Effects of Non-Starch Polysaccharide Enzymes (Roxazyme G2G and/or Ronozyme VP) on Growth Performance of Nursery Pigs Fed Normal or Drought-Stressed Corn[1]

C.K. Jones[2], E.L. Franz, H.L. Frobose, J.M DeRouchey, R.D. Goodband, M.D. Tokach, and J.R. Bergstrom[3]

Summary

A total of 360 barrows (PIC 1050 × 337, initially 12.9 lb BW) were used to determine the effects of non-starch polysaccharide enzymes (Roxazyme G2G and/or Ronozyme VP; DSM Nutritional Products, Inc., Parsippany, NJ) on growth performance and nutrient digestibility of nursery pigs fed normal or drought-stressed corn. Initially, corn samples were collected from 34 separate lots and analyzed to find representatives of normal and drought-stressed corn. These same lots were also used in a separate experiment measuring the impact of drought stress on diet manufacturing characteristics. The lot selected to represent the normal corn had a test weight of 55.9 lb/bu, <5 ppb aflatoxin, 15.0% moisture, and contained 0.77% β-glucan. The lot selected to represent drought-stressed corn had a test weight of 54.3 lb/bu, 6 ppb aflatoxin, 14.3% moisture, and 0.83% β-glucan. Pigs were allotted to pens at weaning (d 0) and were acclimated to a common diet for 10 d prior to the start of this experiment. On d 10 post-placement, pigs were weighed and pens of pigs randomly allotted to 1 of 8 dietary treatments in a completely randomized design. Treatments were arranged in a 2 × 4 factorial with main effects of corn (normal vs. drought-stressed) and enzyme inclusion (none vs. 100 ppm Roxazyme G2G vs. 250 ppm Ronozyme VP vs. 100 ppm Roxazyme G2G + 250 ppm Ronozyme VP). Pigs were fed experimental treatments from d 10 to 35 postweaning in two phases. Feed and fecal samples were collected on d 30 postweaning and analyzed to determine apparent total tract digestibility of nutrients.

The nutrient concentrations of normal and drought-stressed corn were similar, which resulted in few treatment or main effects differences of corn type or enzyme inclusion. No interactions were observed ($P > 0.24$) between corn source and enzyme inclusion. Overall (d 10 to 35), there was no effect on ADG or ADFI, but enzyme inclusion tended to improve ($P = 0.09$) F/G, which was primarily driven by the improved ($P = 0.04$) feed efficiency of pigs fed Roxazyme G2G in Phase 1 (d 10 to 25 postweaning). In conclusion, drought stress did not alter the non-starch polysaccharide concentration of corn. Because non-starch polysaccharide substrates were similar across treatments, it was not surprising that enzyme inclusion showed little benefit to nursery pig growth performance; however, improved feed efficiency of pigs fed diets containing Roxazyme G2G from d 10 to 25 postweaning warrants further investigation.

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[2] Department of Grain Science and Industry, Kansas State University.

[3] DSM, Nutritional Products, Parsippany, NJ.

Introduction

Drought conditions are known to affect corn test weight and may affect swine growth performance, but whether commercially available carbohydrase enzymes can mitigate this effect is unknown. When water-stressed, the ratio of corn endosperm (starch-containing portion) to germ (protein and oil-containing portion) decreases, which in turn increases the protein percentage of the grain. In addition, as the endosperm fraction decreases, the pericarp, or hull, portion increases proportionally. This pericarp fraction is primarily composed of non-starch polysaccharides, such as arabinoxylan, β-glucans, α-galactosidans, and galactomannans, which pigs cannot digest.

Although commercial carbohydrase enzymes have not been consistently effective in corn-based diets, the hypothesized increase in non-starch polysaccharide substrate in drought-stressed corn could create an opportunity to realize beneficial enzyme responses. A commercial carbohydrase enzyme could improve the digestibility of these non-starch polysaccharides and thus help restore nutrient availability in drought-stressed corn. Therefore, the objectives of this experiment were to determine how drought stress affects corn composition and the effects of two commercially available carbohydrase enzymes on growth performance and nutrient digestibility of nursery pigs fed diets containing normal or drought-stressed corn.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Segregated Early Weaning Facility in Manhattan.

