Effects of Expander Conditioning of Corn- and Sorghum-Based Diets on Pellet Quality and Performance in Finishing Pigs and Lactating Sows[a]

S. L. Johnston[1], J. D. Hancock[1]*, R. H. Hines[1], G. A. Kennedy[2], S. L. Traylor[3], B. J. Chae[4] and In K. Han[4]
[1] Department of Animal Science & Industry, Kansas State University, Manhattan, KS 66506-0201, USA
[4] Department of Animal Science & Technology, Seoul National University, Suweon 441-744, Korea

ABSTRACT : Two experiments were conducted to determine the effects of conditioning (conventional vs expander) corn- and sorghum-based diets on production traits for lactating sows and finishing pigs. In Exp. 1, one hundred sixty-eight sows (parity 1-4, PIC line C15) were fed the corn or sorghum grain diets as a meal, standard (steam) conditioned pellets, or expanded pellets to give a 2×3 factorial arrangement of treatments. Pellet durability index (PDI) was similar for the sorghum- vs corn-based diets, but increased when diets were expanded pellets for both corn- and sorghum-based diets. The corn-based meal diet supported 3.3% greater litter weight gain than the sorghum-based meal diet (44.0 kg vs 42.8 kg). However, the advantage for the corn-based diet disappeared with expander processing (i.e., sows fed the sorghum-based diet responded more to diets processed with the alternative processing technology). Sow weight change during lactation was similar ($p>0.15$) among treatments, although average daily feed intake tended to be greater ($p<0.09$) for the sows fed sorghum. For Exp. 2, a total of 71 barrows (average initial weight of 58.0 kg) were used in a growth assay to determine the effects of feeding corn- and sorghum-based diets, as meal or pellets, after processing with a conventional steam conditioner or an expander (high-shear) conditioner. PDI was not different for the sorghum- vs corn-based diets, but increased from 84 to 95% with expander conditioning compared to conventional steam conditioning. Rate and efficiency of gain, and carcass leanness were similar for pigs fed sorghum and corn ($p>0.15$). Efficiency of gain was greater ($p<0.04$) for pigs fed the pelleted (356 g/kg) diets compared to those given the meal (348 g/kg) diets. However, efficiencies of gain were similar ($p>0.11$) for pigs fed the conventional- and expander-conditioned diets. Pelleting increased ($p<0.01$) the incidence and severity of stomach lesions regardless of grain type. In conclusion, corn-based meal diet resulted in a greater litter weight gain than the sorghum-based meal diet. However, that advantage disappeared when the diets were expanded and pelleted. Finishing pigs fed pelleted diets were more efficient than those fed meal diets. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 565-572)*

Key Words : Sow, Finishing Pig, Expander, Pellet Quality, Growth Performance, Corn, Sorghum

INTRODUCTION

Sorghum grain is a major crop in Kansas. Sorghum grain was brought to the U.S. from Africa for its heat and drought tolerance. It is grown in dryer areas of Kansas to save irrigation water and expense, and areas of Kansas with higher rainfall because rainfall patterns (i.e., late summer drought) cause the complete loss of dry land corn one out of three years. However, the price of sorghum grain is generally discounted approximately 10% on a weight basis when compared to corn because of grain sorghum's history of reduced animal performance. Historically, sorghum has been thought to have 90 to 95% of the feeding value of corn. Giesemann et al. (1990) reported greater response of nutrient digestibility to particle size reduction in sorghum than for corn. Hancock et al. (1992) reported increased G/F and nutrient digestibilities when extruded sorghum replaced ground sorghum. The reduction in animal performance associated with feeding sorghum has decreased noticeably many experiments comparing the two energy sources would suggest that with newer sorghum varieties and processing conditions, and feed values for sorghum may be closer to those of corn. In grow-finish swine, Tribble (1975) reported no difference between various varieties of grain sorghum and corn for rate and efficiency of gain. Crow et al. (1997) also saw no differences between corn and sorghum for ADG, ADFI, or G/F when mash, pelleted and extruded feed was fed to growing and finishing pigs. While sorghum is a common ingredient in diets for gestating sows and increasing in use in finishing diets, it is rarely used in diets for lactating sows. Louis (1989) saw reduced feed intake and reduced litter weight gain when rolled sorghum replaced ground corn. However, Mills (1994) saw an increase of 2 kg in 21 d litter weights when sorghum fed to sows during lactation was extruded. Expander processing is used in Europe to increase animal production when energy sources other than corn are used. Traylor et al. (1997) showed improved apparent digestibility of nutrients when sorghum was expanded. Therefore, two experiments were designed to compare corn and sorghum as mash, standard conditioned pellets, and expanded pellets for lactating sows and finishing barrows.

