Effects of Xylanase in Growing-Finishing Diets Varying in Dietary Energy and Fiber on Growth Performance, Carcass Characteristics, and Nutrient Digestibility[1]

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Summary

A total of 576 pigs (PIC TR4 × 1050, 106 lb initial BW) were used in a 75-d trial to evaluate effects of xylanase (Porzyme 93010; Danisco Animal Nutrition, St. Louis, MO) in growing-finishing diets varying in dietary energy and fiber on growth performance, carcass characteristics, and nutrient digestibility. Pens of pigs were randomly allotted to 1 of 6 dietary treatments in a 2 × 3 factorial (with or without xylanase and 3 dietary energy levels) with 8 pigs per pen and 12 replications per treatment. The 6 treatments consisted of corn-soybean meal-based diets with added dried distillers grains with solubles (DDGS), wheat middlings (midds), and choice white grease (CWG) arranged to make low- (30% DDGS, 12.5% midds, and 0% CWG), medium- (15% DDGS, 6.25% midds, and 1.2% CWG), and high-energy diets (0% DDGS, 0% midds, and 2.4 % CWG) with or without xylanase (0 or 4,000 units xylanase per kilogram of diet). Diets were formulated to contain increasing dietary CWG in the medium- and high-energy treatments to maintain uniform dietary crude fat levels. All diets were fed in meal form and in 4 phases. No xylanase × energy interactions ($P \geq 0.06$) occurred for any criteria evaluated. Overall (d 0 to 75), pigs fed diets with xylanase had poorer ADG ($P < 0.02$) compared with pigs fed diets without added xylanase. No differences were found in any other growth response criteria between pigs fed diets with or without xylanase. Pigs fed diets with increasing energy had improved (linear; $P < 0.001$) ADG and F/G with no effect on ADFI.

For carcass traits, increasing energy improved carcass yield (linear; $P < 0.01$) and HCW (linear; $P < 0.001$), but increased backfat depth (linear; $P < 0.01$). Furthermore, pigs fed diets with increasing energy had lower lean percentage (linear; $P < 0.003$) and jowl fat iodine value (IV) (linear; $P < 0.001$). Apparent fecal digestibility of ADF improved ($P < 0.002$) with the addition of dietary xylanase; however, there were no differences in any other nutrient digestibility criteria evaluated. As dietary energy increased, apparent digestibility of DM, N, fat, GE, ADF, and NDF increased (linear, $P < 0.02$). Feeding pigs diets with increasing energy levels resulted in improved performance over those fed low-energy diets. Although ADF digestibility was increased with xylanase supplementation, growth performance, carcass characteristics, and other nutrient digestibility values did not improve.

Key words: fiber, finishing pig, xylanase

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Introduction

During fermentation and milling processing of corn and wheat to produce DDGS and midds, the majority of the starch fraction is removed from the kernel. Thus, remaining components, such as fiber, increase in concentration. Both midds and DDGS have higher crude fiber content than corn, thus both contain more arabino-xylans. Arabinoxylans are hydrophilic non-starch polysaccharides (NSP) found in grain as minor constituents in the cell wall that act as anti-nutritional factors. Because swine do not digest NSP efficiently due to their lack of specific digestive enzymes, the dietary energy content of most grain by-products is lower than the parent grain. Under these conditions, endogenous enzymes such as xylanase may be supplemented into diets to make nutrients more available.

Xylanase is a carbohydrase, which is able to break some insoluble bonds that monogastric animals are otherwise unable to digest (Sugimoto and Van Buren, 1970[3]). Xylanase has also been successful in increasing nutrient digestibility of swine diets (Nortey et al., 2008[4]), but because corn is highly digestible and low in fiber, xylanase has not consistently shown improvements in growth performance when used in corn-based diets (Kim et al., 2003[5]). Therefore, xylanase may be more beneficial in corn-soybean meal-based diets when containing ingredients such as DDGS and midds.

