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Effects of enzyme supplementation and particle size of wheat-based diets on nursery and finishing pigs

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EFFECTS OF ENZYME SUPPLEMENTATION AND PARTICLE SIZE OF WHEAT-BASED DIETS ON NURSERY AND FINISHING PIGS [1]

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Summary

In nursery pigs, enzyme supplementation generally had no effect on ADG or F/G, but a trend occurred for greater digestibility of DM in pigs fed enzymes. However, one notable interaction occurred. Enzyme supplementation gave improved F/G at the coarser (1,300 mm) particle size but not at the finer (600 or 400 mm) particle sizes. In finishing pigs, trends for better F/G and digestibilities of DM and N with enzyme supplementation occurred in one experiment (1,300 vs 600 mm) but not in the other experiment (600 vs 400). Thus, the effects of enzyme supplementation were neither large nor consistent, but wheat particle sizes of 600 and 400 mm supported the best growth performances in nursery and finishing pigs, respectively.

(Key Words: Nursery Pigs, Finishing Pigs, Wheat, Enzymes, Particle Size.)

Introduction

Considerable attention has been given to evaluation of enzyme systems for use in diets for nonruminants. Early experiments demonstrated enhanced nutrient utilization and improved growth performance when barley-based diets were supplemented with b-glucanase and fed to poultry. Recently, phytase and b-glucanase have been used successfully in swine diets to enhance digestibility of phytin phosphorus and to reduce concentration of b-glucans.

In previous Swine Day Reports, we reported that wheat has a feeding value approximately 92% that of corn. One explanation for the lower feeding value may be the presence of pentosans, the nonstarch polysaccharide fraction. During digestion, pentosans increase the viscosity of the gastrointestinal fluid, so the flow of digesta is reduced, nutrients become inaccessible to intestinal secretions, and digestion is impaired. Reduction of the pentosan concentration via exogenous enzyme supplementation could result in better growth performance.

Thus, the objective of the experiments reported herein was to determine the effects of enzyme supplementation and particle size reduction in wheat-based diets on growth performance and nutrient digestibility in nursery and finishing pigs.

Procedures

In our first experiement, diets formulated with hard red winter wheat were fed without or with a wheat-specific enzyme product (Porzyme™ 9300; Finnfeeds International, Schaumburg, IL). The enzyme product was derived from *Trichoderma longibrachiatium* fermentation 'reesi' bacteria (xylanase activity of at least 4,000 units per gram of product) and was added at .1% of the finished diet. The wheat was ground coarsely (geometric mean particle size (d_{gw}) of 1,300 mm) in a two pair-high roller mill and ground to intermediate (d_{gw} of 600 microns) and fine (d_{gw} of 400 mm) particle sizes in a hammer-

[1]Appreciation is extended to Craig Wyatt and Finfeeds International for funding this project.

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mill equipped with 1/6 in. and 1/8 in. screens.

A total of 180 (PIC line 326 sires × C15 and C22 dams) nursery pigs with an average initial BW of 12.5 lb was used in a 35-d growth assay. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were six pigs per pen and five pens per treatment. Treatments were arranged as a 2 × 3 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size (1,300, 600, and 400 mm). The diets (Table 1) were formulated to 1.7, 1.5, and 1.3% lysine for d 0 to 7, 7 to 21, and 21 to 35, respectively.

The pigs were housed in an environmentally controlled nursery facility with 100% woven wire flooring. Each pen (4 ft × 5 ft) was equipped with a self-feeder and nipple waterer to allow ad libitum consumption of feed and water. Temperature at animal level was set initially at 90°F and was lowered by 3°F each week. Pigs and feeders were weighed at initiation and the end of each phase to allow calculation of ADG, ADFI, and F/G. On d 6 and 31, fecal samples were collected (four pigs per pen) by rectal massage; pooled within pen; dried; and analyzed for Cr, DM, and N.

The data were analyzed as a randomized complete block design with a 2 × 3 factorial arrangement of treatments using the GLM procedures of SAS. Treatment comparisons were made using polynomials for unequally spaced treatments in the orthogonal contrasts: 1) no enzyme vs enzyme; 2) particle size linear; 3) no enzyme vs enzyme × particle size linear; 4) particle size quadratic; and 5) no enzyme vs enzyme × particle size quadratic. Pen was the experimental unit.