MATERIALS AND METHODS

1. Lactation experiment

One-hundred sixty eight sows (parity 1-4, PIC line C15) were used in a 21 d lactation experiment. During the first 30 d of gestation the sows were housed in an environmentally controlled breeding and gestation

* Address reprint request to J. D. Hancock.
[a] This study was partially funded by the Korea Science and Engineering Foundation (KOSEF) and Kansas Agricultural Experiment Station. Experiment Station Contribution No. 99-283-J.
[2] Dept. of Diagnostic Medicine, Kansas State Univ., USA.
[3] Dept. of Grain Sci. & Industry, Kansas State Univ., USA.
Received December 7, 1998; Accepted January 23, 1999

Table 1. Composition of basal lactation diet[a]

Ingredient	%	
Corn	64.54	-
Sorghum	-	64.54
Soybean meal (46.5% CP)	27.01	27.01
Corn gluten meal (60% CP)	2.50	2.50
Monocalcium phosphte	2.06	2.06
Limestone	1.14	1.14
Soy oil	1.00	1.00
Salt	0.50	0.50
Vitamin premix[b,c]	0.25	0.25
Sow vitamin premix[c,d]	0.25	0.25
Trace mineral premix[e]	0.15	0.15
Lysine · HCL	-	0.02
Corn starch	0.30	0.28
Antibiotic[f]	0.10	0.10
Chromic oxide	0.20	0.20

[a] Diets were formulated to 1.0% lys, 0.9% Ca, and 0.8% P (calculated values).

[b] Supplied per kilogram of diet; 11,023 IU of vitamin A, 1,102 IU of vitamin D_3, 44 IU of vit E, 4.4 mg of vitamin K (as menadione), 8.3 mg of riboflavin, 28.7 mg of pantothenic acid (as d-calcium pantothenate), 49.6 mg niacin, 165.3 mg choline, and 0.03 mg of vitamin B_{12}.

[c] Expanded diets were fortified at 125% of the vitamins of the basal diet.

[e] Supplied per kilogram of diet; 39.7 mg of Mn, 165.3 mg of Fe, 165.3 mg of Zn, 16.5 mg of Cu, 0.3 mg I and 0.3 mg Se.

[f] Supplied 110 mg chlorteteacycline per kg of diet.

building. From d-30 to d-110 of gestation the sows were kept in outdoor lots with sheds. During the first 30 d of gestation they were fed diets according to body condition, from d-30 to d-93 of gestation they were fed 1.8kg and from d-93 to d-110, 3.6 kg of a sorghum based gestation diet. At d 110 of gestation sows were washed and moved into an environmentally controlled farrowing facility, and they were blocked by parity and randomly assigned a dietary treatment of corn-based 1) meal; 2) standard conditioned pellet; 3) expander conditioned pellet; and sorghum based 4) meal; 5) standard conditioned pellet; and 6) expander conditioned pellet, for a 2×3 factorial arrangement of treatments. Treatment began on d-110 of gestation to acclimate sows to consuming a processed feed prior to farrowing. Diets were corn- or sorghum-soybean meal-based (table 1) and formulated to 1.0% lysine, 0.9% Ca, and 0.8% P and met or exceeded NRC (1988) requirements for all other nutrients. In the sorghum-based diets, sorghum replaced corn on a weight for weight basis. To make up for any loss of vitamin potency from expanding the diets, vitamins were added to the expanded diets at 1.25 times the amount of the basal diet, replacing corn starch. The grain portion of the diets were ground using a 1.5 horsepower hammer mill (Model ELT-9506-TF, Bliss Ind., Ponca City, OK) through a screen with 3.2-mm openings to a geometric mean particle size (d_{gw}) of 572 microns for the corn and 528 microns for the sorghum. The standard pellet diets were preconditioned to a temperature of 79℃ using a California Pellet Mill® conditioner with a retention time of 10 sec. The expanded diets were processed using a cone pressure of 14 kg/cm^2 on the expander-conditioner (Amandus-Kahl, high-shear) and the diet was preconditioned prior to expanding to a temperature of 80℃. The pelleted diets were formed by a California Pellet Mill® (Crawfordsville, IN) 1000 series "Master HD" model pellet mill with a die having hole diameter openings of 8-mm. Electrical energy consumption was measured on the main drive motor for the expander and pellet mill using a recording amp-volt meter (Model DMI, Amprobe Instrument, Lynbrook, NY). Pellet durability index was measured on the cooled pellets using the standard determination for pellet durability index S269.3 (ASAE, 1987). However, this procedure was also modified by the adding five 13 mm hexagonal nuts to the pellets prior to tumbling. Sows were housed in individual stalls (0.61 m×2.13 m) with 1.96 m^2 of creep space provided for piglets surrounding the sow, heat lamps and floor mats were furnished. A propane heater was utilized to maintain a targeted temperature in the building of 26℃, drip coolers were activated when the temperature rose above the target.

