Effects of Amylase and Cellulase Supplementation in Sorghum-based Diets for Finishing Pigs**

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ABSTRACT : Three experiments were conducted to determine the effects of a sorghum-specific enzyme system, derived from an *Aspergillus niger* and *Bacillus subtilis* fermentation extract (carbohydrase activity of 1,650 α-amylase units and cellulase activity of 30 fibrinolytic units/mL), on growth performance of finishing pigs. In Exp. 1,192 pigs (average initial BW of 46.1 kg) were fed sorghum-based diets without or with 360 mL of enzyme system per ton of sorghum in a 78 d growth assay. For d 0 to 39, gain/feed was improved ($p<0.03$) with enzyme supplementation, but ADG was not affected ($p>0.15$). For d 39 to 78 and overall (d 0 to 78), ADG, gain/feed, and digestibilities of DM and N were not affected ($p>0.13$) by enzyme supplementation. Backfat thickness, fat-free lean index, and scores for stomach keratinization and ulcers also were not affected ($p>0.15$) by the dietary treatments. In Exp. 2,168 pigs (average initial BW of 58.4 kg) were fed diets without or with 150, 300, or 450 mL/ton of the same enzyme system used in Exp. 1. Adding as much as 450 mL enzyme system / ton of sorghum did not affect ($p>0.15$) ADG or gain/feed for d 0 to 29 of the growth assay. However, during d 29 to 63, ADG increased by 11% (linear effect, $p<0.02$) and gain/feed increased by 10% (linear effect, $p<0.06$) as enzyme concentration was increased from none to 450 mL/ton of sorghum. For the overall period (d 0 to 63), ADG tended to increase ($p<0.08$) with enzyme supplementation, but gain/feed and digestibilities of DM and N were not affected ($p>0.14$). Carcass characteristics (dressing percentage, backfat thickness, and fat free lean index) also were not affected ($p>0.20$) by addition of the enzyme system. In Exp. 3,176 pigs (average initial BW of 46.7 kg) were fed diets without or with 450, 900, or 1,350 mL/ton of the same enzyme system used in Exp. 1 and 2 in a 71 d growth assay. Adding up to 1,350 mL/ton of enzyme had no effects ($p>0.15$) on ADG, gain/feed, digestibilities of DM and N, and carcass characteristics (dressing percentage, backfat thickness, and fat-free lean index). In conclusion, finishing pigs fed diets with a sorghum-specific enzyme system showed some positive trends for improved growth performance, but those effects were not large and (or) consistent. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 1 : 70-76)***

Key Words : Sorghum, Cellulase, Amylase, Growth, Carcass, Stomach, Pig

INTRODUCTION

The energy value (i.e. rate of gain, efficiency of gain) of sorghum grain is, on average, 3 to 5% less than that of corn. Starch granules in sorghum are small, compact, and spherical in shape (Tobey et al., 1997). These physical attributes are thought to make sorghum starch less susceptible to enzymatic degradation compared to the hexagonal and uniform starch granules found in corn and sorghum proteins are less soluble and, thus, less digestible than those in corn (Tobey et al., 1997). Therefore, a means of improving utilization of the starch and (or) protein from sorghum grain would be of great benefit.

Supplementation of β-glucanase increased growth rate and improved protein digestibilities in weanling pigs fed rye-based diets (Bedford et al., 1992). Also, β-glucanase supplementation to the barley-based diets increased ileal apparent starch digestibility (Graham et al., 1989) and improved the ileal digestibilities of GE, CP, and amino acids in young pigs (Li et al., 1996). Han and Froseth (1993) demonstrated greater utilization of energy when β-glucanase was added to barley-based diets for growing pigs.

In early study, Mahan et al. (1966) reported physical condition of stomach content was the factor contributing to stomach ulcers. The dietary enzyme might change the physical characteristics of digesta in stomach and relationship between dietary enzyme and stomach ulcer has not been studied. Thus, the objective of the experiments reported herein was to determine the effects of enzyme supplementation in sorghum-based diets on growth performance, nutrient utilization, and stomach ulcers in finishing pigs.

MATERIALS AND METHODS

Experiment 1

A total of 192 (Line 326 sires × C 22 dams; PIC, Franklin,

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KY) pigs, with an average initial BW of 46.1 kg, were used in a 74 d growth assay. The pigs were blocked by weight and allotted to pens based on sex and ancestry. There were 12 gilts in each pen (there were 8 pens) and 12 barrows in each pen (there were 8 pens) with four pens per treatment.

