Effects of Cellulase Enzymes and Bacterial Feed Additives on the Nutritional Value of Sorghum Grain for Finishing Pigs

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ABSTRACT : One hundred and twenty-eight finishing pigs (51.3 kg average initial body weight) were used to determine the effects of adding cellulase enzymes and *lactobacillus acidophilus* to sorghum-based diets on growth performance, carcass merit, and nutrient digestibility in finishing pigs. Treatments were: 1) corn-soybean meal-based positive control; 2) sorghum-soybean meal-based negative control; 3) Diet 2 with celluloytic enzymes; and 4) Diet 2 with a bacterial feed additive (*lactobacillus acidophilus*). There was a trend for greater average daily gain (ADG) in pigs fed corn versus the sorghum treatments for day 0 to 28 ($p < .09$), but there was no effect of treatment ($p > .15$) on overall ADG (i.e., day 0 to 63). Feed consumption was not affected by treatment during the experiment ($p > .19$). Pigs fed the corn-soybean meal-based diet had 3.5% greater overall gain/feed than pigs fed the other diets ($p < .009$). Dressing percentage was not affected by treatment ($p > .22$), but there was a trend for backfat thickness at the last rib to be greater for pigs fed corn versus the sorghum treatments ($p < .09$). Pigs fed the sorghum treatments had 1% greater fat free lean index ($p < .10$) compared to pigs fed the corn-soybean meal-based positive control. Pigs fed corn had greater apparent digestibilities of DM, N, and GE than pigs fed the sorghum treatments ($p < .03$), and greater DE intake ($p < .07$) suggesting that the increased carcass fatness for pigs fed the corn-based control diet resulted from greater energy status of those pigs. In conclusion, pigs fed the corn-soybean meal-based control diet had no improved growth performance but tended to be fatter than pigs fed sorghum. Adding cellulolytic enzymes or a bacterial feed additive to diets for finishing pigs did not affect growth performance, carcass merit, or nutrient utilization.
(Key Words: *Lactobacillus*, Enzyme, Performance, Digestibility, Carcass, Pig)

INTRODUCTION

Corn is the most widely accepted energy source used in livestock feeding. In general, it has greater energy concentration thus greater feeding value than other cereal grains. Although the feeding value of sorghum is on average 5% less than that of corn (Hancock et al., 1991), the hardy nature of sorghum and its availability make it appealing to farmers and livestock producers in the high-plains, southeastern state of the U. S., and in arid regions of the world. Thus, a means of improving nutrient utilization from sorghum would be of great benefit. *Lactobacillus acidophilus* is termed a probiotic with growth promotant claims and has been suggested as an alternative to growth promotion levels of antibiotics. However, variable results have been reported. Hawley et al. (1959) reported that *lactobacillus* organisms improved function of the gastro-intestinal tract via reduction of *E. coli* numbers and increment of lactate synthesis. However, their data are in contrast with those of Cline et al. (1976) and Holden (1976) who suggested that adding *lactoba cillus* organisms to diets for pigs had no effect on growth performance.

As an alternative to feeding microorganisms, some researchers have suggested that enzyme supplementation can improve nutrient utilization and growth performance. Cromwell et al. (1993) demonstrated that phytase additions improve utilization of phytin phosphorus in diets for swine. Also, Han and Froseth (1993) and Goodman et al. (1993) reported improved utilization of energy when β-glucanase was added to barley-based diets for growing pigs and broilers, respectively.

Political and natural pressures to decrease irrigation are likely to continue for the foreseeable future and, as such, will result in increased use of alternative feed grains for livestock production. Also, concern is increasing to find means of decreasing the use of feed-grade antibiotics

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and the amount of waste from livestock operations that enters the environment. Therefore, use of enzymes and microbial feed additives to increase the utilization of nutrients from various feedstuffs would be of benefit.

Thus, the objective of the present experiment was to determine if cellulase enzymes or *lactobacillus acidophilus* feed additives could improve the nutritional value of sorghum grain.