Sows were scanned ultrasonically (Renco Preg-Alert®, Renco Corportation, Minneapolis, Minnesota) to determine backfat thickness and weighed at farrowing, d 10, and at weaning at d 21 to determine lactation backfat and weight change. Backfat readings were taken at the last rib off midline on both sides, at first rib, last rib, and lower lumbar on midline and averaged. Litters size was equalized by d 2 of lactation and piglet weights were recorded at farrowing, d 10, and weaning.

Weights for sows and litters weaned on other than d 21 were adjusted by subtracting the d 10 weight from the weaning weight, dividing by days on treatment minus 10, multiplying by 11 and adding the d 10 weight. Adjustments for backfat and feed intake were made in the same manner. Sows weaning fewer than 9 pigs per litter were not included in the data set. Sows had *ad libitum* access to water and were fed four times daily at 08:00, 12:00, 16:00, and 22:00 h to insure *ad libitum* access to feed while minimizing feed wastage. Feed disappearance was recorded at d 10 and weaning to allow calculation of ADFI. Feed contained 0.20% chromic oxide and on d 18 grab samples of feces were collected from each sow. Feed and feces were analyzed for N, using the Kjeldahl procedure, DM by drying for 12 h at 100℃ (AOAC, 1990), and GE by oxygen bomb calorimetry (Parr Co., Oxygen Bomb Calorimeter, Model No. 13031, Moline, IL). Chromium concentrations in the feed and feces were determined by atomic absorption spectrophotometry (Williams et al., 1962) to allow calculation of apparent digestibilities of protein, dry matter, and gross energy. Starch gelatinization was measured by using a glucose release (Xiong et al., 1990) procedure. At weaning sows were moved to an environmentally controlled breeding and gestation facility for detection of estrus and breeding. Data were analyzed using the GLM procedure of SAS (1985) using the following orthogonal contrasts: 1) corn vs sorghum; 2) meal vs pellet; 3) standard conditioned pellet vs expander conditioned pellet; 4) corn vs sorghum × meal vs pellet; and 5) corn vs sorghum × standard pellet vs expanded pellet, with parity, farrowing group, and treatment as sources of variation and individual sow as the experimental unit.

2. Finishing experiment

A total of 72 (avg initial wt of 58 kg) terminal-cross barrows (PIC line 326 boars × C15 sows) were blocked by weight, sorted by ancestry and allotted to 36 pens. There were two pigs per pen and six pens per treatment. Treatments of corn- and sorghum-based meal, standard conditioned pellet, and expander conditioned pellet were randomly assigned to one pen within each block for a randomized complete block design. The experiment was arranged in a 2 × 3 factorial, with pen as the experimental unit. Diets (table 2) were corn- and sorghum-based and formulated to 0.9% lysine, 0.65% Ca and 0.55% P.

Table 2. Composition of finishing basal diet

Ingredient	%	
Corn	79.87	-
Sorghum	-	79.87
Soybean meal (46.5% CP)	15.74	15.74
Lysine-HCL	0.29	0.31
Threonine	0.05	0.12
Methionine	0.05	0.14
Tryptophan	0.01	-
Monocalium phosphte	1.07	1.07
Limestone	1.03	1.03
Soy oil	1.00	1.00
Salt	0.30	0.30
Vitamin premix[b,c]	0.15	0.15
Trace mineral premix[d]	0.10	0.10
Corn starch	0.21	0.04
Chromic oxide	0.13	0.13

[a] Diets were formulated to 0.9% lys, 0.65% Ca, and 0.55% P (calculated values).

[b] Supplied per kilogram of diet; 6614 IU of vitamin A, 661 IU of vitamin D_3, 26 IU of vit E, 2.6 mg of vitamin K (as menadione), 5.0 mg of riboflavin, 17.2 mg of pantothenic acid (as d-calcium pantothenate), 29.8 mg niacin, 99.2 mg choline, and 0.02 mg of vitamin B_{12}.

[c] Expanded diets were fortified at 1.25% of the vitamins of the basal diet with the additional vitamins replacing corn starch.

[d] Supplied per kilogram of diet; 26.5 mg of Mn, 110.2 mg of Fe, 110.2 mg of Zn, 11.0 mg of Cu, 0.2 mg I and 0.2 mg Se.