The sorghum was ground to a geometric mean particle size of 712 μm in a full circle hammermill (Jacobson Machine Works, Model No. P-240 B, Minneapolis, MN) equipped with a 4.8 mm screen. The sorghum was used in diets (Table 1) that were formulated to contain 0.9 and 0.8% total lysine, 0.6 and 0.5% Ca, and 0.5 and 0.4% P for Period 1 (46.1 to 82.9 kg) and Period 2 (82.9 to 112.7 kg), respectively. All nutrients met or exceeded NRC (1988) recommendations and the diets were fed in mash form.

Treatments were the sorghum-based diets without or with 360 mL of an enzyme (α-amylase+cellulase) mixture per metric ton of sorghum. This sorghum-specific enzyme product (Digest 'M', Loveland Industries, Inc., Loveland, CO) was derived from an *Aspergillus niger* and *Bacillus subtilis* fermentation extract (activity of 1,650 α-amylase units and 30 fibrinolytic units of cellulase activity/mL of enzyme product). One unit of α-amylase activity was defined as the quantity of enzyme that dextrinized 1 mg starch per min. One fibrinolytic unit was defined as the quantity of enzyme that liberated one micromole of reducing sugar per min. To apply the enzyme system, moisture content of sorghum was measured by Gain Analysis Computer (GACII, Dickey-john Co. Auburn, IL) and was adjusted to 14±0.5% moisture by adding water. Before spraying enzyme, water was added to the enzyme up to 2 L as carrier. The 2 L of enzyme/water mixture was sprayed onto the sorghum (for 7 to 8 min) while mixing, before other dietary ingredients were added to the mixer. Samples (approximately 500 g) of sorghum and the diets were collected, pooled within treatment, mixed thoroughly, and the geometric mean particle size (d_{gw}), log normal standard deviation of the mean (s_{gw}), and surface area were calculated according to procedures suggested by the American Society of Agriculture Engineers (ASAE, 1995). The chemical composition of sorghum were analyzed for DM, CP, amino acids, ether extract, NDF, ADF according to AOAC (1995).

Table 1. Composition of Diets (Exps. 1, 2 and 3, as-fed basis)[a]

Ingredient, %	Period 1[b]	Period 2[c]
Sorghum	82.57	89.91
Soybean meal (46.5% CP)	13.40	6.52
Soybean oil	0.50	0.50
L-Lysine HCl	0.39	0.38
L-Threonine	0.18	0.15
DL-methionine	0.17	0.14
Monocalcium phosphate	1.10	1.00
Limestone	1.02	0.73
Salt	0.30	0.30
Vitamin premix[d]	0.15	0.15
Trace mineral premix[d]	0.10	0.10
Antibiotic[e]	0.12	0.12
Chemical composition, %		
DM	89.8	89.5
CP	14.0	11.4
Ether extract	2.8	2.9
NDF	16.1	16.8
ADF	6.3	6.7

[a] All diets were fed in mash form.

[b] Formulated to contain 0.9% lysine, 0.65% Ca and 0.55% P and fed from d 0 to 39, d 0 to 29, and d 0 to 36 in Exp.1, 2, and 3, respectively.

[c] Formulated to 0.7% lysine, 0.55% Ca, and 0.45% P and fed from d 39 to 78, d 29 to 63, and d 36 to 71 in Exp.1, 2, and 3, respectively.

[d] Supplied the following per kg of complete diet: vitamin A, 8,818 IU; vitamin D_3, 1,323 IU; vitamin E, 35.3 IU; vitamin K (as menadione sodium bisulfite), 3.5 mg; choline, 132.3 mg; niacin, 39.3 mg; pantothenic acid (as d-calcium pantothenate), 22.9 mg; riboflavin, 6.6 mg; vitamin B_{12}, 0.026 mg; Zn, 165 mg; Fe, 165 mg; Mn, 16.5 mg; I, 0.3 mg; and Se, 0.3 mg.

[e] Supplied 110 mg of tylosin per kg of complete diet.

