing cellulose product (Arbocel).
[2]Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

In summary, the addition of cellulose to diets without DDGS resulted in slight improvements in pig removals and economic variables, with no evidence of impact on growth performance. The reduction in performance observed when cellulose was added to diets that contained DDGS may be due to a negative effect of the high fiber level.

Introduction

The nursery phase represents a period of high stress to pigs. Weaned pigs must adapt to abrupt dietary, social, and environmental changes. It is well known that the gastrointestinal tract (GIT) of a 3- to 4-week old pig is not fully developed to digest plant-based diets, and weaning stress can have a profound impact on the energy balance[3] and lead to morphological changes in the GIT.[4] Ultimately, these factors can influence nutrient utilization and compromise growth performance.

Dietary fiber has the ability to interact with both the GIT mucosa and microflora. Therefore, it may have an important role in gut health of young pigs.[4] In a recent review, Flis et al.[5] observed that dietary inclusion of insoluble fiber has the ability to improve growth performance, GIT development, and reduce the incidence of diarrhea and antibiotic interventions. Potential sources of insoluble fiber include wheat bran, oat hulls, or DDGS; however, these ingredients may contain mycotoxins or other components that can potentially reduce pig performance. Pure cellulose products allow for the addition of concentrated insoluble fiber to the diet without some of the risk associated with other sources.

Therefore, the objective of this study was to determine the effects of insoluble fiber sources, cellulose (Arbocel, J. Rettenmaier USA, Schoolcraft, MI) and DDGS, on growth performance of nursery pigs.

Procedures

The trial was conducted at a commercial research facility owned and operated by Holden Farms Inc. (Northfield, MN). A total of 3,171 pigs (PIC 327 × L42; 12.7 ± 0.17 lb initial BW) were used in a 39-d growth trial. There were 33 to 34 pigs per pen with two pens sharing a fenceline feeder. Therefore, there were 66 to 67 pigs per feeder, which served as the experimental unit. Pens were randomly assigned to dietary treatment within weight blocks. The treatment structure was a 2 × 2 factorial, with main effects of added cellulose (0 or 1%; Arbocel, J. Rettenmaier USA, Schoolcraft, MI) and DDGS (0 or 5% in phase 1 and 0 or 15% in phase 2 diets; Tables 1 and 2). Phase 1 diets were offered from placement until d 10, and phase 2 diets were offered from d 10 to 25. A common diet with 25% DDGS was offered from d 25 to 39. Daily feed additions

[3]Bruinix, E.M.A.M., C.M.C. Van der Peet-Schwering, J.W. Schrama, P.F.G. Vereijken, P.C. Vesseur, H. Everts, L.A. den Hartog, and A.C. Beynen. 2001. Individually measured feed intake characteristics and growth performance of group-housed weanling pigs: Effects of sex, individual body weight, and body weight distribution within groups. J. Anim. Sci. 79:301-308.
[4]Montagne, L., J.R. Pluske, and D.J. Hampson. 2003. A review of interaction between dietary fibre and the intestinal mucosa, and their consequence on digestive health in young non-ruminant animals. Anim. Feed Sci. Technol. 108:95-117.
[5]Flis, M., W. Sobotka, and Z. Antoszkiewicz. 2017. Fiber substrates in the nutrition of weaned piglets – a review. Ann. Anim. Sci. 17:627-643.

to each feeder were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) able to record feed amounts for individual pens.

Pens of pigs were weighed on d 0, 10, 18, 25, 32, and 39 of the trial to determine ADG, ADFI, and feed-to-gain ratio (F/G). An economic analysis was performed to determine the financial impact of dietary treatments, for which Arbocel was valued at \$0.60/lb and DDGS at \$114/ton. Feed cost per pig placed was calculated by multiplying the feed delivered to the pen by the feed cost and dividing by number of pigs placed. Revenue per pig placed was obtained by multiplying the final pen weight by an assumed value of \$0.60 per lb of live weight and dividing by the number of pigs placed. Income over feed cost per pig placed was calculated by subtracting feed cost per pig placed from revenue.

Growth performance data were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC) with two pens that shared a feeder as the experimental unit. The statistical model included dietary treatment as a fixed effect and block as a random effect. Removal data were analyzed with the GLIMMIX procedure specifying a binomial distribution. Results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

From d 0 to 25, there was an interaction between cellulose and DDGS ($P = 0.040$) for ADG (Table 3). Pigs fed diets with DDGS and cellulose had lower ADG than those fed diets without DDGS, regardless of addition of cellulose, with pigs fed diets with DDGS without the addition of cellulose having intermediate ADG. There was no evidence for interaction ($P > 0.10$) for ADFI or F/G. However, pigs fed diets with DDGS had lower (main effect; $P < 0.01$) ADFI and a marginally significant (main effect; $P = 0.062$) improvement in F/G. There was a significant (main effect; $P = 0.004$) response to cellulose for F/G, with pigs not fed cellulose having an improvement in F/G compared with pigs fed cellulose.