Treatments were the same, and diets were conditioned, as described for the lactation experiment. However, a pellet mill die with openings of 4.8mm was used. Pigs were housed in an environmentally controlled building. Each pen was 1.5 m × 1.5 m with a slatted concrete floor. Pens were equipped with a one-hole self-feeder and nipple waterer to allow *ad libitum* consumption of food and water. The pigs and feeders were weighed at initiation, d 32, and conclusion of the growth assay to allow calculation of ADG, ADFI, and G/F. Stomachs were collected at slaughter and scored for keratosis and ulceration. On d 32 feed was weighed and removed and diets containing chromic oxide (0.20%) as an indigestible marker were fed. After 5 d a grab sample of feces was taken from all pigs and pooled by pen. Apparent nutrient digestibilities and percent starch availability were determined as in the lactation experiment. Pigs were slaughtered on d 50 (average final BW 110 kg). Hot carcass weights were taken to allow for determination of dressing percentage. Growth data were analyzed using the GLM procedure of SAS (1985) using the following orthogonal contrasts: 1) corn vs sorghum; 2) meal vs pellet; 3) standard conditioned pellet vs expander conditioned pellet, 4) corn vs sorghum × meal vs pellet; and 5) corn vs sorghum × standard pellet vs expanded pellet; with weight block and treatment as sources of variation. Last rib fat depth was measured at the mid-line on both sides of a split carcass and averaged and data analyzed with hot carcass weight, block, and treatment as sources of variation. Stomachs were collected and were scored for keratinization: 0 = normal; 1 =mild keratinization; 2 = moderate keratinization, and 3 = severe keratinization; and for ulceration: 0 = normal; 1 = mild ulceration; 2 = moderate ulceration; and 3=severe ulceration. Stomach morphological changes were analyzed using the Cochran-Mantel-Haenszel procedure of SAS (1985).

RESULTS AND DISCUSSION

1. Lactation

Pellet durability index (table 3) for the standard corn pellet was 60.8% (average of standard and modified ASAE 1987 procedures) and 66.0% for the standard sorghum pellet. The expanded corn pellet had a PDI of 90.2 % while the PDI for the expanded sorghum was 86.3%. Total gross motor load for the standard pellets averaged 6.7 kWh/t while for the expanded diets it was 37.0 kWh/t.

Sow weight loss was not different between the corn- and sorghum-based diets for the entire lactation. Sows gained weight from farrowing to d 10 on both diets. In the period from d 10 to weaning at d 21, during which sows on all treatments lost weight, the sows on the corn-based diets lost more weight ($p<0.02$) than did the sows on the sorghum-based diets; -3.4 kg vs -1.6 kg. Sows fed the sorghum treatments had feed intakes that were 0.3 kg higher than those of corn during that period, d 10 to weaning, ($p<0.03$) and tended ($p<0.08$) to have higher feed intakes throughout the entire lactation. This would be in contrast to Louis (1989) who showed decreased feed intakes in lactating first and second parity sows fed ground sorghum when compared to ground corn. There was no difference for sow body

Table 3. Effects of standard and expander conditioning of corn- and sorghum-based diets for lactating sows on processing charateristics and pellet quality

Item	Corn		Sorghum	
	Standard pellet	Expanded pellet	Standard pellet	Expanded pellet
Pellet production rate, kg/h	1,859	1,101	1,072	1,156
Electrical energy consumption, kWh/t				
Pellet mill				
Idle	3.8	6.3	3.9	6.0
Specific	2.7	2.0	3.0	2.7
Gross	6.5	8.3	6.9	8.7
Expander				
Idle	-	20.6	-	19.7
Specific	-	8.4	-	8.3
Gross	-	29.0	-	28.0
Total gross	6.5	37.3	6.9	36.7
Pellet durability index, %				
Standard[a]	65.7	91.4	71.7	90.4
Modified[b]	55.8	89.0	60.2	88.8

[a] ASAE (1987).
[b] ASAE (1987) modified with the addition of five (13-mm) hexagonal nuts prior to tumbling.

weight change, or daily feed intake for either period or overall, ($p>0.12$) when the meal diets were compared to the pelleted treatments or when the standard pellet was compared to the expanded pellet. There was an interesting interaction as the sows fed the corn-based standard conditioned pellet gained more in the first period and overall than did the sows fed the expanded corn-based diet, while sows fed the sorghum-based standard conditioned diet gained less for the first period and overall than the sows fed the expanded sorghum pellet. This might be explained by a trend ($p<0.07$) for increased feed intake during the first period of the expanded sorghum pellet and a slight decrease of the expanded corn pellet compared to the standard conditioned diets during the first period. The percentage of sows that returned to estrus in the 30 d period following weaning and the length of time between weaning and estrus for those sows showing estrus within 30 d was similar for all treatments ($p>0.2$). There was no difference in change in sow backfat for the lactation period.