Initially, 34 samples of corn were collected and analyzed to determine those that would represent the normal and drought-stressed corn used in this experiment. The two lots were selected based on comparisons of growing season temperatures and precipitation as well as β-glucan concentration. The selected corn samples originated from either Harlan, IA (normal corn) or Lewis, IA (drought-stressed corn; Table 1).

A total of 360 barrows (PIC 1050 × 337, initially 12.9 lb and 21 d of age) were allotted to pens at weaning (d 0) and were acclimated to a common diet for 10 d. Starting on d 10 postweaning, pigs were utilized in a 25-d growth and nutrient digestibility experiment. Dietary treatments were arranged in a 2 × 4 factorial with main effects of corn (normal vs. drought-stressed) and enzyme inclusion (none vs. 100 ppm Roxazyme G2G vs. 250 ppm Ronozyme VP vs. 100 ppm Roxzayme G2G + 250 ppm Ronozyme VP). Roxazyme G2G is a multipurpose enzyme cocktail containing cellulase, β-glucanase, and xylanase enzymes, and Ronozyme VP is a multipurpose enzyme cocktail containing β-glucanase, hemicellulase, and pectinase enzymes. On d 10 post-placement, pigs were weighed and pens of pigs randomly allotted to 1 of 8 dietary treatments in a completely randomized design with 5 pigs per pen and 9 pens per treatment. Pigs were provided unlimited access to feed and water through a 4-hole dry self-feeder and a cup waterer in each pen (5 × 5 ft). Treatments were fed in in two phases: Phase 1 from d 10 to 25 postweaning and Phase 2 from d 25 to 35 postweaning. Pigs were weighed and feed disappearance was measured on d 10, 25, and 35 postweaning.

Normal and drought-affected corn were ground in a hammer mill to a common particle size and similar SD. Within phase, all diets were manufactured from the same formulation (Table 2), with both corn types given equal nutritive value. The enzymes were included at the expense of corn. Diets included 0.4% titanium dioxide as an indigestible marker to determine apparent total tract digestibility of nutrients. Diets were analyzed for proximate analysis and carbohydrate composition. Feed and fecal samples were collected on d 30 post-placement, stored at 0°F, then oven-dried and analyzed for DM, ash, CP, crude fat, crude fiber, and titanium to calculate DM and apparent total tract digestibility.

Data were analyzed using the GLIMMIX procedure of SAS with the main effects and their interaction serving as fixed effects. There were no random effects. All interactions were insignificant ($P > 0.24$) and thus removed from the model. Preplanned orthogonal contrasts included enzyme vs. no enzyme inclusion (regardless of enzyme type or corn type), Roxazyme G2G inclusion vs. no enzyme inclusion (regardless of corn type), and Ronozyme VP inclusion vs. no enzyme inclusion (regardless of corn type). Results were considered significant if $P < 0.05$ and trends if $0.05 < P < 0.10$.

Results and Discussion

Total precipitation during the growing season for drought-stressed corn was 58% of the 5-year average compared with 83.5% for normal corn (Table 1). Average temperatures during the growing season for drought-stressed corn were 1.8°F warmer than normal corn. Normal corn substantially outyielded drought-stressed corn (140 vs. 87 bu/acre) and had a slightly heavier test weight (55.9 vs. 54.3 lb/bu). Chemical analysis of the grains showed that drought-stressed corn had 0.9% greater CP concentration as well as 21% greater lignin and 7% greater β-glucan concentration than normal corn, but other chemical components were similar (Table 2). These results partially confirmed our hypothesis because the increased CP concentration in drought-stressed corn suggests that the endosperm:germ ratio shifted; however, starch concentrations were actually 1.4% greater in drought-stressed grains, and differences in cellulose and hemicellulose concentrations were minimal.