MATERIALS AND METHODS

A total of 128 crossbred (Yorkshire × Duroc × Hampshire × Chester White) finishing pigs, with an average initial body weight of 51.3 kg, were blocked by weight and allotted to four dietary treatments based on weight, sex, and ancestry. There were four barrows and four gilts in each pen and four pens per treatment. 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 three-hole self-feeder and nipple waterer to allow *ad libitum* consumption of feed and water. Treatments were: 1) corn-soybean meal-based positive control; 2) sorghum-soybean meal-based negative control; 3) Diet 2 with cellulolytic enzymes; and 4) Diet 2 with a bacterial feed additive (*lactobacillus acidophilus*). All diets were formulated to contain .70% lysine, .65% Ca and .55% P (table 1), and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988). The diets were fed in meal form.

Table 1. Composition of diets (as-fed basis), %[a]

Ingredient	Corn-soy	Sorghum-soy	Sorghum-soy +enzyme	Sorghum-soy +bacteria
Corn	81.30	–	–	–
Sorghum	–	81.28	81.28	81.28
Soybean meal (48% CP)	14.85	14.85	14.85	14.85
Enzyme premix[b]	–	–	0.05	–
Bacteria premix[c]	–	–	–	0.05
Soybean oil	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.08	1.08	1.08	1.08
Limestone	1.02	1.02	0.97	0.97
Salt	0.30	0.30	0.30	0.30
Vitamin premix[d]	0.15	0.15	0.15	0.15
Tracer mineral premix[e]	0.10	0.10	0.10	0.10
Lysine · HCl	0.05	0.07	0.07	0.07
Antibiotic[f]	0.15	0.15	0.15	0.15
Total	100.00	100.00	100.00	100.00
Calculted values				
CP (%)	14.1	14.4	14.4	14.4
Lysine (%)	0.70	0.70	0.70	0.70
DE (kcal/kg)	3,490	3,400	3,400	3,400

[a] All diets were formulated to contain .65% Ca and .55% P, and to meet or exceed concentrations for all other nutrients as suggested by NRC (1988).

[b] Supplied 500 mg enzyme product per kilogram of complete diets.

[c] Supplied 500 mg bacterial product per kilogram of complete diets.

[d] Provided the following per kilogram of the complete diet; 3,307 IU of vitamin A; 331 IU of vitamin D_3; 13 IU of vitamin E; 1.3 mg of vitamin K (as menadione sodium bisulfate complex); 3.3 mg of riboflavin; 18.2 mg of niacin; 8.3 mg of pantothenic acid (as d-calcium pantothenate); 331 mg of choline; and 17 μg of vitamin B_{12}.

[e] Provided the following per kilogram of the complete diet: 66 mg of Mn; 66 mg of Fe; 66 mg of Zn; 6.6 mg of Cu; 2.0 mg of I; 0.20 mg of Se; and 0.66 mg of Co.

[f] Supplied 150 mg chlortetracycline per kilogram of complete diets.

Pigs and feeders were weighed at beginning (0 day), middle (28 days), and end (63 days) of the growth assay to determine average daily gain (ADG), average daily feed intake (ADFI), and gain/feed and additions of feed were recorded daily. On day 44 of the experiment, Cr_2O_3 (.25%) was added to the diets, and after a 4 days adjustment period, fecal samples were collected from two barrows and two gilts per pen, pooled within pen, and frozen. The feces were oven dried at 50℃ for 24 hours and ground before chemical analysis. The feed and feces were analyzed for DM and N concentrations using the procedures suggested by AOAC (1990). Gross energy concentrations were determined by bomb calorimetry (Model No. 13031, Parr Oxygen Bomb Calorimeter, Moline, IL) and Cr concentrations were determined with atomic absorption spectrometry (Model No. 1475, Varian Techtron, Springvale, Springvale, Australia) as described by Williams et al. (1962). Apparent digestibilities of DM, N, and GE were calculated using the indirect ratio method (Maynard et al., 1979) with Cr_2O_3 as the indigestible marker, and the difference between the amounts of DM and N consumed and DM and N digested was reported as fecal excretion.