In Exp. 2, a total of 160 (PIC line 326 sire × C15 and C22 dams) finishing pigs, with an average initial BW of 148 lb was used to determine the effects of enzyme supplementation of coarsely (1,300 mm) and intermediately (600 mm) ground wheat-based diets on growth performance, apparent nutrient digestibility, carcass characteristics, viscosity of intestinal digesta, and stomach morphology. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were 10 pigs per pen and four pens per treatment. Treatments were arranged as a 2 × 2 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size of the wheat(1300 mm vs 400 mm). The enzyme used and feed manufacturing processes were the same as those described for Exp. 1. The diets (Table 2) were formulated to .9 and .8% lysine, .6 and .5% Ca, and .5 and .4% P for the first and second phases, respectively. All other nutrient concentration met or exceeded NRC recommendations, and the diets were fed in meal form.

The pigs were housed in a modified open-front finishing facility with 50% solid-concrete and 50% concrete-slat flooring. Each pen (6 ft × 16 ft) was equipped with a two-hole self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Pigs and feeders were weighed at the initiation, middle, and conclusion of the growth assay to allow calculation of ADG, ADFI, and F/G. On d 23 (approximately midexperiment), fecal samples were collected (six pigs per pen) by rectal massage, pooled within pen, dried, and ground as described for Exp. 1. Concentrations of Cr, DM, and N in the feces and diets were determined.

When pigs in the heaviest pen in a weight block reached an average BW of 250 lb, the entire block was removed from the growth assay. Two blocks reached the end weight on d 51 and two blocks on d 58 of the experiment. The pigs were shipped at 3:00 a.m. to a commercial slaughter facility and killed at 7:00 a.m.. Hot carcass weight was recorded to allow calculation of dressing percentage. Last rib backfat thickness was measured on each half of the split carcass at the midline, and fat-free lean index was calculated using the equations suggested by the NPPC. Digesta samples (five pigs per pen and two pens per treatment) were collected from the terminal ileum and transferred to our laboratory in an ice bath. The samples were centrifuged, and fluid viscosity was measured at room temperature. Additionally, the esopha-

geal region of each stomach was collected and scored for severity of keratinization and ulceration. The scoring system used for keratinization was 0 = normal, 1 = mild, 2 = moderate, and 3 = severe keratosis, and that for ulcers was 0 = normal, 1 = erosion, 2 = ulcer, and 3 = severe ulcer.

The data were analyzed as a randomized complete block design with a 2 × 2 factorial arrangement of treatments, using the GLM procedures of SAS. Hot carcass weight was used as a covariate for the analyses of backfat thickness, dressing percentage, and fat-free lean index. Treatment comparisons were made using the orthogonal contrasts: 1) no enzyme vs enzyme; 2) 1,300 vs 600 mm; and 3) no enzyme vs enzyme × 1,300 vs 600 mm. Because stomach scores were categorical data, they were tested initially for significant main effects of enzyme supplementation and particle size using the Cohran-Mantel-Haenszel procedure of SAS (i.e., a row mean scores differ test for categorical data), with pen as the experimental unit.

For Exp. 3, a total of 160 (PIC line 326 sire × C15 and C22 dams) finishing pigs, with an average initial BW of 139 lb, was used to determine the effects of enzyme supplementation of intermediately (600 mm) and finely (400 mm) ground wheat-based diets on growth performance, apparent nutrient digestibility, carcass characteristics, viscosity of intestinal digesta, and stomach morphology. The pigs were grouped by initial BW and assigned to treatments based on sex and ancestry. There were 10 pigs per pen and four pens per treatment. Treatments were arranged as a 2 × 2 factorial with main effects of enzyme supplementation (none and .1% of the diet) and particle size of the wheat (600 vs 400 mm). The diets were formulated to the same nutrient concentrations used in Exp. 2 Housing and management of the pigs was the same as in Exp. 2.

Two blocks reached the targeted end weight of 250 lb on d 53 and two blocks on d 61 of the experiment. Slaughter procedures and collection of carcass data, digesta, and stomach tissues were the same as in Exp. 2, with the exception that digesta was collected from five pigs per pen in four pens per treatment. Laboratory analyses and statistical treatment of data were the same as in Exp. 2.

Results and Discussion

Laboratory analyses (Table 3) indicated that nutrient content was typical (11% moisture and 13.9% CP) for hard red winter wheat. A noteworthy exception was that pentosans were 28.7 g/lb. This value, although not unusual for the hard red wheat grown in Kansas, is quite low compared to some varieties grown elsewhere in the world (e.g., Canada and Europe). Also, mean particle sizes of the ground grain was very close to the targeted particle sizes of 1,300, 600, and 400 mm (Table 4).