The objective of this study was to evaluate xylanase in corn-soybean meal-based diets varying in dietary energy and fiber on growth performance, carcass characteristics, and nutrient digestibility of grow-finish pigs.

Procedures

The Institutional Animal Care and Use Committees at Kansas State University and Danisco Animal Nutrition approved protocols used in this experiment. This experiment was conducted at the K-State Swine Teaching Research Center finishing barn.

The facility was a totally enclosed, environmentally controlled, mechanically ventilated barn. The barn had 2 identical rooms containing 40 pens each. Each pen was equipped with a Farmweld (Teutopolis, IL) single-sided, dry self-feeder with 2 eating spaces in the fence line and a cup waterer. Pens were located over a completely slatted concrete floor with a 4-ft-deep pit underneath for manure storage. The facility was also equipped with an automated feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of delivering and recording diets as specified on an individual pen basis.

Animals and Diets. Two groups of finishing pigs were used to complete this experiment. The first group of pigs was fed from April through June 2010, and the second group was fed from May through July 2010. Both groups were fed 4-phase diets with the same time duration for each phase.

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[3] Sugimoto, H., and J. P. Van Buren. 1970. Removal of oligosaccharides from soy milk by an enzyme from *Aspergillussaitoi*. J. Food Sci. 35:655-660.

[4] Nortey, T. N., J. F. Patience, J. S. Sands, N. L. Trottier, and R. T. Zijlstra. 2008. Effects of xylanase supplementation on the apparent digestibility and digestible content of energy, amino acids, phosphorus, and calcium in wheat and wheat by-products from dry milling fed to grower pigs. J. Anim. Sci. 86:3450-3464.

[5] Kim, S.W., D. A. Knabe, K. J. Hong, and R. A. Easter. 2003. Use of carbohydrases in corn-soybean meal-based nursery diets. J. Anim. Sci. 81:2496-2504.

A total of 576 pigs (TR4 × 1050: PIC Hendersonville, TN; 106 lb initial BW) were used and stocked with 8 pigs (4 barrows and 4 gilts) in each pen. All pigs were assigned to pens by balanced initial BW and gender and were randomly allotted to 1 of 6 dietary treatments in a 2 × 3 factorial design with 12 replications per treatment in a 75-d experiment. The 6 treatments consisted of corn-soybean meal-based diets with DDGS, midds, and CWG to make low- (30% DDGS, 12.5% midds, and 0% CWG), medium- (15% DDGS, 6.25% midds, and 1.2% CWG), and high-energy diets (0% DDGS, 0% midds, and 2.4 % CWG), with or without xylanase (0 or 4000 units of xylanase per kilogram of diet; Porzyme 93010). Diets were formulated to contain increasing dietary CWG in the medium- and high-energy treatments to maintain uniform dietary crude fat levels. All diets were fed in meal form and pigs were fed in 4 phases from approximately 106 to 141, 141 to 181, 181 to 202, and 202 to 270 lb BW for Phases 1 through 4, respectively (Tables 1 and 2). Pigs were allowed ad libitum access to food and water. Diets were formulated to meet all requirements recommended by NRC (1998[6]).

Pigs and feeders were weighed on d 0, 17, 35, 52, and 75 to calculate ADG, ADFI, and F/G. Feed intake and F/G were determined from feed delivery data generated through the automated feeding system and the amount of feed remaining in each pen's feeder on every weigh date.

On d 75, pigs were weighed and transported to a commercial processing plant (Triumph Foods LLC, St. Joseph, MO). Each pig had been individually tattooed according to pen number to allow for data retrieval by pen and carcass data collection at the packing plant. Hot carcass weights were measured immediately after evisceration and each carcass was evaluated for backfat, loin depth, and lean percentage. Fat depth and loin depth were measured with an optical probe inserted between the 3rd and 4th last rib (counting from the ham end of the carcass) at a distance approximately 2.8 in. from the dorsal midline. Lean percentage was provided from the packing plant by using a proprietary equation. Jowl samples were collected and analyzed by Near Infrared Spectroscopy (NIR; Bruker MPA; Multi Purpose Analyzer) for fat IV. Percentage yield was calculated by dividing HCW by live weight obtained before transport to the packing plant.