Diet chemical analysis revealed that Phase 1 diets with Roxazyme G2G had an average of 1.6% more CP than other diets (Table 3). Diets manufactured with normal corn and no enzyme had 4.4% more starch than diets manufactured with drought-stressed corn and no enzyme, but this was reversed in Phase 2 diets. Interestingly, diets manufactured with drought-stressed corn and no enzyme had greater lignin concentrations than all other diets, particularly those with Roxazyme G2G or Ronozyme VP; however, neither starch nor any other non-starch polysaccharide concentrations were different, including cellulose, β-glucan, or hemicellulose.

During the overall period of both phases (d 10 to 35), dietary treatment did not affect BW, ADG, ADFI, or F/G (Table 4; $P > 0.10$). Preplanned orthogonal contrasts showed that, regardless of corn type, enzyme inclusion did not affect BW or ADFI. Pigs fed Roxazyme G2G tended to have greater ($P = 0.09$) overall ADG compared with those fed diets not containing enzymes. Pigs fed diets with Roxazyme G2G had improved ($P = 0.04$) feed efficiency compared with those not supplemented with Roxazyme from d 10 to 25 postweaning, but the overall effect on feed efficiency was insignificant ($P = 0.11$).

Similar to the treatment and contrast effects, there were few main effects of corn or enzyme type on growth performance (Table 5). Neither corn type nor enzyme inclusion affected BW, ADG, or ADFI. Enzyme inclusion tended to affect ($P = 0.09$) overall F/G, which again reflected improved feed efficiency in pigs fed diets including Roxazyme G2G.

Apparent total tract digestibility of ash and fat tended to be affected ($P = 0.10$) by treatment, but no other impacts on digestibility of DM, CP, or crude fiber were observed. Preplanned contrasts found significant improvement ($P = 0.03$) in ash digestibility in diets containing enzyme compared with those not containing enzyme, which was primarily driven by the improved ($P = 0.01$) ash digestibility of pigs fed diets containing Roxazyme G2G compared with those fed diets with no enzyme. Enzyme inclusion had no effects on digestibility of other nutrients ($P > 0.10$).

Pigs fed normal corn had improved fat digestibility compared with those fed drought-stressed corn ($P = 0.01$, 53.7 vs. 48.0%), but digestibility of other nutrients was not affected ($P > 0.47$) by corn type.

In conclusion, drought-stressed corn appears to have altered CP and starch content compared with normal corn, but the non-starch polysaccharide concentrations are not different, thereby disproving our hypothesis that they would be increased due to changes of the endosperm:pericarp ratio. Because non-starch polysaccharide substrates were similar across treatments, it was not surprising that enzyme inclusion showed little benefit to nursery pig growth performance. Still, the improved feed efficiency of pigs fed diets containing Roxazyme G2G during Phase 1 warrants further investigation.

Table 1. Growing conditions, characteristics, and nutrient composition of corn types

Item	Normal corn[1]	Drought corn[2]
Growing conditions (March through September 2012)		
Temperature		
Average actual temperature, °F[3]	63.9	65.7
Difference from normal average temperature, °F	-3.5	-1.7
Percentage of normal average temperature, %	94.8	97.5
Precipitation		
Total actual rainfall, in.[4]	21.8	14.0
Difference from total normal rainfall, in.	-4.3	-12.1
Percentage of total normal rainfall, %	83.5	58.0
Average actual soil moisture, in.[3]	11.8	7.9
Characteristics		
Yield, bu/acre	140	87
Aflatoxin, ppb	< 5	6
Test weight, lb/bu	55.9	54.3
Moisture, %	15.0	14.3
Total damaged kernels, %	2.9	0.2
Broken corn and foreign material, %	0.5	0.8
Ground corn particle size mean (dgw), μm	404	403
Ground corn SD (sgw)	2.15	2.03
Analyzed nutrient composition, %		
CP	8.5	9.4
Moisture	12.6	12.4
Crude fat	3.2	3.2
Crude fiber	1.4	1.5
Ash	1.4	1.3
Starch	64.3	65.7
ADF	2.9	3.0
NDF	10.6	10.6
Cellulose	2.5	2.5
β-glucan	0.77	0.83
Calculated nutrient composition, %		
Lignin[5]	0.38	0.48
Hemicellulose[6]	7.8	7.6

