Effects of Expander Processing and Enzyme Supplementation of Wheat-based Diets for Finishing Pigs**

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ABSTRACT : Two experiments were conducted to determine the effects of expander processing and enzyme supplementation of wheat-based diets on growth performance and nutrient digestibility in finishing pigs. For Exp. 1, 60 finishing pigs (average initial BW of 49.5 kg) were fed meal, standard pellets and expanded pellets in a 70 d growth assay. From 49.5 to 79.0 kg, 79.0 to 111.8 kg, and overall (49.5 to 111.8 kg), ADG and ADFI were not affected by pelleting or standard vs expander conditioning ($p>0.22$). However, from 49.5 to 79.0 kg, pigs fed pellets have greater gain/feed than pigs fed mash ($p<0.04$), and pigs fed expanded pellets tended to have greater ($p<0.10$) gain/feed than pigs fed standard pellets. Overall (i.e. from 49.5 to 111.8 kg), gain/feed ($p<0.02$) and apparent fecal digestibilities of DM ($p<0.001$) and N ($p<0.02$) were improved by pelleting the diets. Also, expander processing further improved gain/feed ($p<0.06$) and digestibility of DM ($p<0.04$) compared to standard steam conditioning. Scores for keratinization ($p<0.002$) and ulceration ($p<0.003$) of the stomach were increased by pelleting, but the mean scores for the various treatments ranged only from 0.05 to 1.08 (i.e., low to mild keratosis and ulceration). For Exp. 2, 80 pigs (average initial BW of 54.1 kg) were fed mash and pellets (standard or expander) without and with xylanase. The enzyme was added to supply 4,000 units of xylanase activity/kg of diet. Adding xylanase to the mash diet improved gain/feed from 90.7 to 115.9 kg ($p<0.04$) of the growth assay and digestibility of DM ($p<0.05$) on d 39. However, in pelleted diets, adding the enzyme did not improve growth performance or digestibility of nutrients. Pelleting tended to increase scores for ulceration ($p<0.06$), and enzyme supplementation decreased stomach keratinization scores for pigs fed the standard pellets ($p<0.01$). However, as in Exp. 1, the mean scores for all treatment groups were quiet low (i.e., ranging from normal to mild). In conclusion, pelleting improved efficiency of growth, but additional benefits from expander conditioning were observed only in Exp. 1. Finally, xylanase tended to improve growth performance and nutrient digestibility, only in pigs fed mash diets but not in pigs fed pellets.
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Key Words : Wheat, Pellet, Expander, Enzyme, Stomach, Pig

INTRODUCTION

The cell walls of cereal grains have complex carbohydrates referred to as non-starch polysaccharides (NSP). The NSP in cell walls of wheat, rye, and triticale primarily is arabinoxylan, which is D-xylose linked with arabinose (Henry, 1987). Antoniou and Marquardt (1982) and White et al. (1983) suggested that β-glucans and arabinoxylans caused viscous intestinal contents that impeded digestion of nutrients in pigs and chicks.

Wheat has a feeding value approximately 92% that of corn (Hancock et al., 1993), so a means of improving nutrient utilization from wheat would be of great benefit. Feed processing techniques, such as pelleting and extruding, damage cell walls, denature proteins and gelatinize starch (Tovar et al., 1991). These physical changes in the processed feed stuffs are thought to be responsible for the improved efficiency of growth and nutrient digestibility observed when pelleted/extruded feed stuffs are fed to swine and poultry (Hancock et al., 1989, 1990abc, 1992, 1993). Also, experiments with broiler chick demonstrated improved growth performance and enhanced nutrient digestibility when barley-based diets were supplemented with β-glucanase (Brufau et al., 1991; Pettersson et al., 1991). However, few experiments have addressed the possible additive effects of enzymes and processing technologies in diets for pigs.

Thus, the objective of the experiments reported herein was to determine the effects of conditioning (steam and expander), pelleting and enzyme supplementation of wheat-based diets on growth performance and nutrient digestibility of finishing pigs.