Chemical Analysis. Feces samples were collected on d 7 of phase 3 (d 42 of trial) via rectal massage from at least 4 pigs/pen. All Phase 3 diets contained 0.5% chromic oxide as the digestibility marker. Samples of feces were stored in a freezer (-4°F) until they were then thawed and homogenized within each pen. Fecal samples were then dried at 122°F in a forced-air oven then ground for analysis of bomb calorimetry and chromium concentration.

Gross energy of diets and ground fecal samples were determined with an adiabatic bomb calorimeter (Parr Instruments, Moline, IL). Diets and ground fecal samples were also analyzed for chromium concentration with an atomic absorption spectrometer.

Samples of corn, soybean meal, DDGS (Abengoa, York, NE), and midds (Archer Daniels Midland, Lincoln, NE) were collected at the time of feed manufacture and a composite sample was analyzed for moisture, CP, crude fat, crude fiber, ash, Ca, and

[6] NRC. 1998. Nutrient Requirements of Swine. 10th ed. Natl. Acad. Press, Washington, DC.

P at Danisco Animal Nutrition Laboratory. A complete amino acid profile was also conducted at the University of Missouri Agricultural Experiment Station Chemical laboratories (Columbia, MO).

Diet samples were collected from each feeder and combined for a single composite sample by treatment for each phase to measure moisture, CP, crude fat, crude fiber, ash, Ca, P, and bulk density (Seedburo Model 8800, Seedburo Equipment, Chicago, IL). Fecal samples were also analyzed for moisture, CP, crude fat, crude fiber, ash, Ca, and P.

Xylanase activity was analyzed at Danisco Animal Nutrition Laboratory in which 1 unit of xylanase activity (XU) is defined as the amount of xylanase that will liberate 0.5 μmol of reducing sugars (expressed as xylose equivalents) from a cross-linked oat spelt xylan substrate (at pH 5.3 and 122°F in 1 min).

Statistical Analysis. Data were analyzed as a 2 × 3 factorial using the PROC-MIXED procedure in SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Linear and quadratic polynomial contrasts were conducted to determine effects of increasing dietary energy. Because HCW differed with treatments, it was used as a covariate for backfat, loin depth, and percentage lean. Results were considered significant at $P \leq 0.05$.

Results and Discussion

Chemical analysis. Ingredient samples of corn, DDGS, midds, and SBM were found to be generally similar to those used in formulation (Table 3). The minor differences would not be expected to influence the results of the experiment. Nutrient analysis of the treatment diets showed that for most of the nutrients, the levels were similar to formulated values (Tables 4 and 5). The only exception was crude fat, where all values were lower than expected, especially for the high-energy diets where the greatest level of CWG was added.

Treatment diets containing xylanase were formulated to contain 4,000 units of xylanase activity per kilogram of diet. Chemical analysis revealed some variation in dietary xylanase activity. On average, most of the treatments tested slightly below formulated levels. As midds and DDGS were added to the diets in increasing amounts, dietary bulk density was decreased as expected.

Growth and Carcass. No xylanase × energy interactions occurred for any growth performance criteria evaluated (Table 6); thus, for overall (d 0 to 75) main effects, pigs fed diets with xylanase had poorer ($P < 0.02$) ADG compared with pigs fed diets without added xylanase (Table 7), but no differences were found among treatments for ADFI or F/G. Pigs fed diets with increasing energy had improved (linear; $P < 0.001$) ADG and F/G, with no change in ADFI. Due to the improvement in ADG from increasing diet energy, final BW was also increased (linear, $P < 0.01$).