For the growth assay, the pigs were housed in a modified open-front building with 50% solid concrete and 50% concrete slat flooring. Each pen (1.8 m × 4.9 m) had a two-hole self-feeder and nipple waterer to allow *ad libitum* consumption of feed and water. Pigs and feeders were weighed at the beginning, middle, and end of the growth assay to allow calculations of ADG, ADFI, and gain/feed. On d 39, 0.25% of chromic oxide was added to the diets at the expense of sorghum as an indigestible marker. After a 4 d adjustment period, fecal samples were collected at 06:30 by rectal massage from four pigs per pen. The samples were pooled within pen and frozen. For analyses, the fecal samples were oven-dried at 50°C for 72 h and ground to fine mash. Feed and feces then were analyzed for concentrations of Cr (Williams et al., 1962), DM and N (AOAC, 1995) to allow calculation of apparent digestibilities of DM and N using the indicator method (Arentson and Zimmerman, 1992). Digestibilities were calculated by following equation.

Apparent nutrients digestibility={(% nutrient in feed/% Cr_2O_3 in feed)-(% nutrient in feces / % Cr_2O_3 in feces)}/{% nutrient in feed/% Cr_2O_3 in feed}×100

The pigs were slaughtered when average BW in the heaviest pen of a weight block reached 113 kg. The pigs were shipped at 02:00 to a commercial slaughter facility and killed at 07:00. Hot carcass weight was recorded and last rib backfat thickness (at the midline) was measured with a ruler on each half of the split carcass. Fat-free lean index was calculated from hot carcass weight and backfat thickness with the equation proposed by the National Pork Producers Council (1996). Additionally, the esophageal region of the stomach was collected, delivered (at 12:00) to our Veterinary Diagnostics Laboratory, and scored for

severity of esophagogastric keratinization and ulceration. The scoring system for both was 0=normal, 1=mild, 2=moderate, and 3=severe (Muggenburg et al., 1964).

All data were analyzed as a randomized complete block design (Steel et al., 1997) with initial BW as the blocking criterion, using the GLM procedures of SAS (1996). Enzyme supplementation and weight block were defined sources of variation and pen was the experimental unit. Hot carcass weight was used as a covariate for analyses of dressing percentage, backfat thickness, and fat-free lean index. Stomach scores were analyzed using the Cochran-Mantel-Haenszel procedure of SAS (i.e., a row mean scores differ test) for categorical data (Steel et al., 1997). Response criteria were ADG, ADFI, gain/feed, apparent digestibilities of DM and N, dressing percentage, last rib backfat thickness, fat-free lean index, and scores for keratinazation and ulceration of the stomach.

Experiment 2

A total of 168 (Line 326 sires × C 22 dams; PIC, Franklin, KY) pigs, with an average initial BW of 58.4 kg, were blocked by weight and allotted to pens based on sex and ancestry. There were 11 gilts in each pen (there were 8 pens) and 10 barrows in each pen (there were 8 pens) with four pens per treatment. Housing and management of the pigs was the same as in Exp. 1.

The sorghum-based diets used in Exp. 1 were supplemented with none, 150, 300, or 350 mL of the enzyme per metric ton of sorghum. The sorghum was adjusted to 14±0.5% moisture by adding water. Before spraying enzyme, water was added to the enzyme up to 2 L as carrier. Two liter of enzyme/water mixture was sprayed onto the sorghum (for 8 to 9 min) while mixing, before other ingredients were added. The diets were fed from d 0 to 29 (Period 1) and d 29 to 63 (Period 2). On d 29, .25% of chromic oxide was added to the diets at the expense of sorghum as an indigestible marker. After a 4 d adjustment period, fecal samples were collected at 06:30 by rectal massage from four pigs per pen and storage, preparation, and data analyses were the same as in Exp. 1.

All data were analyzed as a randomized complete block (with initial BW as the blocking criterion), and polynomial regression (Steel et al., 1997) was used to characterize the shape of the response curve. Pen was the experimental unit and response criteria (e.g., growth performance, nutrient digestibility, and carcass measurements) were the same as in Exp. 1.

Experiment 3

A total of 176 (Line 326 sires × C 22 dams; PIC, Franklin, KY) pigs, with an average initial BW of 46.7 kg, were blocked by weight and allotted to pen based on sex and ancestry. There were 11 gilts in each pen (there were 8 pens) and 11 barrows in each pen (there were 8 pens) with four pens per treatment. The same sorghum-based diets used in Exp. 1 and 2, were supplemented with none, 450, 900, or 1,350 mL of enzyme per metric ton of sorghum. The method for adding enzyme/water mixture was the same as in Exp. 1 and 2 (i. e. the sorghum was adjusted to 14±0.5% moisture and the enzyme/water mixture was sprayed onto the sorghum before other ingredients were added).