The pigs were slaughtered when the heaviest pen in a weight block reached an average body weight of 118 kg. Dressing percentage and last rib backfat thickness for each pig were adjusted to the average final body weight (using regression analysis) before being pooled within pen. Dressing percentage was determined from live weight and hot carcass weight. Backfat thickness was measured with a ruler at the last ribs from both the right and left side of the carcass. Response criteria were ADG, ADFI, gain/feed, dressing percentage, last rib backfat thickness, fat free lean index, apparent digestibilities of DM, N, and GE, and excretion of DM and N in feces.

All data were analyzed using the GLM procedures of SAS (1988). The statistical model included block and treatment as defined sources of variation, and pen was the experimental unit. Treatment means were separated using orthogonal comparisons as described by Steel and Torrie (1980). Contrasts were: 1) corn-soybean meal-based positive control versus all sorghum treatments; 2) sorghum-soybean meal negative control versus added cellulase enzymes and *lactobacilli*; and 3) Cellulase enzymes versus *lactobacilli*.

RESULTS AND DISCUSSION

Average daily gain for day 0 to 28 tended to be greater ($p < .09$) for pigs fed the corn-soybean meal-based positive control compared to the sorghum-soybean meal treatments, and gain/feed was 4% greater ($p < .08$) for pigs fed corn (table 2). Adding the enzymes and bacteria did not increase growth performance compared to the sorghum-soybean meal-based negative control ($p > .12$). For day 28 to 63, ADG, ADFI, and gain/feed were not affected by treatment ($p > .11$). Overall (day 0 to 63), ADG and ADFI were not affected by grain source ($p > .15$) but pigs fed the corn-soybean meal-based positive control had 3.5% greater gain/feed ($p < .009$) than pigs fed the sorghum treatments. Adding the cellulase enzymes and *lactobacillus* organisms did not improve overall growth performance compared to the sorghum-soybean meal-based negative control ($p > .15$). However, Francis et al. (1978) reported greater ADG and gain/feed when broilers and turkey poults were fed *lactobacillus* culture. Also, they suggested that the addition of either *lactobacilli* or zinc bacitracin to the diet reduced total aerobic count in the digestive tracts of the poultry. Tortuero (1973) suggested that *lactobacillus acidophilus* acted in a similar manner to antibiotics, resulting in greater ADG and gain/feed in broiler chicks. These data are in agreement with those of Collington et al. (1988), who indicated that antibiotic or a probiotic in the basal diet resulted in an improvement in growth performance. Both these treatments also had effects on the development of digestive enzyme function within the intestinal mucosa which were, in general, more significant in the preweaning than in the postweaning period. Conversely, feed intake, egg production, fertility, and mortality were not affected by adding *lactobacillus* culture to the diets of Bobwhite quail (Miles et al., 1981ab). Buenrostro and Kratzer (1983) report decreased ADG and gain/feed when chicks were fed a diet with *lactobacillus acidophilus* and various levels of biotin. Harrell et al. (1988) reported that growth performance was not affected by adding *lactobacilli* to diets of nursery pigs. However, they noted a trend for greater growth performance in pigs fed a mixture of amylases and proteases with the *lactobacilli* when compared to the control diet. Pollmann et al. (1980) reported that growth performance in weaning pigs was improved by adding *lactobacillus acidophilus* to their diets. However, *lactobacillus acidophilus* did not affect performance in growing-finishing pigs (Pollman et al., 1980). It is noteworthy that younger pigs respond better to acid producing organism while older growing-finishing pigs do not. Other researchers (Redmond and Moore, 1965; Kershaw et al., 1966; Nedyalkov et al., 1967) reported that *lactobacillus acidophilus* reduced enteritis and improved weight gains of pigs. However, Hines and Koch (1971) and Mahan and Newland (1976) argued that adding *lactobacillus acidophilus* to diets of weaning and

Table 2. Effects of cellulass enzymes and *lactobacillus acidophilus* on growth performance of finishing pigs[a]