For d 0 to 7 of the nursery experiement, a quadratic increase (P<.04) in F/G occurred as particle size was reduced, with 600 mm supporting the greatest efficiency of growth (Table 5). Overall (d 0 to 35), the best ADG (quadratic effect, P<.01) and F/G also were achieved at 600 mm. However, the effects of diet particle size and enzyme supplementation were not independent, with decreasing particle size improving overall F/G primarily in the diets without enzyme (enzyme supplementation × particle size quadratic effect, P<.01).

For finishing pigs (Exp. 2), ADG was not influenced (P>.15) by enzyme supplementation, but a trend (P<.10) for improved F/G occurred from 148 to 205 lbs. Also, enzyme supplementation resulted in trends for increased apparent digestibilities of DM (P<.10) and N (P<.07). Feed/gain was improved by reduced particle size in the 205 to 253 lb phase (P<.03), with numerical differences in favor of the smaller particle size overall. Reduced particle size also increased digestibilities of DM (P<.02) and N (P<.04).

Dressing percentage, last rib backfat thickness, and fat-free lean index were not influenced (P>.45) by the dietary treatments. Viscosity of the digesta also was not influenced by the dietary treatments (P>.42). This is in agreement with other research

reports suggesting that digesta viscosity is not influenced easily in pigs and, therefore, probably not a factor that routinely affects nutrient digestibility.

Keratinization score was greater (P<.01) in pigs fed the 600 versus 1,300 mm treatments (Table 7). However, stomach ulceration was not affected by reducing particle size to 600 mm (P>.15). These results are in contrast with some reports suggesting that wheat-based diets should be coarsely ground to avoid ulcer development in finishing pigs. Apparently, a combination of stressful factors is needed for pigs to develop stomach ulcers and, thus, blaming increased incidence of stomach lesions on finely ground, wheat-based diets is overly simplistic.

For the final finishing pig experiment (Exp. 3), enzyme supplementation increased ADG (P<.04) in the 198 to 253 lb phase of growth (Table 8). However, no other enzyme-related effects were observed (P>.11) for growth performance or digestibility of nutrients. Reducing particle size from 600 to 400 mm resulted in better F/G (P<.05) for the 139 to 198 lb and overall (P<.04) periods and better apparent digestibilities of DM and N (P<.01).

Carcass characteristics were not affected by enzyme treatment (P>.15); however, a trend (P<.06) occurred for reduced backfat thickness and, consequently, increased fat-free lean index as d_{gw} was reduced from 600 to 400 mm. Digesta viscosity was not influenced (P>.50) by the enzyme or particle size (P>15) treatments.

Stomach morphology was not affected by enzyme supplementation of the diets, but stomach keratinization and ulceration were increased (P<.01) as wheat particle size was reduced from 600 to 400 mm. However, these differences were not associated with negative effects on growth performance.

In conclusion, enzyme supplementation had beneficial effects but they were not large or consistent. Our results do not preclude the potential for a larger response to enzyme supplementation in diets based on wheat with greater pentosan content. Also, particle sizes of 400 to 600 mm improved F/G compared to 1,300 mm.

Jarrod Nash, undergraduate, and Mark Nelson, Swine Farm Manager.

Table 1. Compositions of Nursery Diets

Item	Phase 1	Phase 2	Phase 3
Ingredients, %			
Wheat (hard red winter)	32.89	54.30	70.46
Soybean meal (46.5% CP)	16.78	26.63	22.81
Edible grade whey	20.00	10.00	-
Lactose	10.00	-	-
Menhaden fish meal	5.00	1.00	-
Spray-dried porcine plasma	4.00	-	-
Spray-dried wheat gluten	4.00	-	-
Spray-dried blood meal	1.00	1.00	-
Soybean oil	2.00	2.00	1.00
Monocalcium phosphate	1.29	1.90	2.19
Limestone	.42	.71	.81
Salt	.10	.20	.30
Vitamin premix	.25	.25	.25
Trace mineral premix	.15	.15	.15
Zinc oxide	.39	.19	-
Cooper sulfate	-	-	.09
Lysine HCl	.30	.34	.45
DL-methionine	.18	.19	.13
Threonine	.05	.14	.16
Enzyme[a]	-	-	-
Chromic oxide[b]	.20	-	.20
Antibiotic[c]	1.00	1.00	1.00
Calculated analysis			
Crude protein (N × 6.25), %	25.80	23.50	21.20
Lysine, %	1.70	1.50	1.30
Ca, %	.90	.85	.80
P, %	.80	.75	.70
Metabolizable energy, kcal/lb	1,485	1,462	1,438