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MATERIALS AND METHODS

Experiment 1. Sixty crossbred gilts (line 326 boars×C 22 sow; PIC, Franklin, KY) with an average initial BW of 49.5 kg were used in a 70 d growth assay. The pigs were blocked by weight and allotted to pens based on ancestry.

There were 10 pens per treatment with two pigs per pen in an environmentally controlled building with slatted concrete floors. Each pen (1.5 m×1.5 m) had a self-feeder and nipple waterer to allow *ad libitum* consumption of feed and water. Treatments were meal, standard pellets, and expanded pellets.

Diets (Table 1) were formulated to contain 0.9% lysine, 0.6% Ca and 0.5% P for Phase 1 (from 49.5 to 79.0 kg) and 0.8% lysine, 0.5% Ca and 0.4% P for Phase 2 (from 79.0 to 111.8 kg). All other nutrients met or exceeded National Research Council (NRC, 1988) recommendations. The wheat was ground using hammermill (Model P-240 B, Jacobson Machine Works, Minneapolis, MN) equipped with a screen having 3.2 mm openings. The geometric mean particle size of the ground wheat was 612 μm (Table 3). For the standard pellets, the complete diet was steam conditioned (California Pellet Mill® conditioner, Crawfordsville, IN) at 79°C with a retention of time 10 sec. For the expanded pellets, the diet was preconditioned at 80°C (retention time of 10 sec) prior to expanding at a cone pressure of 12 kg/cm^2 in a 100 HP expander-conditioner (Model OE15.2, Amandus-Kahl, Hamburg, Germany). Both diets were pelleted in a California Pellet Mill® 1000 series Master HD model pellet mill having a 38 mm thick die with 4.8 mm holes. Pellets were cooled using forced ambient air in a double pass cooler. The diets were stored in paper bags (22.6 kg capacity) until feeding pigs.

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

Ingredient, %	Period 1[a]	Period 2[b]
Wheat (hard red winter)	86.09	91.07
Soybean meal (46.5% CP)	9.51	4.72
Soybean oil	1.00	1.00
Lysine HCl	0.38	0.41
DL-methionine	0.03	0.02
Monocalcium phosphate	1.55	1.20
Limestone	0.66	0.60
Salt	0.30	0.30
Vitamin premix[c]	0.20	0.20
Trace mineral premix[c]	0.15	0.15
Chromic oxide[d]	-	0.20
Antibiotic[c]	0.13	0.13
Enzyme[e]	-	-
Calculated analysis		
CP, %	17.0	15.5
Total lysine, %	0.9	0.8
Ca, %	0.6	0.5
P, %	0.5	0.4
ME, kcal/kg	3,223	3,229

[a] Fed from d 49.5 to 79.0 kg and 54.1 to 90.7 kg in Exp.1 and 2, respectively.
[b] Fed from d 79.0 to 111.8 kg and d 90.7 to 115.9 kg in Exp.1 and 2, respectively.
[c] Supplied (per kilogram of complete diet): 8,818 IU of vitamin A; 1,323 IU of vitamin D$_3$; 35.3 IU of vitamin E; 3.5 mg of vitamin K (as menadione sodium bisulfite); 132.3 mg of choline; 39.7 mg of niacin; 22.9 mg of pantothenic acid (as d-calcium pantothenate); 6.6 mg of Mn; 0.3 mg of I; 0.3 mg of Se; and 110 mg of tylosin.
[d] Used as an indigestible marker.
[e] Porzyme™ 9300 (Finnfeed Interational, Schaumburg, IL) was added as 0.1% of the finished diet, and Porzyme™ 9310 was sprayed on as 0.05% of the finished diet after pelleting.