Item	Corn-soy	Sorghum-soy	Sorghum-soy + enzyme	Sorghum-soy + bacteria	SE	Contrasts[b]		
						1	2	3
Day 0 to 28								
ADG (kg)	0.88	0.83	0.86	0.86	0.02	0.09	0.12	–[c]
ADFI (kg)	2.84	2.82	2.92	2.85	0.07	–	–	–
Gain/feed	0.310	0.294	0.295	0.302	0.003	0.08	–	–
Day 28 to 63								
ADG (kg)	1.01	1.00	1.03	1.02	0.03	–	–	–
ADFI (kg)	3.52	3.57	3.71	3.70	0.07	0.11	–	–
Gain/feed	0.297	0.280	0.278	0.276	0.003	–	–	–
Day 0 to 63								
ADG (kg)	0.95	0.93	0.96	0.95	0.01	–	–	–
ADFI (kg)	3.23	3.26	3.38	3.34	0.06	–	–	–
Gain/feed	0.294	0.285	0.284	0.284	0.001	0.09	–	–

[a] A total of 128 finishing pigs (eight pigs/pen and four pens/treatment) were fed from an average initial body weight of 51.3 kg to an average final body weight of 113.9 kg.

[b] Contrasts were: 1) corn versus other treatments; 2) sorghum versus enzymes and bacteria; and 3) enzymes versus bacteria.

[c] Dashes indicate p > .15.

finishing pigs did not improve ADG, ADFI, or gain/feed. Similarly, ADG, ADFI, and gain/feed of pigs fed *lactobacillus acidophilus* were unaffected in growing-finishing pigs (Kornegay et al., 1990).

Overall (day 0 to 63), there were no difference in growth performance among pigs fed the cellulase enzyme versus the *lactobacilli* (p > .49). Peters et al. (1992) examined the feeding value of barley cultivars with or without a crude pectinase mixture. The enzyme mixture did not affect performance of growing pigs, but, did improve ADG and gain/feed of finishing pigs. However, Thacker et al. (1992) and Bolduan and Hackl (1995) reported that addition of β-glucanase and pentosanase to barley- or rye-based diets of growing and finishing pigs had no effect on performance. Conversely, Antoniou and Marquardt (1981) and Grootwassink et al. (1989) reported that supplementation of rye-based diets with a pentosanase preparation consistently improved the rate and efficiency of live weight gain in chickens.

Dressing percentage (p > .22) was not affected by dietary treatment (table 3). Kornegay et al. (1990) reported that dressing percentage was not affected by adding *lactobacillus acidophilus* to diets. However, last rib backfat thickness was affected by treatment in our experiment (p < .09), with pigs fed the corn-soybean meal-based positive control having 6% greater backfat

Table 3. Effects of cellulase enzymes and *lactobacillus acidophilus* on carcass characteristics in finishing pigs[a]

Item	Corn-soy	Sorghum-soy	Sorghum-soy + enzyme	Sorghum-soy + bacteria	SE	Contrasts[b]		
						1	2	3
Live body weight (kg)	118.0	119.1	117.1	119.0	1.5	–[c]	–	–
Hot carcass weight (kg)	84.9	84.1	84.6	84.8	0.4	–	–	–
Dressing percentage (%)	71.9	71.1	71.5	71.7	0.3	–	–	–
Last rib backfat (mm)	32.9	32.1	31.1	30.3	0.9	0.09	–	–
Fat free lean index (%)[d]	45.7	45.9	46.3	46.6	0.3	0.10	–	–

[a] A total of 128 finishing pigs (four pigs/pen and four pens/treatment) were fed from an average initial body weight of 51.3 kg to an average final body weight of 113.9 kg.

[b] Contrasts were: 1) corn versus other treatments; 2) sorghum versus enzymes and bacteria; and 3) enzymes versus bacteria.

[c] Dashes indicate p > .15

[d] Equation (NPPC, 1991) was: Fat free lean index = 51.537 + (0.035 × hot carcass weight) − (12.26 × off-midline backfat thickness).

depth than pigs fed the sorghum treatments. Pigs fed the sorghum treatments had 1% greater fat free lean index ($p < .10$) compared to pigs fed the corn-soybean meal-based positive control.