[1] Grown in Lewis, IA.
[2] Grown in Harlan, IA.
[3] Calculated by the Climate Prediction Center, National Oceanic and Atmospheric Administration.
[4] As reported by the Advanced Hydrologic Prediction Service, National Oceanic and Atmospheric Administration.
[5] Calculated using the equation: ADF - cellulose = lignin.
[6] Calculated using the equation: NDF - ADF = hemicellulose.

Table 2. Diet composition (as-fed basis)

Item	Phase 1[1]	Phase 2[2]
Ingredient, %		
Corn	55.15	64.30
Soybean meal, 46.5%	27.15	30.40
Select menhaden fish meal	3.00	---
Spray-dried whey	10.00	---
Soy oil	2.00	2.00
Monocalcium P, 21% P	0.65	1.05
Limestone	0.89	1.00
Salt	0.35	0.35
Vitamin premix	0.25	0.25
Trace mineral premix	0.15	0.15
Lysine HCl	0.24	0.31
DL-methionine	0.12	0.12
L-threonine	0.11	0.12
Phytase[3]	0.02	0.02
Total	100	100
Calculated analyses		
Standardized ileal digestible (SID) amino acids, %		
Lysine	1.25	1.20
Isoleucine:lysine	62	62
Leucine:lysine	129	131
Methionine:lysine	34	33
Met & Cys:lysine	58	58
Threonine:lysine	64	63
Tryptophan:lysine	17.5	17.5
Valine:lysine	69	69
Total lysine, %	1.38	1.33
CP, %	20.8	20.0
ME, kcal/lb	1,547	1,550
Ca, %	0.80	0.70
P, %	0.64	0.61
Available P, %	0.50	0.43

[1] Phase 1 diets were fed from d 10 to 25 postweaning.
[2] Phase 2 diets were fed from d 25 to 35 postweaning.
[3] Ronozyme P-CT, DSM Nutritional Products, Parsipanny, NJ, provided 839 phytase units (FTU)/lb, with a release of 0.10% available P.

Table 3. Analyzed or calculated nutrient composition of nursery pig diets

Item	Normal + no enzyme	Drought + no enzyme	Normal + Roxazyme G2G	Drought + Roxazyme G2G	Normal + Ronozyme VP	Drought + Ronozyme VP	Normal + G2G + VP	Drought + G2G + VP
Phase 1 diet analyzed composition, %[1]								
CP	20.5	21.0	22.7	22.5	20.7	20.3	20.3	20.0
Moisture	9.9	9.7	9.0	9.8	9.7	9.4	9.8	9.5
Crude fat	3.4	4.4	3.8	3.6	4.2	4.7	4.6	4.3
Crude fiber	1.9	2.0	2.2	2.2	2.0	2.2	1.9	2.2
Ash	6.1	6.1	6.2	5.8	6.4	6.4	5.7	6.3
Starch	39.2	34.8	37.3	41.1	39.8	40.2	37.4	37.0
ADF	3.1	3.2	3.2	3.2	3.5	3.4	3.5	3.7
NDF	9.0	9.1	9.0	9.1	8.9	8.3	9.7	9.5
Cellulose	2.6	2.7	2.9	2.7	3.0	2.9	2.9	3.1
β–glucan	0.48	0.42	0.45	0.50	0.49	0.49	0.45	0.45
Phase 1 calculated composition, %[1]								
Lignin[1]	0.46	0.47	0.38	0.51	0.54	0.51	0.64	0.65
Hemicellulose[2]	5.9	5.9	5.8	5.9	5.4	4.9	6.2	5.7
Phase 2 analyzed composition, %[2]								
CP	21.0	17.8	21.2	18.7	18.1	20.0	19.9	19.8
Moisture	10.5	10.4	10.1	10.3	10.0	10.3	10.7	9.9
Crude fat	4.2	3.8	4.2	4.1	4.5	4.1	4.1	4.0
Crude fiber	2.5	2.2	2.3	2.7	2.2	2.6	2.3	2.3
Ash	4.9	5.3	5.6	5.9	5.5	5.4	5.7	5.3
Starch	40.2	43.3	45.4	47.2	46.9	45.8	46.4	41.4
ADF	3.6	3.7	3.4	3.7	3.2	3.8	3.4	3.8
NDF	9.8	9.8	9.3	10.3	10.0	10.8	9.8	9.3
Cellulose	3.3	3.3	3.2	3.4	2.9	3.5	3.2	3.5
β–glucan	0.49	0.53	0.55	0.58	0.57	0.56	0.57	0.50
Phase 2 calculated composition, %[2]								
Lignin[3]	0.35	0.42	0.17	0.29	0.31	0.31	0.29	0.28
Hemicellulose[4]	6.2	6.1	5.9	6.5	6.8	7.1	6.4	5.5