Equalizing litters insured that no differences ($p>0.4$) existed in weight or number of pigs at the start of the experiment. There was no difference in the number of

Table 4. The effect of standard and expander pelletizing of corn and grain sorghum diets on sows[a] and litters

Item	Corn			Sorghum			SE
	Meal	Standard Pellet	Expanded Pellet	Meal	Standard Pellet	Expanded Pellet	
Sow BW farrowing[b], kg	197.5	193.7	196.4	198.8	193.0	198.5	6.3
Sow body weight change							
Farrowing to d 10	6.7	10.3	4.9	6.1	6.8	8.5	2.6
d 10 to 21	-4.1	-2.8	-3.3	-1.8	-1.8	-1.1	2.0
Total change	2.6	7.5	1.6	4.3	5.0	7.4	3.0
Fat depth farrowing, mm	20.9	20.0	22.3	21.8	19.5	21.5	1.3
Farrowing to d 10	-2.4	-0.3	-1.6	0.0	-2.0	2.6	1.0
d 10 to weaning	0.4	-1.2	0.4	-1.1	0.0	1.2	1.4
Total change	-2.0	-1.5	-1.2	-1.1	-2.0	-1.4	1.2
ADFI, kg							
Farrowing to d 10	5.7	5.9	5.7	5.7	5.7	6.1	0.4
10 d to weaning	6.1	6.2	6.2	6.3	6.5	6.6	0.4
Average entire lactation	5.9	6.1	6.0	6.0	6.1	6.4	0.3
Litter performance							
Initial pigs/litter	11.4	11.6	11.5	11.6	11.5	11.6	0.4
Pigs/litter	10.8	10.6	10.5	10.8	10.7	10.9	0.4
Pigs weaned/litter	10.6	10.5	10.5	10.5	10.6	10.6	0.4
Survivability, %	93.0	90.5	91.3	90.5	92.2	91.4	0.04
Litter weight, kg							
Initial weight	16.8	17.2	17.2	17.0	17.1	17.4	1.0
d 10	36.1	34.8	36.5	36.0	35.7	37.7	2.2
d 21	60.8	58.1	61.3	59.8	61.4	62.7	3.6
Litter weight gain, kg							
Farrowing to d 10	19.3	17.6	19.3	19.0	18.6	20.3	1.8
d 10 to 21	24.7	23.3	24.8	23.8	25.7	25.0	2.0
Total	44.0	40.9	44.1	42.8	44.3	45.3	3.3
Return to estrus, %[c]	76.9	82.8	76.9	87.1	85.7	71.4	16.0
Days to estrus[d]	5.0	5.1	4.5	4.5	5.3	4.9	0.1

[a] One hundred sixty-eight sows, parities 1-4, (PIC C15).
[b] Within 24 h postfarrowing.
[c] Percent of sows returning to estrus within 30 d of weaning.
[d] For sows returning to estrus within 30 d of weaning.

pigs at d 10, number of pigs weaned, or survivability of the pigs from any treatment. Final litter weight of sows fed the sorghum-based meal diet was 3% lower than that of the corn-based meal treatment. This difference disappeared in the standard- and expanded-pellet treatments. Litter weight gain (p<0.05) was higher and therefore litter weights tended (p<0.08) to be higher for the sows fed expanded pellets compared to the standard pellets from farrowing to d 10. This was not true, however, for the period from d 10 to weaning (p>0.7), or for the entire lactation period (p>0.19).

There was no difference in apparent digestibility of GE or DM between the corn- and sorghum-based treatments (p>0.2), but digestibility of N was 3% higher (p<0.001), and DE of the diet was 1% less (p<0.004) for the sorghum treatments when compared to the corn-based treatments (table 6).

There was no difference (p>0.9) for daily intake of DE for the period from farrowing to d 10 between corn and sorghum treatments. However, due to a numerical increase in feed intake of the sorghum diets for the period from d 10 to weaning, DE intake, Mcal/d, for

Table 5. Sow and litter probability table

Item	Contrasts[a]				
	1	2	3	4	5
Sow BW farrowing, kg	-[b]	-	-	-	-
Sow body weight change					
Farrowing to d 10	-	-	0.13	-	0.006
d 10 to 21	0.02	-	-	-	-
Total change	-	0.13	-	-	0.005
Fat depth farrowing, mm	-	-	0.04	-	-
Farrowing to d 10	-	-	-	0.03	-
d 10 to weaning	-	-	-	-	-
Total change	-	-	-	-	-
ADFI, kg					
Farrowing to d 10	-	-	-	-	0.07
d 10 to weaning	0.03	-	-	-	-
Average entire lactation	0.08	-	-	-	-
Litter performance					
Initial pigs/litter	-	-	-	-	-
Pigs/litter	-	-	-	-	-
Pigs weaned/litter	-	-	-	-	-
Survivability, %	-	-	-	-	-
Litter weight, kg					
Initial weight	-	-	-	-	-
d 10	-	-	0.08	-	-
d 21	-	-	-	-	-
Litter weight gain, kg					
Farrowing to d 10	-	-	0.05	-	-
d 10 to 21	-	-	-	-	-
Total	-	-	-	-	-
Return to estrus, %	-	-	-	-	-
Days to estrus	-	-	-	-	-

[a] Contrasts were: 1) corn vs sorghum; 2) meal vs pellet; 3) standard pellet vs expanded pellet; 4) corn vs sorghum × mash vs pellet; 5) corn vs sorghum × standard pellet vs expanded pellet.