Housing and management of the pigs were the same as in the previous experiments. On d 36, 0.25% of chromic oxide was added to the diets at the expense of sorghum as an indigestible marker. Fecal samples were collected at 06:30 by rectal massage from four pigs per pen on d 40 in this experiment. However, a different slaughter plant was used, and collection of carcass data was slightly different. Backfat thickness was measured off-midline (at the tenth rib) using a Fat-O-Meter probe (model s71, Kund Simmonsen Industries, Ltd., Rexdale, Ontario, Canada), and hot carcass weights were collected with the head attached.

Response criteria and statistical analyses were the same as in Exp. 2, with all data analyzed as a randomized complete block design using the GLM procedure of SAS (1996). Polynomial regression was used to characterize the shape of the response curve and pen was the experimental unit.

RESULTS AND DISCUSSON

Experiment 1

Proximate analyses of sorghum (Table 2) indicated that DM (89.8%), CP (9.3%), and ether extract (3.2%) were as expected and similar to those published by the National Research Council (NRC. 1988). Also, amino acid concentrations for the sorghum were similar to those

Table 2. Chemical composition of sorghum (as-fed basis)[a]

Item, %	Exp. 1	Exp. 2	Exp. 3
DM	89.8	89.1	89.2
CP	9.3	10.1	9.2
Ether extract	3.2	3.1	3.3
NDF	17.6	16.8	15.8
ADF	7.3	6.7	7.2
Ash	1.4	1.3	1.3
Arginine	0.36	0.39	0.36
Histidine	0.23	0.24	0.23
Isoleucine	0.39	0.41	0.39
Leucine	1.30	1.38	1.31
Lysine	0.22	0.23	0.22
Methionine + cystine	0.38	0.39	0.37
Phenylalanine + tyrosine	0.82	0.86	0.82
Threonine	0.31	0.32	0.30
Tryptophan	0.08	0.08	0.08
Valine	0.49	0.51	0.50

[a] AOAC (1995).

expected (e. g., 0.22% lysine).

In the pig growth assay (Table 3), ADG was not affected ($p>0.33$) for d 0 to 39 but gain/feed was improved ($p<0.02$) by 3.6% with enzyme supplementation. For d 39 to 78 and overall (d 0 to 78), ADG and gain/feed were not different ($p>0.36$) among pigs fed diets without or with added enzymes. Thus, the early (d 0 to 39) improvement in gain /feed with enzyme supplementation of the diet had disappeared by conclusion of the 78 d growth assay. In previous studies, addition of amylase (Burnett and Neil, 1964) and β-glucanase (Thacker et al., 1988) to barley-based diets did not improved ADG and gain/feed grower and finishing pigs.

Apparent digestibilities of DM and N (d 43) were not affected ($p>0.24$) by adding enzymes to our sorghum-based diets. Earlier research from our laboratory (Kim et al., 1998) indicated that cellulase and lactobacilli did not improve nutrient digestibility in finishing pigs fed sorghum-based diets. In weanling pigs, Mellange et al. (1992) reported that a mixture of xylanase, amylase, pectinase, and β-glucanase improved nutrient digestibility of pigs fed diets with wheat, barley, and beet pulp.

Table 3. Effects of enzyme supplementation on growth performance and apparent nutrient digestibility in finishing pigs (Exp.1)[a]

	Enzyme concentration, mL/metric ton of sorghum[b]		SE	P value
	None	360		
d 0 to 39				
ADG, kg	0.96	0.98	0.02	-[c]
ADFI, kg	2.21	2.18	0.06	-
Gain/feed, kg/kg	0.44	0.46	0.08	0.02
d 39 to 78				
ADG, kg	0.86	0.88	0.03	-
ADFI, kg	2.57	2.71	0.08	0.04
Gain/feed, kg/kg	0.34	0.33	0.08	-
Overall (d 0 to 78)				
ADG, kg	0.91	0.93	0.02	-
ADFI, kg	2.44	2.50	0.09	-
Gain/feed, kg/kg	0.37	0.38	0.01	-
Nutrient digestibility (d 43), %				
DM	84.4	85.4	0.9	0.13
N	66.0	67.1	1.9	-
Carcass measurements				
Dressing percentage, %	72.9	72.7	0.4	-
Backfat thickness, mm	25.7	25.8	0.8	-
Fat-free lean, %	45.6	45.4	0.4	-

[a] A total of 192 finishing pigs was fed from an average initial BW of 46.1 kg to an average final BW of 112.7 kg.