[a]Porzyme™ 9300 (Finnfeeds International) was added as .1% of the diets at the expense of corn.
[b]Used as an indigestible marker.
[c]Provided 75 mg of apramycin (Phases I and II) and 25 mg of carbadox (Phase III) per lb of complete diet.

Table 2. Compositions of Finishing Diets

Item	Phase 1	Phase 2
Ingredient, %		
Wheat (hard red winter)	85.76	90.95
Soybean meal (46.5% CP)	9.51	4.72
Soybean oil	1.00	1.00
Monocalcium phosphate	1.55	1.20
Limestone	.66	.60
Salt	.30	.30
Vitamin premix	.20	.20
Trace mineral premix	.15	.15
Lysine HCl	.38	.41
DL-methionine	.03	.02
Threonine	.13	.12
Enzyme[a]	-	-
Chromic oxide[b]	.20	.20
Antibiotic[c]	.13	.13
Calculated analysis		
Crude protein (N x 6.25), %	17.0	15.5
Lysine, %	.9	.8
Ca, %	.6	.5
P, %	.5	.4
Metabolizable energy, kcal/lb	1,463	1,466

[a]Porzyme™ 9300 (Finnfeeds International) was added as .1% of the diets at the expense of corn.
[b]Used as an indigestible marker.
[c]Provided 45.5 mg of tylosin per lb of complete diet.

Table 3. Chemical Analyses and Physical Characteristics of Hard Red Winter Wheat

Item	Amount
Bulk density, lb/bu	52
Foreign material, %	2.1
Dry matter, %	89
Crude protein (N x 6.25), %	13.9
Ether extract, %	1.7
Ash, %	1.7
Crude fiber, %	1.4
Nitrogen free extract, %	70.1
Pentosans, g/lb	28.7
Gross energy, kcal/lb	1,876
Amino acids, %	
Arginine	.63
Histidine	.30
Isoleucine	.44
Leucine	.89
Lysine	.37
Methionine	.21
Phenylalanine	.60
Threonine	.37
Tryptophan	.19
Valine	.58

Table 4. Characteristics of Ground Wheat[a]

	Treatment Particle Size, mm						
	Exp. 1			Exp. 2		Exp. 3	
Item	1,300	600	400	1,300	600	600	400
Geometric mean particle size, mm	1,352	614	390	1,288	628	614	406
Standard deviation of particle size	2.04	2.22	1.99	2.06	2.21	2.24	2.02
Surface area, cm^2/g	43	102	148	46	99	103	143
Distribution of particles, %[b]							
Sieve opening, mm							
4,760	0	0	0	0	0	0	0
3,360	.2	0	0	.2	.1	.1	.1
2,380	11.7	.2	0	10.4	.2	.2	.3
1,680	38.7	4.2	.2	35.5	4.3	4.7	.5
1,191	25.2	17.8	.9	25.8	18.9	18.3	1.2
841	7.7	22.2	11.9	9.7	22.0	20.6	14.1
594	3.5	13.8	17.4	4.5	14.0	13.8	17.6
420	3.4	12.3	20.1	4.0	11.9	12.5	18.0
297	3.4	10.4	17.6	3.6	9.7	9.4	15.0
212	3.1	8.7	14.2	3.3	8.9	10.4	15.1
150	1.2	4.0	7.0	1.2	4.0	3.7	8.8
103	.8	2.9	5.3	.7	2.6	2.8	6.1
74	.8	2.4	4.1	.8	2.4	2.5	2.5
53	.2	.8	1.0	.2	.8	.8	.5
Pan	.1	.3	.3	.1	.2	.2	.2

[a]Am. Soc. Agric. Engin. method (1995).