[b] Dashes indicate p>0.15.

the sorghum diets was 4% higher than for the corn diets for that period (p<0.001) and 1% higher for the entire lactation (p<0.002). The increase in DE intake during that period would account for the sows on the sorghum diet losing less weight than did the sows on the corn treatments. Pelleting improved apparent digestibility of GE, DM, and N (p<0.001). This is consistent with experiments reported by Wondra (1995) and Traylor (1997). Stark (1994) showed increased DM digestibility in finishing pigs, however, N digestibility was not affected. DE kcal/kg in diets, and DE intake for both periods and overall (p<0.001) were also improved by pelleting. Expanding prior to pelleting improved (p<0.05) GE and DE of the diet and tended (p<0.08) to improve apparent N digestibility of the corn and sorghum-based diets. Digestible energy intake was higher for the expanded diets (p<0.002) for all periods. Digestibility of the sorghum-based diets increased more for GE, DE, (p<0.008) and N (p<0.04), as the sorghum-based diet was pelleted than did the digestibilities of the corn-based diet. Intake per day of digestible energy also increased at a higher rate (p<0.001) when sorghum-based diets were pelleted than did DE intake of the corn-based diet. Daily intake of DE decreased from corn-based standard conditioned pellet to the expanded pellet, whereas calorie intake increased for the sorghum expanded pellet when compared to the standard conditioned pellet for the first 10 d and for the overall lactation (p<0.001).

2. Finishing

Pellet durability index (table 7) for the standard corn pellet was 77.6% (average of standard and modified ASAE 1987 procedures) and 78.0% for the standard sorghum pellet. The expanded corn pellet had a PDI of 96.6% while the PDI for the expanded sorghum was 91.3%. Total gross motor load for the standard pellets averaged 8.9 kWh/t and for the expanded diets it was 39.2 kWh/t.

There was no difference (p>0.15) between the pigs fed the corn- and the sorghum-based diets for daily feed intake, rate of gain or efficiency (table 8). This would be in contrast to work done with finishing pigs by Grabouski (1987), but in agreement with the research reported by Tribble (1975) and Crow (1997). Pelleting of finishing diets provides inconsistent results on rate of gain. In this experiment pelleted diets did not impact ADG, which agrees with experiments reported by Stark (1994). However, efficiency of gain is consistently improved with pelleting. Wondra (1993) reported 7% improvement in efficiency of gain, and in this experiment pelleting increased G/F (p<0.04) by 6% for both corn and sorghum. Average daily feed intake was reduced (p<0.005) by pelleting, 2% for the corn- and 9% for the sorghum-based diets. Feed intake (p>0.35), rate of gain (p>0.33), and gain to feed ratios (p>0.11) did not change when pigs were fed standard pellets or expanded pellets. Feed intake showed a notable interaction with intake of the corn-based diet decreasing

Table 6. The effect of standard and expander pelletizing of corn and grain sorghum diets on apparent digestibility of nutrients and energy intake in diets fed to lactating sows

Item	Corn			Sorghum			SE
	Meal	Pellet		Meal	Pellet		
		Standard	Expanded		Standard	Expanded	
Apparent digestibility, %							
GE	88.3	88.9	90.6	86.5	89.6	90.1	0.5
DM	85.5	87.1	87.7	85.4	87.0	87.2	0.4
N	89.1	89.2	91.0	84.9	87.7	88.1	0.8
DE kcal/kg	3,456	3,471	3,544	3,360	3,490	3,490	20.0
DE intake, Mcal/d							
Farrowing to d 10	19.7	20.5	20.2	19.1	19.8	21.3	0.1
10 d to weaning	21.0	21.6	21.9	21.2	22.7	23.1	0.1
Avg. total lactation	20.5	21.2	21.3	20.1	21.3	22.4	0.1
Starch gelatinization, %	25.5	35.4	45.8	27.1	34.0	47.5	-
Contrasts[a]	1	2		3	4		5
Apparent digestibility, %							
GE	-[b]	0.001		0.05	0.008		0.13
DM	-	0.001		-	-		-
N	0.001	0.001		0.08	0.08		-
DE kcal/kg	0.004	0.001		0.05	0.05		0.13
DE intake, Mcal/d							
Farrowing to d 10	-	0.001		0.001	0.001		0.001
10 d to weaning	0.001	0.001		0.002	0.001		-
Avg. total lactation	0.002	0.001		0.001	0.001		0.001
Starch gelatinization, %	-	-		-	-		-

[a] Contrasts were; 1) corn vs sorghum; 2) meal vs pellet; 3) standard pellet vs expanded pellet; 40 corn vs sorghum × mash vs pellet; 5) corn vs sorghum × standard pellet vs expanded pellet.
[b] Dashes indicate p>0.15.