There were no xylanase × energy interactions for any carcass criteria evaluated. Pigs fed diets with increased energy had improved yield (linear; $P < 0.01$) and HCW (linear; $P < 0.001$), but also had increased backfat depth (linear; $P < 0.001$). Furthermore, pigs fed diets with increased energy had lower lean percentage (linear; $P < 0.003$) and jowl fat IV (linear; $P < 0.001$). The lower IV with increasing dietary energy was due to the changing composition of the dietary fat from more to less polyunsaturated fat sources whereas the crude fat content of the diets was similar across treatments. Additionally, dietary energy did not affect loin depth. Adding xylanase to the diet did not influence carcass characteristics.

Nutrient Digestibility. No significant xylanase × energy interactions occurred for apparent digestibility in this study (Table 8). Thus, for the main effects, apparent fecal digestibility of ADF improved ($P < 0.002$) with the addition of dietary xylanase (Table 9); however, no differences occurred in any other nutrient digestibility criteria evaluated. Also, as dietary energy increased, apparent digestibility of DM, N, fat, GE, ADF, and NDF increased (linear, $P < 0.02$).

Although ADF digestibility increased with xylanase supplementation, growth performance, carcass characteristics, and other nutrient digestibility values did not improve. As expected, pigs fed diets of increasing dietary energy had improved performance compared with pigs fed low-energy diets. Due to the varied response to xylanase in different trials, more research is needed to further explain its mode of action and how it can affect finishing pig performance.

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

	Phase 1			Phase 2		
Xylanase:	+	+	+	+	+	+
Item Energy:	Low	Medium	High	Low	Medium	High
Ingredient,%						
Corn	42.20	57.83	73.17	45.11	60.97	76.42
Soybean meal (46.5% CP)	12.82	17.24	21.68	10.02	14.27	18.70
DDGS[2]	30.00	15.00	---	30.00	15.00	---
Wheat middlings	12.50	6.25	---	12.50	6.25	---
Choice white grease	---	1.20	2.45	---	1.15	2.35
Monocalcium phosphate (21% P)	---	0.05	0.50	---	---	0.40
Limestone	1.25	1.23	0.98	1.23	1.23	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.15	0.15	0.15	0.13	0.13	0.13
Trace mineral premix	0.15	0.15	0.15	0.13	0.13	0.13
L-Lysine HCl	0.39	0.33	0.27	0.37	0.31	0.25
DL-Methionine	---	0.01	0.05	---	---	0.03
L-Threonine	---	0.04	0.07	---	0.04	0.07
Phytase[3]	0.09	0.09	0.09	0.09	0.09	0.09
Xylanase premix[4]	0.10	0.10	0.10	0.10	0.10	0.10
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible (SID) amino acids						
Lysine, %	0.95	0.95	0.95	0.86	0.86	0.86
Methionine:lysine, %	32	30	31	34	31	30
Met & Cys:lys, %	67	61	58	71	63	58
Threonine:lysine, %	62	62	62	64	64	64
Tryptophan:lysine, %	17	17	17	17	17	17
Total lysine, %	1.11	1.08	1.06	1.01	0.99	0.96
CP, %	20.1	18.4	16.7	19.0	17.2	15.5
SID lysine:ME, g/Mcal	2.88	2.81	2.75	2.60	2.54	2.49
ME, kcal/lb	1,497	1,532	1,565	1,499	1,533	1,565
Ca, %	0.56	0.56	0.56	0.54	0.54	0.54
P, %	0.54	0.46	0.46	0.52	0.43	0.43
Available P, %	0.35	0.27	0.27	0.35	0.26	0.25
Crude fat, %	5.6	5.6	5.6	5.6	5.6	5.6
Crude fiber, %	4.5	3.5	2.5	4.5	3.4	2.4

[1] Dietary treatment fed in meal form from 106 to 141 lb BW for Phase 1 and from 141 to 181 lb BW for Phase 2.
[2] Corn dried distillers grains with solubles (Abengoa; York, NE).
[3] Phyzyme 600 (Danisco Animal Nutrition, St Louis, MO) provided 245 FTU/lb and 0.10% available P released.
[4] A premix was a mixture of Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO) with ground corn and provided 4,000 units of xylanase per kilogram of complete feed. For non-xylanase treatments, the premix was replaced by corn.