The pigs and feeders were weighed at the beginning, in the middle, and at the end of the growth assay to allow calculation of ADG, ADFI and gain/feed. On d 37 (approximately mid-experiment), chromic oxide (0.2%) was added to the diets as an indigestible marker. After a 4 d adjustment period, fecal samples were collected at 06:30, pooled within pen, and frozen. The feces were oven-dried at 50°C for 72 h and ground. Feed and feces were analyzed for concentrations of DM and N (AOAC, 1995) and Cr (Williams et al., 1962) to allow calculation of apparent digestibilities of DM and N using the indirect ratio method.

The pigs were slaughtered when average BW in the heaviest pen of a weight block reached 113 kg. Dressing percentage (hot carcass weight/final live weight×100) and last rib backfat thickness (measured on the midline of the split carcass) for each pig were adjusted (using regression analysis) to the average final BW before being pooled within pen. Fat-free lean index for each pen was calculated using the equation proposed by the National Pork Producers Council (NPPC, 1996). Additionally, the esophageal region of each stomach was collected and scored for severity of keratinization and ulceration (Muggenburg et al., 1964). The scoring system used for keratinization was 0=normal tissue, 1=mild keratosis, 2=moderate keratosis, and 3= severe keratosis. For ulcers, the scoring system was 0= normal tissue, 1=mild ulceration, 2=moderate ulceration, and 3=severe ulceration.

Growth data were analyzed as a randomized complete block design (with BW as the blocking criterion) using the GLM Procedure of SAS (SAS, 1996). Means were separated with the orthogonal contrasts: 1) mash vs pellets; and 2) standard pellets vs expanded pellets. Processing treatment and weight block were defined sources of variation and pen was the experimental unit. Stomach scores were analyzed using the Cochran-Mantel-Haenszel procedure of SAS (i.e., a row mean scores differ test for categorical data) and the orthogonal contrast used for the other data.

Experiment 2. Eighty crossbred gilts (line 326 boars×C 22 sows; PIC, Franklin, KY) with an average initial BW of 54.1 kg were used in a 55 d growth assay. The pigs were blocked by weight and allotted to pens based on ancestry. There were five pens per treatment with two pigs per pen in the same building used for Exp. 1. Pigs and feeder management were the same as in Exp. 1. The pigs also were fed mash and pellets (standard steam conditioned and expanded) without and with enzymes (Porzyme™ 9300 and Porzyme™ 9310; Finnfeed International, Schauburg, IL). Both enzyme products were derived from Trichoderma longibrachiatium, a fermentation 'reesi' bacterium. Xlyanase activities were 4.000 units/g of product for Porzyme[TM] 9300 (powder form) and 8.000 units/g of product for Porzyme[TM] 9310 (liquid form). The powdered enzyme was added to the mixer as 0.1% of the diet. and the liquid enzyme preparation was sprayed onto the pellets. after processing. as 0.05% of the diet. Thus, both the powdered and liquid preparations supplied approximately 4.000 xylanase units/kg of complete diet. Treatments were: 1) meal, 2) meal with xylanase. 3) pellets, 4) pellets with xylanase added at the mixer. 5) pellets with xylanase sprayed on after pelleting. 6) expanded pellets, 7) expanded pellets with xylanase added at the mixer, and 8) expanded pellet with xylanase sprayed on after pelleting.

The diets (Table 1) were formulated to contain 0.9% lysine. 0.6% Ca, and 0.5% P from 54.1 to 90.7 kg and 0.8% lysine. 0.5% Ca and 0.4% P for from 90.7 to 115.9 kg. All other nutrients met or exceeded National Research Council (NRC. 1988) recommendations. The wheat was ground and the pellets formed in the same equipment and with the same processing conditions used in Exp. 1.

At approximately mid experiment (d 39), chromic oxide (0.2%) was added to the diets as an indigestible marker. After a 4 d adjustment period. fecal samples were collected from two pigs per pen. pooled within pen. and frozen. The feces were oven-dried at 50°C for 72 h and ground. Feed and feces were analyzed for concentrations of DM. N and Cr, as in Exp. 1 to allow calculation of apparent digestibilities of DM and N. Slaughter procedure and collecting of carcass data also were the same as in Exp. 1.