Table 5. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Nursery Pigs (Exp. 1)[a]

	No Enzyme			Enzyme				Contrasts[b]				
Item	1,300[c]	600	400	1,300	600	400	SE	1	2	3	4	5
Growth performance												
Day 0 to 7												
ADG, lb	.45	.59	.59	.62	.62	.52	.05	-[d]	-	.08	-	-
ADFI, lb	.64	.65	.64	.71	.70	.59	.06	-	.10	.12	-	-
F/G	1.42	1.10	1.08	1.14	1.13	1.13	.09	-	.05	.10	.04	.12
Overall (Day 0 to 35)												
ADG, lb	.90	1.00	.92	.95	1.03	.92	.02	-	-	.09	.01	-
ADFI, lb	1.20	1.15	1.15	1.19	1.26	1.11	.03	-	.01	-	-	.05
F/G	1.34	1.15	1.19	1.26	1.22	1.21	.06	-	.01	.14	.01	.01
Apparent digestibility, %												
Day 6												
DM	81.7	83.8	84.0	86.8	85.0	84.1	1.2	.08	-	.14	-	-
N	78.1	79.6	79.2	83.9	81.7	77.9	1.8	-	-	.12	-	-
Day 31												
DM	85.9	87.2	85.8	86.1	87.8	88.4	.7	.11	-	-	.12	-
N	85.4	86.9	85.5	85.5	88.0	88.5	1.1	-	-	-	-	-

[a]A total of 180 pigs (six pigs/pen and five pens/treatment) with an avg initial BW of 12.5 lb and an avg final BW of 46 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) particle size linear; 3) no enzyme vs enzyme × particle size linear; 4) particle size quadratic; and 5) no enzyme vs enzyme × particle size quadratic.
[c]Geometrical mean particle size, µm.
[d]Dashes indicate P>.15.

Table 6. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Finishing Pigs (Exp. 2)[a]

	No Enzyme		Enzyme			Contrasts[b]		
Item	1,300[c]	600	1,300	600	SE	1	2	3
Growth performance								
148 to 205 lb								
ADG, lb	2.08	2.00	2.10	2.01	.04	-[f]	.10	-
ADFI, lb	6.45	6.48	6.37	6.23	.09	.10	-	-
F/G	3.10	3.23	3.04	3.10	.01	.10	-	-
205 to 253 lb								
ADG, lb	1.78	1.91	1.74	1.83	.07	-	-	-
ADFI, lb	7.22	6.98	6.96	6.50	.15	.05	.06	-
F/G	4.05	3.66	3.99	3.55	.02	-	.03	-
Overall (148 to 253 lb)								
ADG, lb	1.93	1.96	1.93	1.92	.05	-	-	-
ADFI, lb	6.85	6.72	6.65	6.37	.09	.02	.06	-
F/G	3.55	3.43	3.46	3.31	.02	-	.14	-
Apparent digestibility, (d 23) %								
DM	83.7	87.6	86.7	87.6	.8	.10	.02	.10
N	80.4	85.5	85.1	85.9	1.2	.07	.04	.11
Carcass characteristics								
Dressing percentage	73.3	73.2	73.2	73.4	2	-	-	-
Last rib fat thickness, in	.81	.80	.80	.78	.03	-	-	-
Fat-free lean index, %[d]	50.0	50.1	50.0	50.3	.3	-	-	-
Digesta viscosity, cps[e]	5.0	3.9	5.1	4.4	.7	-	-	-

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 1,300 vs 600 microns; and 3) no enzyme vs enzyme × 1,300 vs 600 μm.
[c]Geometrical mean particle size.
[d]NPPC (1994) equation.
[e]A total of 40 pigs (five pigs/pen and two pens/treatment). Poise (cps) is equal to the viscosity of a fluid that would require a shearing force of 1 dyne to move a cm^2 of either layer of fluid 1 cm apart with a velocity of 1 cm/sec relative to the other layer with the space between the layers being filled with the fluid.
[f]Dashes indicate P>.15.

Table 7. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Stomach Morphology in Finishing Pigs (Exp. 2)[a]

	No Enzyme		Enzyme			Contrasts[b]		
Item	1,300[c]	600	1,300	600	SE	1	2	3
Stomach keratinization								
No. of observations	38	36	34	37	-	-	-	-
Normal	38	24	33	25	-	-	-	-
Mild	0	12	1	7	-	-	-	-
Moderate	0	0	0	2	-	-	-	-
Severe	0	0	0	3	-	-	-	-
Mean score[d]	0	.33	.03	.54	.12	NS[f]	.01	NS
Stomach ulceration								
No. of observations	38	36	34	37	-	-	-	-
Normal	38	35	34	36	-	-	-	-
Erosion	0	0	0	1	-	-	-	-
Ulcer	0	1	0	0	-	-	-	-
Severe ulcer	0	0	0	0	-	-	-	-
Mean score[e]	0	.06	0	.03	.04	NS	NS	NS

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 1,300 vs 600 μm; and 3) no enzyme vs enzyme × 1,300 vs 600 mm.
[c]Geometrical mean particle size.
[d]Scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe keratosis (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[e]Scoring system was: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P>.17).
[f]Not significant (P>.15).