[b] Activity of 1,650 α-amylase units and 30 fibrinolytic units/mL of enzyme mixture.

[c] Dash indicates $p>0.15$.

Dressing percentages ($p>0.30$), backfat thickness, and fat-free lean index were not affected ($p>0.28$) by the enzyme treatments. Finally, stomach keratinization and ulceration were not affected ($p>0.21$) by enzyme supplementation (Table 4). Factors contributing to stomach ulcers in swine have been proposed to include grain type (Riker et al., 1967), genetic predisposition (Berruecos and Robison, 1972), overcrowding (Pickett et al., 1969), fine grinding (Healy et al., 1994; Wondra et al., 1995ac), pelleting (Wondra et al., 1995b; Johnston et al., 1999a) and expanding (Johnston et al., 1999ab). In early study, Mahan et al. (1966) reported physical condition of stomach content was the factor contributing to stomach ulcers. In our experiment no incidence of stomach ulceration occurred in pigs fed the diets with amylase and cellulase and only one pig in the control group had mild ulceration. So, amylase and cellulase supplementation might not change physical condition of stomach content of pig fed sorghum-based diet. Thus, it does not appear that dietary enzyme supplementation contributes to this malady.

Experiment 2

Adding as much as 450 mL of enzyme supplement (742.500 activity units of α-amylase and 13.500 activity units of cellulase/ton of sorghum) did not affect ($p>0.73$) ADG, ADFI, or gain/feed for d 0 to 29 of the growth assay (Table 5). However, during d 29 to 63, an 11% increase on

Table 4. Effects of enzyme supplementation on stomach morphology in finishing pigs (Exp. 1)[a]

Item	Enzyme concentration, mL/metric ton of sorghum[b]		SE	P value
	None	360		
Keratinization[b]				
Total observations	96	95		
Normal	52	55		
Mild	34	33		
Moderate	7	5		
Severe	3	2		
Mean score[c]	0.49	0.37	0.45	0.21
Ulceration[d]				
Total observations	96	95		
Normal	95	95		
Mild	1	0		
Moderate	0	0		
Severe	0	0		
Mean score[e]	0.01	0.00	0.05	0.32

[a] A total of 192 finishing pigs was fed from an average initial BW of 46.1 kg to an average final BW of 112.7 kg.

[b] Scoring system was: 0=normal; 1=mild kerosis; 2=moderate kerosis; and 3=severe kerosis.

[c] Cochran-Mantel-Haenszel statistic, row mean scores differ test.

[d] Scoring system was: 0=normal; 1=mild ulceration; 2=moderate ulceration; and 3=severe ulceration.

[e] Cochran-Mantel-Haenszel statistic, row mean scores differ test.

Table 5. Effects of enzyme supplementation on growth performance and apparent nutrient digestibility in finishing pigs (Exp. 2)[a]

Item	Enzyme concentration, mL/ton of sorghum[b]				SE	P value		
	none	150	300	450		Lin	Quad	Cubic
d 0 to 29								
ADG, kg	0.97	0.98	0.96	0.97	0.04	-[c]	-	-
ADFI, kg	2.13	2.16	2.15	2.11	0.05	-	-	-
Gain/feed, kg/kg	0.46	0.46	0.45	0.46	0.01	-	-	-
d 29 to 63								
ADG, kg	0.85	0.91	0.90	0.95	0.02	0.02	-	-
ADFI, kg	2.68	2.76	2.70	2.71	0.07	-	-	-
Gain/feed, kg/kg	0.32	0.33	0.33	0.35	0.01	0.06	-	-
Overall (d 0 to 63)								
ADG, kg	0.90	0.94	0.93	0.96	0.02	0.08	-	-
ADFI, kg	2.51	2.58	2.54	2.51	0.09	-	-	-
Gain/feed, kg/kg	0.36	0.37	0.37	0.38	0.01	0.14	-	-
Nutrient digestibility (d 33),%								
DM	83.4	84.5	84.0	84.7	0.9	-	-	-
N	62.4	62.7	61.6	63.3	1.4	-	-	-
Carcass measurements								
Dressing percentage, %	72.6	74.5	72.9	73.1	0.7	-	-	-
Backfat thickness, mm	25.7	24.4	25.3	24.8	0.8	-	-	-
Fat-free lean, %	45.6	46.3	45.8	46.0	0.4	-	-	-

[a] A total of 168 finishing pigs was fed from an average initial BW of 58.4 kg to an average final BW of 116.0 kg.
[b] Activity of 1,650 α-amylase units and 30 fibrinolytic units/mL of enzyme mixture.
[c] Dash indicates p>0.15.