Pigs fed the corn-soybean meal-based positive control had greater digestibilities of DM ($p < .03$), N ($p < .001$), and GE ($p < .005$) than pigs fed the sorghum-soybean meal-based negative control (table 4). Those greater nutrient digestibilities probably contributed to a surfeit of circulating nutrients that resulted greater fat thickness for pigs fed the corn-based diet. Cellulase enzymes and *lactobacilli* did not improve nutrient digestibilities compared to the sorghum-soybean meal-based negative control ($p > .25$). Also, nutrient digestibilities were not different for pigs fed the cellulase enzymes versus *lactobacillus acidophilus* treatment ($p > .68$). These data agree with those of Hale and Newton (1979), which indicated that DM digestibility in pigs fed a basal diet and a diet with *lactobacillus* fermentation product was similar. Also N digestibility and balance were not affected by adding the lactobacillus fermentation product. Li et al. (1993) reported that CP and GE digestibilities in nursery pigs fed wheat-, corn-, and rye-based diets, supplemented cellulase, were no effect; however, when cellulase was supplemented to a barley-based diet, CP and energy digestibilities were increased. Previous research (Mellange et al., 1992) reported that the effects of a mixture of xylanase, amylase, pectinase, and β-glucanase on performance and fecal nutrient digestibility of starter pigs fed diets containing wheat, barley, or wheat and beet pulp. Enzyme supplementation increased growth rate and feed efficiency, with the greatest response on diets containing barley or wheat and beet pulp. Inconsistent effects of bacterial feed additives and cellulase enzymes should not be confused with the consistent improvements in phoshorus utilization from diets supplemented with phytases (Jongbloed et al., 1991; Beers and Jongbloed, 1992; Mroz et al., 1992). Graham et al. (1988) reported that N digestibility measured at the terminal ileum had improved in 19 to 25 kg pigs fed β-glucanase supplementation of barley-based diets. However, added enzyme had no effect on ileal digestibilities of nutrients in finishing pigs fed a barley-based diet (Jondreville et al., 1995). Nutrient digestibility of a corn-soybean meal diet was not influenced by two bacillus products (Kornegay and Risley, 1995).

Table 4. Effects of cellulase enzymes and *lactobacillus acidophilus* on apparent nutrient digestibilities in finishing pigs[a]

Item	Corn-soy	Sorghum-soy	Sorghum-soy + enzyme	Sorghum-soy + bacteria	SE	Contrasts[b] 1	2	3
DM intake (g/d)	2,802	2,839	2,937	2,919	3	0.0001	0.0001	0.004
N intake (g/d)	66.0	67.8	71.0	68.0	0.1	0.0001	0.0001	0.0001
GE intake (kcal/d)	12,719	12,703	13,151	12,927	14	0.0001	0.0001	0.0001
Apparent digestibility (%)								
DM	83.4	80.3	81.2	80.7	0.9	0.03	–[c]	–
N	76.1	65.1	66.8	67.7	1.4	0.001	–	–
GE	84.3	80.6	81.3	80.9	0.8	0.005	–	–
Intake of digestible nutrients								
DM (g/d)	2,337	2,280	2,385	2,356	27	–	0.02	–
N (g/d)	50.2	44.1	47.4	46.0	1.1	0.005	0.06	–
DE (kcal/d)	10,722	10,239	10,692	10,458	107	0.07	0.03	0.14
Fecal excretion								
DM (g/d)	465	559	552	563	26	0.009	–	–
N (g/d)	15.8	23.7	23.6	22.0	1.0	0.0001	–	–

[a] A total 128 finishing pigs (four pigs/pen and four pens/treatment) were fed from an average initial body weight of 51.3 kg to an average final body weight of 113.9 kg.

[b] Contrasts were: 1) corn versus other treatments; 2) sorghum versus enzymes and bacteria; and 3) enzymes versus bacteria.

[c] Dashes indicate $p > .15$

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