[1] Phase 1 diets were fed from d 10 to 25 postweaning.
[2] Phase 2 diets were fed from d 25 to 35 postweaning.
[3] Calculated using the equation: ADF - cellulose = lignin.
[4] Calculated using the equation: NDF - ADF = hemicellulose.

Table 4. Treatment effects of drought-affected corn and/or carbohydrase enzyme inclusion on nursery pig growth performance and nutrient digestibility[1]

										P =			
Item	Normal + no enzyme	Drought + no enzyme	Normal + G2G	Drought + G2G	Normal + VP	Drought + VP	Normal + G2G + VP	Drought + G2G + VP	SEM	Treatment	Enzyme vs. none[2]	Roxazyme G2G vs. none[2]	Roxazyme VP vs. none[2]
Body weight, lb													
d 0	12.9	12.9	12.9	12.9	12.9	12.8	12.9	12.9	0.01	0.92	0.26	0.63	0.20
d 10	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	0.21	1.00	0.76	0.99	0.50
d 25	25.8	25.3	26.6	26.2	25.8	25.4	25.9	25.9	0.67	0.92	0.50	0.23	0.95
d 35	38.7	37.4	39.0	38.9	37.5	37.8	38.6	37.5	0.91	0.80	0.83	0.33	0.65
d 10 to 25													
ADG, lb	0.74	0.70	0.79	0.76	0.71	0.71	0.74	0.71	0.036	0.67	0.58	0.14	0.78
ADFI, lb	1.01	1.01	1.03	1.01	1.01	1.00	1.00	0.98	0.039	0.99	0.91	0.77	0.94
F/G	1.36	1.44	1.30	1.33	1.42	1.41	1.35	1.38	0.020	0.24	0.28	0.04	0.66
d 25 to 35													
ADG, lb	1.21	1.21	1.24	1.27	1.17	1.24	1.27	1.17	0.048	0.66	0.74	0.38	0.82
ADFI, lb	1.85	1.74	1.88	1.84	1.81	1.82	1.85	1.74	0.058	0.62	0.57	0.28	0.73
F/G	1.53	1.44	1.52	1.45	1.55	1.47	1.46	1.49	0.023	0.73	0.93	0.99	0.60
d 10 to 35													
ADG, lb	0.92	0.91	0.97	0.96	0.89	0.92	0.95	0.89	0.030	0.41	0.49	0.09	0.77
ADFI, lb	1.34	1.30	1.37	1.34	1.33	1.33	1.34	1.28	0.042	0.89	0.73	0.40	0.82
F/G	1.46	1.43	1.41	1.40	1.49	1.45	1.41	1.44	0.012	0.22	0.19	0.11	0.35
ATTD, %[3]													
DM	85.3	85.9	85.3	85.9	85.2	84.9	85.3	84.2	0.78	0.85	0.51	0.94	0.51
Ash	47.1	49.4	54.2	58.5	50.3	49.6	54.9	54.1	2.82	0.10	0.03	0.01	0.57
CP	80.0	78.0	80.3	79.1	75.6	78.6	78.6	78.3	1.28	0.17	0.60	0.57	0.16
Fat	52.6	48.2	49.9	46.5	58.3	49.8	54.0	47.0	3.11	0.10	0.85	0.47	0.27
Fiber	58.4	43.9	51.6	66.9	60.0	59.6	63.2	45.5	8.82	0.54	0.37	0.35	0.35