Growth data were analyzed as a randomized complete block design (with BW as the blocking criterion) using the GLM Procedure of SAS (SAS. 1996). The contrasts used to separate treatment means were: 1) meal vs pellets. 2) meal vs meal+xylanase. 3) standard pellets vs expanded pellets. 4) pellets vs pellets+xylanase. 5) standard pellets vs expanded pellets×pellets vs pellets+xylanase. 6) xylanase application before pelleting vs after pelleting. and 7) standard pellets vs expanded pellets×xylanase application before pelleting vs after pelleting. Stomach scores were analyzed, as in Exp. 1, using the Cochran-Mantel-Haenszel procedure of SAS on orthogonal contrast.

RESULTS AND DISCUSSION

Experiment 1. Proximate analyses (Table 2) indicated that values for DM (89.2%), CP (12.7%) and ether extract (1.7%) were similar to those published by the National Research Council (NRC, 1988). Also, amino acid concentrations for the wheat were similar to those expected (e.g., 0.33 % lysine and 0.52% methionine+cystine).

From 49.5 to 70.0 kg and 70.0 to 111.8 kg. and overall (from 45.5 to 111.8 kg). no differences in ADG (p>0.26) and ADFI (p>0.24) occurred among pigs fed meal vs pellets. However, overall (from 49.5 to 111.8 kg). pelleting had an effect (p<0.02) on gain/feed (i.e. a 7% improvement compared to mash). These data agree with those of Hanke et al. (1972). Baird (1973). Harris et al. (1979), Tribble et al. (1975) and Wondra et al. (1995a) who also demonstrated improved efficiency of growth when pigs were fed pelleted diets. Skoch et al. (1983) reported that pelleting increased

Table 2. Chemical composition of wheat (as-fed basis)

Item[a]	%
DM	89.2
CP	12.7
Ether extract	1.7
NDF	15.3
ADF	3.1
Pentosans, g/kg[b]	64.2
Amino acids	
Arginine	0.56
Histidine	0.28
Isoleucine	0.42
Leucine	0.81
Lysine	0.33
Methionine+cystine	0.52
Phenylalanine+tyrosine	0.85
Threonine	0.33
Tryptophan	0.16
Valine	0.52

[a] AOAC (1995).
[b] Englyst and Cummings (1984).

Table 3. Particle size of wheat

Item	Exp. 1	Exp. 2
Grain characteristics[a]		
Geometric mean particle size, μm	612	606
Standard deviation of particle size	2.01	2.04
Surface area, cm^2/g	94.8	96.6
Distribution of particle, %[b]		
Sieve opening, μm		
4,760	0	0
3,369	0	0
2,380	0.5	0.5
1,680	5.8	5.7
1,191	13.1	12.5
841	16.3	16.2
594	17.6	18.5
420	19.3	17.2
297	10.6	11.1
212	10.1	9.5
150	5.9	5.8
103	1.2	1.9
74	0.5	0.6
53	0.1	0.2
Pan	0	0

[a] Geometric mean particle size (d_{gw}). log normal standard deviation of particle size (s_{gw}). and surface area were determined according to ASAE (1995) procedures.
[b] Value are the grams of a 100 g sample retained on top of sieves after 10 min of shaking on a Ro-Tap shaker (W. S. Tyler, Mentor, OH).

Table 4. Effects of steam and expander conditioning on growth performance of finishing pigs fed wheat-based diets (Exp. 1)[a]