Table 6. Effects of enzyme supplementation on growth performance and apparent nutrient digestibility in finishing pigs (Exp. 3)[a]

Item	Enzyme concentration, mL/ton of sorghum[b]				SE	P value		
	none	450	900	1,350		Lin	Quad	Cubic
d 0 to 36								
ADG, kg	0.95	0.95	0.96	0.98	0.02	-[c]	-	-
ADFI, kg	2.54	2.45	2.49	2.52	0.05	-	-	-
Gain/feed, kg/kg	0.38	0.39	0.39	0.39	0.08	-	-	-
d 36 to 71								
ADG, kg	0.95	0.94	0.96	0.93	0.02	-	-	-
ADFI, kg	3.17	3.15	3.15	3.11	0.06	-	-	-
Gain/feed, kg/kg	0.30	0.30	0.30	0.29	0.06	-	-	-
Overall (d 0 to 71)								
ADG, kg	0.95	0.95	0.96	0.96	0.02	-	-	-
ADFI, kg	2.97	2.94	2.93	2.95	0.04	-	-	-
Gain/feed, kg/kg	0.32	0.32	0.33	0.32	0.05	-	-	-
Nutrient digestibility (d 40),%								
DM	83.6	83.7	83.8	84.2	0.4	-	-	-
N	62.7	64.4	63.7	64.2	1.1	-	-	-
Carcass measurements								
Dressing percentage, %	76.5	76.1	74.3	76.5	1.2	-	-	-
Backfat thickness, mm	18.3	18.0	17.5	17.8	0.5	-	-	-
Fat-free lean, %	49.4	49.5	49.7	49.7	0.5	-	-	-

[a] A total of 176 finishing pigs was fed from an average initial BW of 46.7 kg to an average final BW of 114.3 kg.
[b] Activity of 1,650 α-amylase units and 30 fibrinolytic units/mL of enzyme mixture.
[c] Dash indicates p>0.15.

ADG (p<0.02) and a 10% increase in gain/feed (p<0.06) occurred as enzyme concentration was increased from none to 450 mL/ton of sorghum. Overall (d 0 to 63), ADG tended (p<0.08) to increase with enzyme supplementation, but ADFI (p>0.44) and gain/feed (p>0.14) were not affected.

No differences in apparent digestibilities of DM and N (p>0.58) occurred among pigs fed the various treatments. Also, dressing percentage, backfat thickness, and fat-free

lean index were not affected ($p>0.23$) by enzyme supplementation.

Experiment 3

Feeding up to 1,350 mL of the enzyme system per ton of sorghum had no effects ($p>0.34$) on ADG, ADFI and gain/feed for d 0 to 36, d 36 to 71 and overall (Table 6). Also, apparent digestibilities (d 39) of DM and N, dressing percentage, backfat thickness, and fat-free lean index were not affected ($p>0.32$) by addition of enzymes to the diets. The age of the pigs may affects response to enzyme supplementation. Lindemann et al. (1986) suggested that digestibility of nutrients may be limiting only in baby pigs (after weaning). In early study Lewis et al. (1955) reported that proteolytic enzymes, when added to corn-based diets, improved weight gain and feed efficiency in weanling pigs. Amylase addition to a barley-based diets improved ADG and gain/feed in young pigs but not in grower and finishing pigs (Burnett and Neil, 1964). Also, Moran (1982) reported that advantages from adding α-amylase was minor in growing pigs because older pigs have larger duodenal lactobacilli populations capable of degrading β-glucan (Graham et al., 1986). The response to supplemental β-glucanase improved weight gain and protein digestibility only in weanling but not growing or finishing pigs (Dierick and Decuypere, 1994). Thus, in the older pigs used in our experiments, the enzyme system might have been expected to have potentially less effect than in very young piglets.

IMPLICATIONS

The use of α-amylase and cellulase improved ADG and G/F in two BW ranges in two of the three experiments. The lack of an effect of the supplemented enzymes on digestibilites indicated that nutrient utilization was not significantly improved. Therefore, the use of the enzyme mixture in sorghum-based diets will not substantially improve animal performance. Still, the feeding value of sorghum is less than that of corn and, for that reason, the search for an effective enzyme supplement most likely will continue.

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