[1] After a 10-d acclimation period, a total of 360 pigs were fed 1 of 8 treatment diets. There were 5 pigs per pen and 9 pens per treatment. Pigs were fed Phase 1 treatment diets from d 10 to 25 postweaning and Phase 2 diets from d 25 to 35 postweaning.

[2] Preplanned orthogonal contrasts to compare Roxazyme inclusion (regardless of or corn type) vs. no enzyme.

[3] Apparent total tract digestibility. Calculated from analyzed feed and fecal samples collected on d 30 of the experiment and analyzed using titanium dioxide as an indigestible marker.

Table 5. Main effects of drought-affected corn and/or carbohydrase enzyme inclusion on nursery pig growth performance and nutrient digestibility[1,2]

	Normal vs. drought				Enzyme inclusion					
Item	Normal	Drought	SEM	*P* =	None	Roxazyme G2G	Ronozyme VP	Roxazyme G2G + VP	SEM	*P* =
Body weight, lb										
d 0	12.9	12.9	0.01	0.78	12.9	12.9	12.9	12.9	0.01	0.53
d 10	14.8	14.8	0.11	0.87	14.8	14.8	14.8	14.8	0.15	1.00
d 25	26.0	25.7	0.33	0.48	25.8	26.2	25.6	25.9	0.46	0.82
d 35	38.4	37.9	0.44	0.46	38.3	38.7	37.6	38.1	0.63	0.66
d 10 to 25										
ADG, lb	0.74	0.72	0.017	0.40	0.73	0.77	0.71	0.73	0.025	0.43
ADFI, lb	1.01	1.00	0.019	0.64	1.02	1.01	1.01	0.99	0.027	0.89
F/G	1.38	1.39	0.019	0.65	1.39	1.33	1.43	1.37	0.027	0.11
d 25 to 35										
ADG, lb	1.22	1.22	0.025	0.93	1.22	1.25	1.20	1.22	0.034	0.80
ADFI, lb	1.85	1.79	0.029	0.15	1.81	1.85	1.81	1.79	0.041	0.82
F/G	1.52	1.47	0.026	0.20	1.49	1.49	1.52	1.48	0.037	0.89
d 10 to 35										
ADG, lb	0.92	0.93	0.015	0.61	0.93	0.96	0.91	0.92	0.021	0.33
ADFI, lb	1.34	1.31	0.021	0.30	1.33	1.35	1.33	1.31	0.029	0.86
F/G	1.44	1.42	0.013	0.32	1.44	1.40	1.47	1.42	0.019	0.09
ATTD, %[3]										
DM	85.3	85.2	0.39	0.85	85.6	85.6	85.1	84.8	0.55	0.65
Ash	51.6	53.1	1.38	0.47	48.2	56.3	50.2	54.7	1.95	0.02
CP	78.6	78.4	0.64	0.82	79.1	79.7	76.6	78.5	0.91	0.10
Fat	53.7	48.0	1.52	0.01	50.3	48.1	54.4	50.7	2.14	0.21
Fiber	85.3	85.2	0.39	0.85	85.6	85.6	85.1	84.8	0.55	0.65

[1] After a 10-d acclimation period, a total of 360 pigs were fed 1 of 8 treatment diets. Pigs were fed Phase 1 treatment diets from d 10 to 25 postweaning and Phase 2 diets from d 25 to 35 postweaning.
[2] Main effect interactions were not significant for any measured variable ($P > 0.24$) and were thus removed from the model.
[3] Apparent total tract digestibility. Calculated from analyzed feed and fecal samples collected on d 30 of the experiment and analyzed using titanium dioxide as an indigestible marker.