Table 7. Effects of standard and expander conditioning of corn- and sorghum-based diets for finishing swine on processing characteristics and pellet quality

Item	Corn		Sorghum	
	Standard	Expanded	Standard	Expanded
Pellet production rate, kg/h	1,410	1,136	1,445	1,142
Electrical energy consumption, kWh/t				
Pellet mill				
Idle	5.3	6.6	5.3	6.6
Specific	3.3	2.1	3.8	3.8
Gross	8.6	8.7	9.1	10.4
Expander				
Idle	-	19.5	-	19.6
Specific	-	12.6	-	7.6
Gross	-	32.1	-	27.2
Total gross	8.6	40.8	9.1	37.6
Pellet durability index, %				
Standard[a]	83.0	96.6	83.7	93.4
Modified[b]	72.2	96.2	72.3	89.2

[a] ASAE (1987).
[b] ASAE (1987) modified with the addition of five (13-mm) hexagonal nuts prior to tumbling.

7% when comparing a standard pellet to an expanded pellet, while the sorghum-based diet showed an increase in intake of 3% for the expanded pellet versus the standard pellet. As in the lactation experiment, apparent digestibilities (table 8) of gross energy (p>0.7) and dry matter (p>0.15) were not different for the corn- and sorghum-based diets, while nitrogen digestibility (p<0.001) and DE of the diet (kcal/kg) were lower (p<0.0001) for the sorghum diets than for the corn diets. In his lactation experiment, Louis (1989) saw equal digestibility of energy and dry matter for corn and sorghum while the digestibility of N was lower for the sorghum diets. Pelleting the diets improved (p<0.001) apparent digestibilities of GE, N, DM and DE of the diets, again consistent with the lactation experiment. Expander preconditioning before pelleting increased (p<0.003) the apparent digestibilities of gross energy and dry matter and increased the digestible energy of the diet when compared to the standard conditioned pellet. There was no difference between the conditioning treatments for nitrogen digestibility. When considering carcass characteristics, there was no treatment effect on dressing percentage (p>0.11) or last rib fat depth (p>0.45).

In 1959, Bullard reported the death of a boar due to stomach ulceration, since then many production practices have been found to be associated with ulcers: fine

Table 8. The effect of standard and expander pelletizing of corn and sorghum grain diets on finishing barrows[a]

Item	Corn			Sorghum			SE
	Meal	Standard	Expanded	Meal	Standard	Expanded	
ADG, g	1,046	1,085	1,073	1,112	1,041	1,107	27.5
ADFI, g	3,117	3,158	2,934	3,317	2,969	3,058	71.6
G/F	0.34	0.34	0.37	0.34	0.35	0.36	0.01
Carcass characteristics							
Dressing percentage	73.5	73.7	73.0	72.5	73.4	72.6	0.5
LRFD, mm	28.9	29.2	28.4	29.4	28.1	29.1	1.2
Apparent digestibilities, %							
GE	90.5	92.2	93.3	90.5	92.3	93.4	0.31
N	86.9	89.0	90.1	84.3	86.7	87.8	0.76
DM	90.5	91.4	92.4	90.8	91.8	92.9	0.30
DE of diet, kcal/kg	3,686	3,758	3,800	3,631	3,700	3,744	13
Satrch gelatinization, %	29.8	35.1	50.0	24.2	32.8	46.8	-

Contrasts[b]	1	2	3	4	5
ADG, g	-[c]	-	-	0.15	-
ADFI, g	-	0.005	-	0.08	0.04
G/F	-	0.04	0.12	-	-
Carcass characteristics					
Dressing percentage	-	-	0.12	-	-
LRFD, mm	-	-	-	-	-
Apparent digestibilities, %					
GE	-	0.001	0.003	-	-
N	0.001	0.001	-	-	-
DM	-	0.001	0.003	-	-
DE of diet, kcal/kg	0.001	0.001	0.003	-	-
Satrch gelatinization, %	-	-	-	-	-

[a] A total of 71 pigs (avg initial wt of 58.0 kg) 2 pigs/pen with 6 replications/treatment was used, one pig having been removed from the experiment due to lameness.
[b] Contrasts were; 1) corn vs sorghum; 2) meal vs pellet; 3) standard pellet vs expanded pellet; 4) corn vs sorghum × mash vs pellet; and 5) corn vs sorghum × standard pellet vs expanded pellet.
[c] Dashes indicate p>0.15.