Table 2. Phase 3 and Phase 4 diet composition (as-fed basis)[1]

	Phase 3			Phase 4		
Xylanase:	+	+	+	+	+	+
Item Energy:	Low	Medium	High	Low	Medium	High
Ingredient,%						
Corn	46.90	62.60	78.12	49.79	65.59	81.12
Soybean meal (46.5% CP)	7.81	12.22	16.64	5.51	9.84	14.27
DDGS[2]	30.00	15.00	---	30.00	15.00	---
Wheat middlings	12.50	6.25	---	12.50	6.25	---
Choice white grease	---	1.20	2.35	---	1.20	2.40
Monocalcium phosphate (21% P)	---	---	0.35	---	---	0.30
Limestone	1.23	1.20	1.03	1.23	1.20	1.03
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.08	0.08	0.08
Trace mineral premix	0.10	0.10	0.10	0.08	0.08	0.08
L-Lysine HCl	0.34	0.28	0.22	0.29	0.24	0.18
DL-Methionine	---	---	0.03	---	---	0.02
L-Threonine	---	0.02	0.05	---	---	0.03
Phytase[3]	0.09	0.09	0.09	0.09	0.09	0.09
Xylanase premix[4]	0.10	0.10	0.10	0.10	0.10	0.10
Chromic oxide	0.50	0.50	0.50	---	---	---
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis						
Standardized ileal digestible (SID) amino acids						
Lysine, %	0.78	0.78	0.78	0.69	0.69	0.69
Methionine:lysine, %	37	32	30	40	35	31
Met & Cys:lys, %	75	67	60	82	73	63
Threonine:lysine, %	66	65	65	71	66	66
Tryptophan:lysine, %	17	17	18	18	18	18
Total lys, %	0.93	0.90	0.88	0.83	0.81	0.78
CP, %	18.1	16.4	14.6	17.2	15.5	13.7
SID lysine:ME, g/Mcal	2.37	2.32	2.27	2.09	2.04	1.99
ME, kcal/lb	1,492	1,528	1,560	1,501	1,536	1,569
Ca, %	0.53	0.53	0.53	0.52	0.52	0.52
P, %	0.51	0.42	0.41	0.51	0.42	0.39
Available P, %	0.35	0.25	0.23	0.34	0.25	0.22
Crude fat, %	5.7	5.7	5.7	5.8	5.8	5.8
Crude fiber, %	4.4	3.4	2.4	4.4	3.4	2.3

[1] Dietary treatment fed in meal form from 181 to 202 lb BW for phase 3 and from 202 to 270 lb for Phase 4.
[2] Corn dried distillers grains with solubles (Abengoa; York, NE).
[3] Phyzyme 600 (Danisco Animal Nutrition, St Louis, MO) provided 245 FTU/lb and 0.10% available P released.
[4] A premix was a mixture of Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO) with ground corn and provided 4,000 units of xylanase per kilogram of complete feed. For non-xylanase treatments, the premix was replaced by corn.

Table 3. Analyzed composition of dietary ingredients[1] (as-fed basis)