Table 8. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Growth Performance and Apparent Nutrient Digestibility in Finishing Pigs (Exp. 3)[a]

	No Enzyme		Enzyme			Contrasts[b]		
Item	600[c]	400	600	400	SE	1	2	3
Growth performance								
139 to 198 lb								
ADG, lb	2.09	2.06	2.09	2.04	.05	-[f]	-	-
ADFI, lb	6.39	6.08	6.54	5.99	.09	-	.01	-
Feed/gain	3.05	2.96	3.13	2.94	.01	-	.05	-
198 to 253 lb								
ADG, lb	1.87	1.96	2.00	2.01	.04	.04	-	-
ADFI, lb	6.43	6.43	6.61	6.52	.11	-	-	-
Feed/gain	3.43	3.29	3.30	3.24	.02	-	-	-
Overall (139 to 253 lb)								
ADG, lb	1.98	2.01	2.05	2.02	.03	-	-	-
ADFI, lb	6.41	6.26	6.59	6.26	.09	-	.04	-
Feed/gain	3.23	3.11	3.22	3.10	.01	-	.04	-
Apparent digestibility, %								
DM	84.7	87.3	86.0	87.6	.6	.11	.01	-
N	81.9	86.6	84.8	87.3	1.0	-	.01	-
Carcass characteristics								
Dressing percentage	74.0	74.2	74.0	74.0	.1	-	-	-
Last rib fat thickness, in	.86	.84	.87	.81	.01	-	.06	-
Fat-free lean index, %[d]	49.6	49.8	49.5	50.0	.2	-	.06	-
Digesta viscosity, cps[e]	5.0	5.1	5.7	5.4	.7	-	-	-

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 148 and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 600 vs 400 mm; and 3) no enzyme vs enzyme × 600 vs 400 mm.
[c]Geometrical mean particle size.
[d]NPPC (1994) equation.
[e]A total of 40 pigs (five pigs/pen and two pens/treatment). Poise (cps) is equal to the viscosity of a fluid that would require a shearing force of 1 dyne to move a cm^2 of either layer of fluid 1 cm apart with a velocity of 1 cm per sec relative to the other layer with the space between the layers being filled with the fluid.
[f]Dashes indicate P>.15.

Table 9. Effects of Enzyme Supplementation and Particle Size of Wheat-Based Diets on Stomach Morphology in Finishing Pigs (Exp. 3)[a]

	No Enzyme		Enzyme			Contrasts[b]		
Item	600[c]	400	600	400	SE	1	2	3
Stomach keratinization								
No. of observations	38	35	33	36	-	-	-	-
Normal	26	4	24	2	-	-	-	-
Mild	6	12	7	18	-	-	-	-
Moderate	6	8	2	7	-	-	-	-
Severe	0	11	0	9	-	-	-	-
Mean score[d]	.47	1.74	.33	1.64	.15	NS[f]	.01	NS
Stomach ulceration								
No. of observations	38	35	33	36	-	-	-	-
Normal	37	21	33	30	-	-	-	-
Erosion	1	10	0	2	-	-	-	-
Ulcer	0	2	0	4	-	-	-	-
Severe ulcer	0	2	0	0	-	-	-	-
Mean score[e]	.03	.57	.0	.28	.09	.13	.01	NS

[a]A total of 160 pigs (10 pigs/pen and four pens/treatment) with an avg initial BW of 139 lbs and an avg final BW of 253 lb.
[b]Contrasts were: 1) no enzyme vs enzyme; 2) 600 vs 400 mm; and 3) no enzyme vs enzyme × 600 vs 400 mm.
[c]Geometrical mean particle size.
[d]Scoring system was: 0 = normal; 1 = mild; 2 = moderate; and 3 = severe ulceration (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[e]Scoring system was: 0 = normal; 1 = erosion; 2 = ulcer; and 3 = severe ulcer (Cochran-Mantel-Haenszel statistic, row mean scores differ test; P<.01).
[f]Not significant (P>.15).