From d 25 to 39, when pigs were fed a common diet, there was no evidence for differences in ADG and F/G ($P > 0.10$). However, there was a marginally significant interaction ($P = 0.080$) for ADFI. Pigs previously fed diets without DDGS and with cellulose had higher ADFI than those fed diets with DDGS and cellulose. Pigs previously fed diets without cellulose had similar ADFI regardless of DDGS inclusion.

In the overall period (d 0 to 39), there was an interaction between cellulose and DDGS ($P = 0.021$) for ADG, similar to d 0 to 25. Feeding diets with DDGS and cellulose resulted in lower ADG compared to diets without DDGS with or without cellulose, whereas pigs fed diets with DDGS without the addition of cellulose were intermediate. The changes in ADG were driven mainly by the marginally significant interaction ($P = 0.057$) for ADFI. There was no evidence for interaction ($P > 0.10$) for F/G. There was a main effect ($P = 0.018$) of DDGS for F/G, with improved F/G when pigs received diets with DDGS.

Molist et al.[6] observed that weaned pigs fed diets with 8% wheat bran, an insoluble fiber source, had improved ADFI and marginally significant improvement in ADG compared to pigs fed a control diet. A similar improvement in growth performance of weaned pigs was observed by Schedle et al.[7] using 3% wheat bran and Gerristsen et al.[8] observed greater ADFI with diets containing oat hulls and wheat straw. However, results are not consistent and others have observed no evidence for effects of fiber sources on growth performance of weaned pigs.[9] An additional challenge for trials conducted with weanling pigs is the high variability in performance observed the first few weeks after weaning. In a recent literature review, Flis et al.[5] summarized that trials showing increased ADFI from supplementing insoluble fiber showed a benefit ranging from 4 to 54% in weaned pigs.

There was a marginally significant interaction ($P = 0.070$) for pig removals. Adding cellulose to diets without DDGS resulted in numerical decrease in pig removals, while the inclusion of cellulose to diets with DDGS resulted in increased pig removals.

Regarding economic effects, there was an interaction for feed cost, revenue, and IOFC ($P < 0.02$). The interaction for feed cost was a result of pigs fed diets without DDGS and the addition of cellulose having higher feed cost compared to those that did not have cellulose in their diet. However, for pigs fed diets with DDGS there was no evidence for difference in feed cost between diets with or without cellulose. For revenue and IOFC, pigs fed diets without DDGS and with the addition of cellulose had higher revenue and IOFC compared to pigs fed diets with DDGS and cellulose. Pigs fed diets without cellulose had similar feed cost regardless of whether DDGS was added or not, and these diets had intermediate revenue and IOFC compared to pigs fed diets with cellulose.

In summary, results of this study indicate there is an interaction between added dietary cellulose and DDGS. When added to diets without DDGS, cellulose resulted in slight improvements in pig removals and economic variables, with no evidence of impact on growth performance. The reduction in performance observed when cellulose was added to diets that contained DDGS may suggest a negative effect of high levels of dietary fiber. Further research should evaluate different inclusion levels and the impact of cellulose on gut microbiota.

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[6]Molist, F., A. Gómez de Segura, J. Gasa, R.G. Hermes, E.G. Manzanilla, M. Anguita, and J.F. Pérez. 2009. Effects of the insoluble and soluble dietary fibre on the physicochemical properties of digesta and the microbial activity in early weaned piglets. Anim. Feed Sci. Tech. 149:346-353.
[7]Schedle, K., C. Plitzner, T. Ettle, L. Zhao, K.J. Domig, and W. Windisch. 2008. Effects of insoluble dietary fibre differing in lignin on performance, gut microbiology, and digestibility in weanling piglets. Arch. Anim. Nutr. 62:141-151.
[8]Gerritsen, R., P. van der Aar, and F. Molist. 2012. Insoluble nonstarch polysaccharides in diets for weaned piglets. J. Anim. Sci. 90:318-320.
[9]Pascoal, L.A.F., M.C. Thomaz, P.H. Watanabe, U.S. Ruiz, J.M.B. Ezequiel, A.B. Amorim, E. Daniel, G.C.I. Masson. 2012. Fiber sources in diets for newly weaned pigs. R. Bras. Zootec. 41:636-642.