Item, %	Corn	DDGS[2]	Midds[4]	SBM
DM	83.1	90.3	86.9	88.4
CP	7.8 (8.5)[3]	26.9 (27.7)	15.6 (15.9)	46.1 (46.5)
Crude fat	4.1 (3.9)	9.3 (10.7)	4.7 (4.2)	1.3 (1.5)
Crude fiber	2.2 (2.2)	6.3 (7.3)	8.4 (7.0)	3.8 (3.9)
Ash	1.5	4.5	6.2	6.5
Ca	0.04 (0.03)	0.06 (0.2)	0.4 (0.1)	0.3 (0.3)
P	0.3 (0.3)	0.8 (0.8)	1.1 (1.0)	0.6 (0.7)
Phytic acid	0.8	0.7	3.2	1.7
ADF	3.02	11.15	11.55	4.47
NDF	11.84	35.23	40.78	7.48
Indispensable amino acids				
Arginine	0.41	1.20	1.02	3.36
Histidine	0.22	0.71	0.39	1.19
Isoleucine	0.30 (0.28)	1.01 (1.01)	0.44 (0.53)	2.15 (2.16)
Leucine	0.93 (0.99)	3.11 (3.17)	0.91 (1.06)	3.59 (3.66)
Lysine	0.29 (0.26)	0.82 (0.78)	0.66 (0.57)	2.95 (3.02)
Methionine	0.17 (0.17)	0.51 (0.55)	0.22 (0.26)	0.62 (0.67)
Phenylalanine	0.39	1.28	0.54	2.33
Threonine	0.29 (0.29)	1.00 (1.06)	0.50 (0.51)	1.68 (1.85)
Tryptophan	0.05 (0.06)	0.19 (0.21)	0.14 (0.20)	0.68 (0.65)
Valine	0.39 (0.39)	1.33 (1.35)	0.67 (0.75)	2.31 (2.27)
Dispensable amino acids				
Alanine	0.56	1.77	0.72	1.97
Asparagine	0.54	1.61	1.08	5.05
Cysteine	0.18 (0.19)	0.53 (0.57)	0.30 (0.32)	0.63 (0.74)
Glutamine	1.43	3.55	2.45	8.29
Glycine	0.34	1.09	0.79	1.94
Proline	0.60	1.91	0.80	2.30
Serine	0.34	1.10	0.54	2.03
Tyrosine	0.25	0.93	0.37	1.68

[1] Samples of corn, soybean meal, dried distillers grains with solubles (DDGS), and wheat middlings (midds) were collected at the time of feed manufacture and a composite sample was analyzed at Danisco Animal Nutrition Laboratory (St. Louis, MO).
[2] Corn dried distillers grains with solubles from Abengoa, York, NE.
[3] Values in parentheses indicate those used in diet formulation.
[4] Wheat middlings from Archer Daniels Midland Co., Lincoln, NE.

Table 4. Chemical analysis and bulk density of Phase 1 and 2 diets (as-fed basis)

	Phase 1						Phase 2					
Xylanase[1]:	-	-	-	+	+	+	-	-	-	+	+	+
Item, % Energy:	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
DM	87.4	86.8	86.0	87.8	86.8	86.0	87.4	86.9	86.4	87.5	86.9	86.7
CP	20.0	18.0	16.4	20.0	17.7	15.9	18.1	17.0	15.0	18.4	17.1	15.3
Crude fat	5.3	5.4	4.2	5.8	5.1	4.2	5.4	4.7	4.0	2.8	4.5	4.1
Crude fiber	3.9	3.2	2.3	4.3	3.1	1.9	4.1	3.2	1.7	4.4	3.2	1.9
Ash	4.9	4.9	3.7	5.0	4.9	4.0	4.6	4.6	3.6	4.7	4.3	3.7
Ca	0.67	0.67	0.65	0.75	0.69	0.68	0.60	0.71	0.69	0.66	0.72	0.60
P	0.55	0.46	0.44	0.57	0.44	0.45	0.58	0.44	0.41	0.58	0.45	0.38
ADF	6.0	4.4	2.6	6.1	4.4	3.07	6.4	4.3	2.3	7.1	4.8	2.4
NDF	19.4	14.8	8.5	19.7	13.8	8.7	22.8	14.5	8.4	20.6	15.0	7.7
Xylanase activity,U/kg[2]	---	---	---	3,261	2,029	1,938	---	---	---	3844	3,343	5,642
Bulk density,g/L[3]	552	609	664	553	551	660	550	620	680	536	604	625

[1] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).
[2] One unit of xylanase activity is defined as amount of xylanase that will liberate 0.5 μmol of reducing sugars from a cross-linked oat spelt xylan (at pH 5.3 and 122°F) substrate in 1 min.
[3] Diet samples were collected from each feeder during each phase, combined, then subsampled for analysis.