Item	Treatment			SE	Contrasts[b]	
	Mash	Standard pellets	Expanded pellets		Meal vs pellets	Standard vs expander
49.5 to 79.0 kg						
ADG, g	875	885	920	20	-[b]	-
ADFI, kg	2.20	2.15	2.13	0.04	-	-
Gain/feed, g/kg	398	411	432	9	0.04	0.01
79.0 to 111.8 kg						
ADG, g	911	914	981	28	-	0.10
ADFI, kg	2.70	2.68	2.71	0.05	-	-
Gain/feed, g/kg	337	341	362	8	0.14	0.05
Overall (49.5 to 111.8 kg)						
ADG, g	876	886	920	20	-	-
ADFI, kg	2.47	2.44	2.43	0.04	-	-
Gain/feed, g/kg	354	363	378	5	0.02	0.06
Digestibility (d 37), %						
Dry matter	85.4	86.9	87.6	0.4	0.001	0.04
Nitrogen	80.0	82.2	82.9	0.9	0.02	-
Dressing percentage, %	74.9	74.9	74.9	0.5	-	-
Back fat thickness, mm	24.4	25.9	26.5	0.1	0.04	-
Fat-free lean index, %	46.3	45.4	45.4	0.5	0.04	-

[a] A total of 60 pigs was fed from an average initial BW of 49.5 kg to an average final BW of 111.8 kg.
[b] Dash indicates $p>0.15$.

Table 5. Effects of steam and expander conditioning on stomach morphology of finishing pigs (Exp. 1)[a]

Item	Treatment			SE	Contrasts[b]	
	Mash	Standard pellets	Expanded pellets		Meal vs pellets	Standard vs expander
Keratinization[b]						
Total observations	20	20	20			
Normal	13	2	6			
Mild	6	13	11			
Moderate	1	4	3			
Severe	0	1	0			
Mean score[c]	0.22	1.08	0.73	0.38	0.002	0.10
Ulceration[d]						
Total observations	20	20	20			
Normal	19	11	10			
Mild	1	5	4			
Moderate	0	1	1			
Severe	0	3	5			
Mean score[e]	0.05	0.70	1.00	0.54	0.003	0.32

[a] A total of 60 pigs was fed from an average initial BW of 49.5 kg to an average final BW of 111.8 kg.
[b] Scoring system was: 0=normal tissu; 1=mild keratosis; 2=moderate keratosis; and 3=severe keratosis.
[c] Cochran-Mantel-Haenszel statistic, row mean scores differ test ($p<0.001$).
[d] Scoring system was: 0=normal tissu; 1=mild ulceration; 2=moderate ulceration; and 3=severe ulceration.
[e] Cochran-Mantel-Haenszel statistic, row mean scores differ test ($p<0.01$).

the bulk density of diets and reduced dustiness, making the diets more palatable. Apparent digestibilities of DM ($p<0.001$) and N ($p<0.02$) were improved by pelleting the diets. These results are similar to those of Wondra et al. (1995a) and Johnston et al. (1999a), who demonstrated that pelleting diets improved apparent digestibilities of DM, N and GE in corn- and sorghum-based diets. In an early study, Jensen and Becker (1965) suggested that pelleting gelatinized starch, thus making it more susceptible to enzymatic digestion.

Compared to standard steam conditioning, pigs fed expanded pellets had greater gain/feed from 79.0 to 111.8 kg ($p<0.05$) and overall ($p<0.06$), and digestibility of DM ($p<0.04$). Recently, O'Doherty and Callen (1998) reported that expanding diets with barley, wheat, and soybean meal did not improve ADG or gain/feed in pigs from 34 to 100 kg BW. However, Johnston et al. (1999a) reported that expanding corn- and sorghum-based diets increased gain/feed and digestibility of DM and GE in finishing pigs. Also, Traylor et al. (1999) demonstrated that digestibility of nutrient increased in diets having corn, sorghum, whole soybeans and wheat-midds with expander processing. However, the authors suggested that expander processing was of no benefit in wheat-based diets. Nonetheless, our data suggest that expander processing improved the nutritional value of wheat-based diets when fed to finishing pigs.

Dressing percentage was not affected by the various treatments (p>0.32), but backfat thickness was greater (p<0.04) and fat-free lean index was lower (p<0.03) for pigs fed pelleted diet. This was likely caused by the greater energy value (e.g., greater digestibility of DM) of those diets. Otherwise, carcass measurements were not affected by the processing treatments (p>0.52).