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

	Without DDGS[2]		With DDGS	
	Without cellulose	With cellulose	Without cellulose	With cellulose
Ingredients, %				
Corn	43.40	42.35	39.25	38.20
Soybean meal (46.5% crude protein)	18.25	18.30	17.50	17.55
DDGS	---	---	5.00	5.00
Fish meal	4.50	4.50	4.50	4.50
HP 300[3]	2.50	2.50	2.50	2.50
Spray-dried whey	25.00	25.00	25.00	25.00
Choice white grease	3.00	3.00	3.00	3.00
Monocalcium phosphate	0.50	0.50	0.40	0.40
Limestone	0.45	0.43	0.50	0.48
Salt	0.32	0.32	0.32	0.32
L-Lysine HCl	0.48	0.48	0.48	0.48
L-Threonine	0.19	0.19	0.18	0.18
L-Tryptophan	0.05	0.05	0.05	0.05
L-Valine	0.13	0.13	0.10	0.10
Methionine hydroxy-analog	0.26	0.26	0.24	0.24
Choline chloride (60%)	0.04	0.04	0.04	0.04
Phytase[4]	0.04	0.04	0.04	0.04
Zinc oxide	0.39	0.39	0.39	0.39
Vitamin E (20,000 IU)	0.05	0.05	0.05	0.05
Sodium metabisulfite	0.25	0.25	0.25	0.25
Selenium (0.06%)	0.05	0.05	0.05	0.05
Trace mineral premix	0.13	0.13	0.13	0.13
Vitamin premix	0.05	0.05	0.05	0.05
Cellulose[5]	---	1.00	---	1.00

continued

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

	Without DDGS[2]		With DDGS	
	Without cellulose	With cellulose	Without cellulose	With cellulose
Calculated analysis				
SID[6] amino acids, %				
Lysine	1.40	1.40	1.40	1.40
Isoleucine:lysine	54	54	55	55
Leucine:lysine	105	105	111	110
Methionine:lysine	37	37	36	36
Methionine and cystine:lysine	56	56	56	56
Threonine:lysine	62	62	62	62
Tryptophan:lysine	19.0	19.0	19.0	19.0
Valine:lysine	67	66	67	66
SID Lysine:net energy, g/Mcal	5.32	5.37	5.34	5.39
Net energy, kcal/lb	1,195	1,183	1,190	1,178
Crude protein, %	20.3	20.2	20.9	20.9
Calcium, %	0.71	0.71	0.71	0.71
STTD P,[7] %	0.60	0.59	0.59	0.59
NDF,[8] %	5.5	6.3	6.5	7.4

[1]Phase 1 was fed from d 0 to 10 (approximately 12.7 to 16.2 lb body weight).
[2]DDGS = dried distillers grains with solubles.
[3]Hamlet Protein (Findlay, OH).
[4]Quantum Blue 5G (AB Vista, Plantation, FL) provided 1,820 FTU/lb.
[5]Arbocel (J. Rettenmaier USA, Schoolcraft, MI).
[6]SID = standardized ileal digestible.
[7]STTD P = standardized total tract digestible P.
[8]NDF = neutral detergent fiber.

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

	Without DDGS[2]		With DDGS	
	Without cellulose	With cellulose	Without cellulose	With cellulose
Ingredients, %				
Corn	61.90	60.85	49.12	48.07
Soybean meal (46.5% crude protein)	26.64	26.71	24.76	24.83
DDGS	---	---	15.00	15.00
Fish meal	3.75	3.75	3.75	3.75
Choice white grease	1.00	1.00	1.00	1.00
Lactose replacement	2.50	2.50	2.50	2.50
Monocalcium phosphate	0.85	0.85	0.55	0.55
Limestone	0.70	0.68	0.85	0.83
Salt	0.60	0.60	0.60	0.60
L-Lysine HCl	0.45	0.45	0.45	0.45
DL-Methionine	0.20	0.20	0.14	0.14
L-Threonine	0.20	0.20	0.15	0.15
L-Tryptophan	0.04	0.04	0.04	0.04
L-Valine	0.08	0.08		
Zinc oxide	0.25	0.25	0.25	0.25
Iron oxide	0.10	0.10	0.10	0.10
Sodium metabisulfite	0.25	0.25	0.25	0.25
Vitamin-mineral premix with phytase[3]	0.50	0.50	0.50	0.50
Cellulose[4]	---	1.00	---	1.00