Table 5. Chemical analysis and bulk density of Phase 3 and 4 diets (as-fed basis)

	Phase 3						Phase 4					
Xylanase[1]:	-	-	-	+	+	+	-	-	-	+	+	+
Item, % Energy:	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
DM	87.0	86.5	85.9	87.0	86.7	86.0	88.0	87.0	86.5	87.4	87.1	86.3
CP	17.2	16.2	14.2	18.3	16.1	14.8	16.9	14.8	12.6	16.6	14.9	13.0
Crude fat	5.4	5.4	4.3	5.5	4.7	3.8	5.4	4.6	4.4	5.1	4.5	3.7
Crude fiber	3.8	3.0	1.8	4.2	2.9	1.8	3.8	2.9	1.9	3.6	2.7	1.9
Ash	5.1	4.5	3.8	4.9	4.3	4.0	5.3	4.3	3.4	4.5	3.9	3.4
Ca	0.77	0.59	0.54	0.66	0.67	0.59	0.87	0.66	0.59	0.66	0.67	0.58
P	0.54	0.42	0.40	0.53	0.43	0.40	0.54	0.39	0.37	0.54	0.42	0.42
ADF	5.96	4.45	2.66	---	---	---	6.18	4.23	2.26	---	---	---
NDF	19.30	13.48	8.32	---	---	---	18.72	13.87	8.31	---	---	---
Xylanase activity, U/kg[2]	---	---	---	4,787	3,879	3,211	---	---	---	3,745	3,279	6,198
Bulk density, g/L[3]	552	609	669	566	604	663	554	599	652	545	582	651

[1] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).
[2] One unit of xylanase activity is defined as amount of xylanase that will liberate 0.5 μmol of reducing sugars from a cross-linked oat spelt xylan (at pH 5.3 and 122°F) substrate in 1 min.
[3] Diet samples were collected from each feeder during each phase, combined, then subsampled for analysis.

Table 6. Interactive effects of dietary xylanase and energy on finishing pig growth performance and carcass characteristics[1]

Xylanase[2]:	-	-	-	+	+	+		Probability, $P <$
Energy:	Low	Medium	High	Low	Medium	High	SEM	Xylanase × energy
Initial wt, lb	106.0	106.1	106.1	106.0	106.1	106.1	2.34	1.00
d 0 to 75								
ADG, lb	2.13	2.20	2.24	2.11	2.17	2.21	0.02	0.33
ADFI, lb	6.47	6.36	6.36	6.29	6.37	6.35	0.07	0.59
F/G	3.04	2.90	2.84	2.99	2.94	2.87	0.03	0.21
Final wt, lb	266.9	272.3	275.1	265.1	267.2	273.3	3.58	1.00
Carcass characteristics								
Yield, %[3]	72.1	73.5	73.4	72.7	72.4	73.4	0.43	0.14
HCW, lb	192.4	200.0	201.9	192.6	193.8	200.6	2.40	0.40
Backfat depth, in.[4]	0.77	0.82	0.85	0.77	0.81	0.85	0.25	0.88
Loin depth, in.[4]	2.34	2.37	2.32	2.34	2.30	2.38	0.28	0.06
Lean, %[4]	52.8	52.5	51.9	52.9	52.3	52.3	0.003	0.39
Jowl fat iodine value	76.0	72.7	69.2	75.5	72.2	69.1	0.36	0.78

[1] 576 pigs (PIC TR4 × 1050; 106 lb initial BW) were used in a 75-d study with 8 pigs per pen and 12 pens per treatment.
[2] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).
[3] Percentage yield was calculated by dividing HCW by live weight obtained before transport to the packing plant.
[4] Data analyzed using HCW value as a covariate.