Scores for keratinization (p<0.002) and ulceration (p<0.003) of the stomach were increased by pelleting but not different for pigs fed the standard vs expanded pellets (p>0.30). However, the mean scores for the various treatments ranged from 0.05 to 1.08, i.e., from essentially none to mild keratosis and ulceration. Factors contributing to stomach ulcers in swine include genetic predisposition (Berruecos and Robison, 1972), overcrowding (Pickett et al., 1969); grain type (Riker et al., 1967), fine grinding (Healy et al., 1994; Wondra et al., 1995cd; Cabrera, 1994), pelleting (Wondra et al., 1995a; Traylor et al., 1999), expanding (Johnston et al., 1999ab), off feed for as little as 24 h (Lawrence et al., 1998). Especially, thermal processing was thought to be critical factor of causing stomach ulcer. However, in our experiment, there was no negative effect on growth performance by pelleting/expanding. Additionally, pigs fed expanded pellets showed greatest gain/feed. Thus, our results suggest that feed processing itself might not be the main factor of ulcer that deteriorate growth performance of pig and interactions with other factors (i.e., housing, management, genotype etc.) may affect the extent of processing.

Experiment 2. From 54.1 to 90.7 kg, pigs fed pellets had greater gain/feed (p<0.02) than pigs fed meal diets. Otherwise, 54.1 to 90.7 kg, 90.7 to 115.9 kg, and overall (from 54.1 to 115.9 kg), ADG, ADFI and gain/feed were not different for pigs fed pellets vs meal (p>0.25). Also, there were no differences for ADG (p>0.35), ADFI (p>0.12), and gain/feed (p>0.15) among pigs fed standard pellets vs expanded pellets. As in Exp. 1, pig fed pellets had greater gain/feed compared to that of pigs fed mash but not significantly different because of higher SE.

Enzyme activities were shown in Table 6. Xylanase activities were lost by thermal processing. However, enzyme applied as liquid at post pelleting have much higher activity compared to enzyme added as powder before pelleting. Bedford and Pack (1998) suggested that this problem can be avoided by the adding liquid enzyme post pelleting. Also, the authors suggested that direct analytical recovery of enzymes from feed after processing alone is misleading and the most accurate and meaningful method for determining enzyme thermostability is to test the efficacy of growth the enzyme in the bird. Bedford et al. (1997) reported that estimates of in-feed enzyme content

Table 6. Effects of steam and expander conditioning and enzyme on growth performance of finishing pigs (Exp. 2)[a]

Item	Meal		Standard pellet			Expanded pellet			SE
	None[b]	Mixer[b]	None	Mixer	Pellets[b]	None	Mixer	Pellets	
Enzyme activity, U/kg of diets	<100	5,200	<100	600	3,438	<100	530	3,482	
54.1 to 90.7 kg									
ADG, g	1,084	1,055	1,066	1,067	1,053	1,019	1,087	1,003	28
ADFI, kg	2.71	2.68	2.50	2.56	2.47	2.51	2.50	2.41	0.07
Gain/feed, g/kg	399	394	426	416	427	406	433	417	13
90.7 to 115.9 kg									
ADG, g	1,061	1,168	1,213	1,048	1,057	1,208	1,146	1,149	39
ADFI, kg	3.05	2.89	3.16	2.99	3.17	3.18	3.16	3.13	0.10
Gain/feed, g/kg	348	404	383	350	333	379	362	367	19
54.1 to 115.9 kg									
ADG, g	1,075	1,099	1,120	1,059	1,055	1,091	1,109	1,059	22
ADFI, kg	2.86	2.76	2.75	2.73	2.74	2.75	2.76	2.68	0.07
Gain/feed, g/kg	376	398	407	388	385	397	401	395	10
Digestibility (d 39), %									
DM	85.5	86.8	86.7	86.7	86.7	87.4	85.9	87.0	0.4
N	86.1	87.5	85.8	86.8	87.0	86.8	85.6	86.6	0.7
Dressing percentage	76.8	75.9	77.2	77.1	77.1	76.9	76.7	76.0	0.6
Back fat thickness, mm	28.8	29.4	29.0	27.0	26.8	28.4	29.2	28.4	1.3
Fat-free lean index, %	44.4	44.3	44.7	45.4	45.6	44.7	44.5	44.7	0.6

[a] A total of 80 pigs were fed from an average initial BW of 54.1 kg to an average final BW of 115.9 kg.