continued

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

	Without DDGS[2]		With DDGS	
	Without cellulose	With cellulose	Without cellulose	With cellulose
Calculated analysis				
SID[5] amino acids, %				
Lysine	1.35	1.35	1.35	1.35
Isoleucine:lysine	56	56	60	60
Leucine:lysine	113	113	130	130
Methionine:lysine	38	38	37	37
Methionine and cystine:lysine	59	59	59	59
Threonine:lysine	63	63	63	63
Tryptophan:lysine	18.8	18.8	18.8	18.8
Valine:lysine	67	67	67	67
SID Lysine:net energy, g/Mcal	5.48	5.54	5.55	5.61
Net energy, kcal/lb	1,117	1,105	1,103	1,091
Crude protein, %	21.1	21.0	23.2	23.1
Calcium, %	0.75	0.75	0.75	0.75
STTD P,[6] %	0.54	0.54	0.54	0.54
NDF,[7] %	7.8	8.7	11.1	11.9

[1]Phase 2 was fed from d 10 to 25 (approximately 16.2 to 28.4 lb body weight).
[2]DDGS = dried distillers grains with solubles.
[3]Quantum Blue 5G (AB Vista, Plantation, FL) provided 1,340 FTU/lb.
[4]Arbocel (J. Rettenmaier USA, Schoolcraft, MI).
[5]SID = standardized ileal digestible.
[6]STTD = standardized total tract digestible.
[7]NDF = neutral detergent fiber.

Table 3. Interactive effects of cellulose and distillers dried grains with solubles (DDGS) on growth performance of nursery pigs[1,2,3]

	Without DDGS		With DDGS			Probability, $P <$		
Item[4]	Without cellulose	With cellulose	Without cellulose	With cellulose	SEM	DDGS × cellulose	DDGS	Cellulose
BW, lb								
d 0	12.7	12.7	12.7	12.8	0.168	0.744	0.913	0.587
d 25	29.0	29.0	28.2	27.5	0.312	0.152	0.001	0.144
d 39	43.6	44.0	43.0	42.4	0.373	0.111	0.001	0.601
Experimental period (d 0 to 25)								
ADG, lb	0.63[a]	0.63[a]	0.60[ab]	0.57[b]	0.009	0.040	0.001	0.142
ADFI, lb	0.75	0.76	0.70	0.69	0.011	0.225	0.001	0.893
F/G	1.20	1.21	1.16	1.21	0.010	0.104	0.062	0.004
Post-test period (d 25 to 39)								
ADG, lb	1.08	1.11	1.10	1.11	0.018	0.304	0.486	0.154
ADFI, lb	1.63[xy]	1.66[x]	1.65[xy]	1.62[y]	0.018	0.080	0.401	0.779
F/G	1.51	1.50	1.50	1.47	0.016	0.554	0.088	0.160
Overall (d 0 to 39)								
ADG, lb	0.78[a]	0.80[a]	0.77[ab]	0.75[b]	0.008	0.021	0.001	0.777
ADFI, lb	1.05[xy]	1.07[x]	1.02[yz]	1.01[z]	0.010	0.057	0.001	0.742
F/G	1.35	1.35	1.33	1.34	0.006	0.431	0.018	0.250
Removals, %	6.4[x]	5.0[xy]	4.7[y]	6.3[x]	0.873	0.070	0.850	0.739
Economics, $/pig placed								
Feed cost[5]	5.06[b]	5.33[a]	4.82[c]	4.77[c]	0.060	0.012	0.001	0.065
Revenue[6]	24.49[ab]	25.13[a]	24.48[ab]	23.81[b]	0.246	0.011	0.010	0.953
IOFC[7]	19.43[ab]	19.80[a]	19.66[ab]	19.04[b]	0.197	0.014	0.169	0.504

[a,b]Means with different superscript are significantly different ($P \leq 0.05$).
[x,y,z]Means with different superscript are marginally significantly different ($0.05 < P \leq 0.10$).
[1]A total of 3,171 pigs (average initial BW = 12.7 lb) were used in a 39-d trial with 33 or 34 pigs per pen and 2 pens that share a feeder as the experimental unit.
[2]Cellulose (Arbocel, J. Rettenmaier USA, Schoolcraft, MI) was added at 1% from d 0 to 25.
[3]DDGS was added at 5% from d 0 to 10 and 15% from d 10 to 25.
[4]BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.
[5]Feed cost = (lb of feed delivered to pen × feed cost) ÷ number of pigs placed.
[6]Revenue = (final pen weight × $0.60) ÷ number of pigs placed.
[7]IOFC (income over feed cost) = revenue – feed cost.