Table 7. Main effects of dietary xylanase and energy level on finishing pig growth performance and carcass characteristics[1]

	Xylanase[2]		Energy			Xylanase	Energy	Probability, P <			
										Energy	
	-	+	Low	Medium	High	SEM	SEM	Xylanase	Energy	Linear	Quadratic
Initial wt, lb	106.1	106.1	106.0	106.1	106.1	1.36	1.66	1.00	1.00	0.98	0.98
d 0 to 75											
ADG, lb	2.19	2.16	2.12	2.17	2.22	0.01	0.01	0.02	<0.0001	<0.001	0.82
ADFI, lb	6.40	6.32	6.37	6.34	6.36	0.04	0.05	0.17	0.95	0.90	0.77
F/G	2.93	2.93	3.01	2.91	2.86	0.02	0.02	0.88	<0.0001	<0.001	0.49
Final wt, lb	271.4	268.5	266.0	269.7	274.2	2.07	2.53	0.31	0.07	0.02	0.89
Carcass characteristics											
Yield, %[3]	73.0	72.9	72.4	73.0	73.4	0.24	0.29	0.66	0.03	0.01	0.93
HCW, lb	198.1	195.7	192.5	196.9	201.3	1.17	1.56	0.22	0.002	0.001	0.93
Backfat depth, in.[4]	0.82	0.81	0.77	0.81	0.85	0.18	0.24	0.49	<0.001	<0.001	0.84
Loin depth, in.[4]	2.34	2.34	2.34	2.33	2.35	0.13	0.18	0.98	0.81	0.74	0.58
Lean, %[4]	52.4	52.5	52.8	52.4	52.1	0.002	0.002	0.72	0.01	0.003	0.80
Jowl fat iodine value	72.6	72.3	75.7	72.5	69.1	0.24	0.26	0.14	<0.001	<0.001	0.48

[1] 576 pigs (PIC TR4 × 1050: 106 lb initial BW) were used in a 75-d study with 8 pigs per pen and 12 pens per treatment.
[2] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).
[3] Percentage yield was calculated by dividing HCW by live weight obtained before transport to the packing plant.
[4] Data analyzed using HCW value as a covariate.

Table 8. Interactive effects of dietary xylanase and energy on finishing pig apparent total tract digestibility[1]

	Xylanase[2]:	-	-	-	+	+	+		Probability, $P <$
Item, %	Energy:	Low	Medium	High	Low	Medium	High	SEM	Xylanase × energy
DM		72.5	78.5	82.6	74.6	78.7	83.2	1.35	0.59
N		69.6	72.5	76.9	72.3	70.4	77.8	1.81	0.26
Fat		42.4	52.0	49.9	45.7	49.8	50.9	2.68	0.49
GE		69.1	75.6	81.3	72.1	75.9	81.1	1.29	0.36
ADF		60.4	68.0	60.9	66.6	68.8	68.3	2.08	0.17
NDF		39.7	50.9	56.2	49.1	48.4	58.0	2.65	0.06

[1] Fecal samples were collected on d 7 of phase 3 (d 42 of trial) via rectal massage from at least 4 pigs/pen.
[2] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).

Table 9. Interactive effects of dietary xylanase and energy on finishing pig apparent total tract digestibility[1]

								Probability, $P <$			
	Xylanase[2]		Energy			Xylanase	Energy			Energy	
Item, %	-	+	Low	Medium	High	SEM	SEM	Xylanase	Energy	Linear	Quadratic
DM	77.9	78.8	73.5	78.6	82.9	1.07	1.14	0.22	<0.0001	<0.0001	0.84
N	73.0	73.5	71.0	71.4	77.4	1.32	1.45	0.67	<0.0001	<0.0001	0.02
Fat	48.2	48.8	44.2	50.9	50.4	1.90	2.11	0.72	0.005	0.006	0.07
GE	75.3	76.4	70.6	75.8	81.2	0.82	0.95	0.29	<0.0001	<0.0001	0.72
ADF	63.1	67.9	63.5	68.4	64.6	1.35	1.56	0.002	0.02	0.52	0.008
NDF	49.0	51.8	44.5	49.6	57.1	1.61	1.91	0.16	<0.0001	<0.0001	0.50

[1] Fecal samples were collected on d 7 of phase 3 (d 42 of trial) via rectal massage from at least 4 pigs/pen.
[2] Porzyme 93010 (Danisco Animal Nutrition, St Louis, MO).