[b] None=no enzyme; mixer=powdered enzyme added at the mixer as 0.1% of the diet; and pellet=liquid enzyme sprayed on the pellets as 0.05% of the diets.

Table 7. Probability values for growth assay (Exp. 2)[a]

Item	Contrasts						
	1	2	3	4	5	6	7
	Mash vs pellets	Mash vs mash+ xylanase	Standard pellets vs expanded pellets	Pellets vs pellets+ xylanase	3×4	Enzyme before pelleting vs Enzyme after pelleting	3×6
54.1 to 90.7 kg							
ADG	-[c]	-	-	-	-	-	-
ADFI	0.01	-	-	-	-	-	-
Gain/feed	0.02	-	-	-	-	-	-
90.7 kg to 115.9 kg							
ADG	-	0.13	0.14	0.01	-	-	-
ADFI	0.12	-	-	-	-	-	-
Gain/feed	-	0.04	-	-	-	-	-
54.1 to115.9 kg							
ADG	-	-	-	0.13	-	-	-
ADFI	-	-	-	-	-	-	-
Gain/feed	-	0.15	-	-	-	-	-
Digestibility (d 39)							
Dry matter	0.11	0.05	-	-	-	-	-
Nitrogen	-	-	-	-	-	-	-
Dressing percentage	-	-	-	-	-	-	-
Back fat thickness	-	-	-	-	-	-	-
Fat-free lean index[b]	-	-	-	-	-	-	-

[a] A total of 80 pigs were fed from an average initial BW of 54.1 kg to an average final BW of 115.9 kg.
[b] NPPC, 1996.
[c] Dash indicates p>0.15.

obtained from a direct assay bear little resemblance to subsequent performance in chicks fed wheat-based diets.

From 90.7 to 115.9 kg, adding xylanase to the meal diets improved (p<0.04) gain/feed by 19% approaching value of pellets, which made no difference in gain/feed between pigs fed meal and pellets. Overall (54.1 to 115.9 kg), the numerical trends in gain/feed (5% improvement) also favored adding enzyme to the meal diets and digestibility of DM was 1.5% greater in pigs fed meal diets with xylanase. In broiler chicks, enzyme supplementation improved weight gain by 11 to 24% and was more effective in a meal diet than diets without enzyme (Pettersson et al., 1991). Also, Flores et al. (1994) also reported that a mixture of β-glucanase, hemicellulase, cellulase and pentosanase added to diets with 60% wheat improved weight gain and gain/feed by 7 and 6%, respectively in broiler chicks. In pigs, Dietick (1989) reported xylanase supplementation of wheat-based diets improved ADG and gain/feed by 3 and 9%, respectively, and Van Lunen and Schulze (1996) found that adding xylanase to diets for 10- to 18-wk-old pigs improved ADG and gain/feed by 9 and 5%, respectively, regardless of wheat and corn inclusion. However, Mavrvaomichalis et al. (1998) reported that supplementation of xylanase in wheat-based diets had inconsistent effects on growth performance of nursery and finishing pigs. Also, Thacker et al. (1991, 1992ab) and Bedford and Classen (1992) reported little benefit of pentosanase supplemention of barley- and rye-based diets. Finally, earlier research from our laboratory (Kim et al., 1998) indicated that adding cellulase did not improve gain/feed or nutrient digestibility in finishing pigs fed sorghum-based diets. In poultry, pentosanases were believed to improve nutrient digestibility via reducing viscosity of the digesta (Pettersson and Aman, 1989; Choct and Annison, 1992). In swine, however, a reduction in digesta viscosity from dietary enzymes has not been demonstrated, and viscosity is not considered a significant factor in nutrient utilization (Campbell and Bedford, 1992; Bedford, 1995; Mavromichalis et al., 1998).

Dressing percentage, backfat thickness, and fat-free lean index were not affected (p>0.35) by pelleting, expanding, or enzyme supplementation. However, pelleting did tend to increase scores for ulceration (p<0.06). Enzyme supplementation decreased keratinization scores for pigs fed the standard pellets (p<0.01) but had no effect on score for pigs fed the expanded diets. Scores for ulceration was not affected by enzyme supplementation (p>0.32). As in Exp. 1, the means for all treatments were quiet low, ranging from 0.05 (normal) to 1.55 (mild). Thus no potential negative effects of enzyme supplementation on stomach tissue was observed in either of the two experiments reported in this paper.

Table 8. Effects of steam and expander conditioning and enzyme on stomach morphology of finishing pigs fed wheat-based deits (Exp. 2)[a]

Item	Meal		Standard pellet			Expanded pellet			SE	Contrasts[c]						
	None	Mixer[b]	None	Mixer[b]	Pellets[b]	None	Mixer	Pellets		1	2	3	4	5	6	7
Keratinization[d]																
Total observations	9	9	10	10	9	9	9	10								
Normal	7	1	1	1	3	3	1	1								
Mild	1	2	1	5	4	5	4	7								
Moderate	1	6	8	3	1	1	4	2								
Severe	0	0	0	1	1	0	0	0								
Mean score[e]	0.94	1.44	1.55	1.10	0.83	0.67	1.22	1.05	0.26	-[h]	-	-	-	0.01	-	-
Ulceration[f]																
Total observations	9	9	10	10	9	9	9	10								
Normal	8	8	8	7	5	8	6	6								
Mild	1	1	0	1	3	1	3	3								
Moderate	0	0	1	1	0	0	0	1								
Severe	0	0	1	1	1	0	0	0								
Mean score[g]	0.05	0.05	0.45	0.55	0.61	0.05	0.33	0.50	0.25	0.06	-	-	-	-	-	-

[a] A total of 80 pigs were fed from an average initial BW of 54.1 kg to an average final BW of 115.9 kg.
[b] None=no enzyme; mixer=powdered enzyme added at the to mixer as 0.1% of the diet; and pellet=liquid enzyme sprayed on the pellets as 0.05% of the diet.
[c] Contrasts were: 1) meal vs pellets; 2) meal vs meal+xylanase; 3) standard pellets vs expanded pellets; 4) pellets vs pellets+xylanase; 5) standard pellets vs expanded pellets×pellets vs pellets+xylanase; 6) enzyme before pelleting vs enzyme after pelleting; and 7) standard pellets vs expanded pellets × enzyme before pelleting vs enzyme after pelleting.
[d] Scoring system was: 0=normal tissue; 1=mild keratosis; 2=moderate keratosis; and 3=severe keratosis.
[e] Cochran-Mantel-Haenszel statistic, row mean scores differ test ($p>0.21$).
[f] Scoring system was: 0=normal tissue; 1=mild ulceration; 2=moderate ulceration; and 3=severe ulceration.
[g] Cochran-Mantel-Haenszel statistic, row mean scores differ test ($p>0.39$).
[h] Dash indicates $p>0.15$.

In conclusion, our results demonstrated that adding xylanase to a wheat-based diet in meal form improved gain/feed and digestibility of DM. However, enzyme addition did not improve the nutritional value of pelleted diets.

IMPLICATIONS

In wheat-based diets, pelleting improved growth performance and nutrient digestibility in finishing pigs compared to those fed meal diets. Adding xylanase to meal diets had some beneficial effects on growth performance and nutrient digestibilty, but those effects were not observed in pigs fed pelleted diets. Effects of adding xylanase will vary with amount of xylan content in feedstuff. Although adding xylanase to pelleted diets had no benefit, the search for an effective enzyme to use on pelleted diets most likely will continue.

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