Table 9. The effects of standard and expander pelletizing of corn- and sorghum-based diets for finishing barrows on stomach morphology

Item	Corn			Sorghum			SE
	Meal	Standard Pellet	Expanded Pellet	Meal	Standard Pellet	Expanded Pellet	
Stomach keratinization[b]							
Total observations	12	11	12	12	11	12	
Normal	7	4	1	5	0	2	
Mild	4	4	7	6	2	5	
Moderate	1	2	4	1	8	4	
Severe	0	1	0	0	1	1	
Mean score	0.50	1	1.25	0.66	1.90	1.30	0.31
Stomach ulcerations[c]							
Total observations	12	12	12	12	11	12	
Normal	12	8	6	12	7	8	
Mild	0	0	5	0	2	1	
Moderate	0	0	1	0	2	2	
Severe	0	4	0	0	0	1	
Mean score	0	1	0.58	0	0.55	0.66	0.34

Contrasts[a]	1	2	3	4	5
Stomach keratinization	0.04	0.001	-[d]	-	0.08
Stomach ulcerations	0.34	-	0.002	-	-

[a] Contrasts were: 1) corn vs sorghum; 2) meal vs pellet; 3) standard pellet vs expanded pellet; 4) corn vs sorghum × mash vs pellet; 5) corn vs sorghum × standard pellet vs expanded pellet.
[b] The scoring system was: 0=normal; 1=mild keratinization; 2=moderate keratinization; and 3=severe keratosis.
[c] The scoring system was; 0=normal; 1= erosion; 2=ulcer; and 3=severe ulcers.
[d] Dashes indicate p>0.15.

grinding (Maharl et al., 1966), overcrowding (Sorrell et al., 1995), pelleting (Chamberlain et al., 1967), and extrusion (Mills, 1994). In this experiment, pigs fed grain sorghum showed an increase (table 9) in keratinization ($p<0.04$) but not in incidence or severity of ulcers ($p>0.5$) when compared to corn. Pelleting the diets increased both keratinization and ulceration ($p<0.002$), however, there was no difference in stomach morphology changes ($p>0.4$) when the standard pellets were compared to the expanded pellets. For the interaction of corn versus sorghum × standard vs expanded, there was a trend ($p<0.08$) for increased keratinization when the corn-based diet was expanded and decreased keratinization when the sorghum diet was expanded.

In conclusion, in these experiments there was little difference between corn and sorghum on animal performance and apparent digestibility of nutrients. This is likely due to advances in grain sorghum hybrids and response of grain sorghum to feed processing. Pelleting improved animal performance in the finishing experiment. The corn-based meal diet supported 3.3% greater litter weight gain than did the sorghum-based meal diet, however this advantage disappeared with pelleting. Nutrient digestibilities increased with pelleting and expanding. Expanding the diets increased electrical energy consumption and enhanced pellet durability.

IMPLICATIONS

The cost of sorghum grain is typically 10% lower than corn. Grain sorghum has been shown to give good performance when used in diets of finishing pigs and lactating sows. Pelleting sorghum-based lactation diets increased the feeding value of the sorghum diet to equal that of corn. Thus, sorghum can be utilized to decrease diet cost while maintaining a high level of animal performance.

REFERENCES

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemist, Arlington, VA.

ASAE. 1987. Wafers, pellets, crumbles-definitions and methods for determining density, durability, and moisture content. ASAE Standard S269.3, Agricultural Engineers Yearbook of Standards. American Society of Agricultural Engineers, St. Joseph, MI. p. 318.

Bullard, J. F. 1959. Gastric ulcer in a large boar. J. Am. Vet. Med. Association. 119:129.

Chamberlain, C. C., G. M Merriman, E. R. Lidvall, and C. T. Gamble. 1967. Effects of feed processing method and diet form on the incidence of esophagogastric ulcers in swine. J. Anim. Sci. 26:72.

Crow, S. D., G. L. Allee, and M. D. Newcomb. 1997. Effects of grain source and physical feed form upon growth performance, carcass measurements and gross stomach morphology in growing and finishing pigs. J. Anim. Sci. 75 (Suppl. 1): 64.

Giesemann, M. A., A. J. Lewis, J. D. Hancock, and E. R. Pee, Jr. 1990. Effect of particle size of corn and grain sorghum on growth and digestibility by growing pigs. J. Anim. Sci. 68 (Suppl. 1): 104.

Hancock, J. D., R. H. Hines, and T. L. Gugle. 1991. Extrusion of sorghum, soybean meal, and whole soybeans improves growth performance and nutrient digestibility in finishing pigs. Kansas State Univ. Swine Day Rep., Manhattan, KS. p. 92.

Louis, G. F. 1989. Feeding value of grain sorghum for the lactating sow MS Thesis. Nebraska State Univ., Lincoln, NE.

Maharl D. C., R. A. Pickett, T. W. Ferry, T. M. Curtin, W. R. Featherstone, and W. M. Beeson. 1966. Influence of various nutritional factors and physical form of feed on esophagogastric ulcers in swine. J. Anim. Sci. 25:1019.

Mills, C. G. 1994. Extrusion of sorghum grain and soybeans for lactating sows. M.S. Thesis. Kansas State Univ., Manhattan, KS.

NRC. 1988. Nutrient Requirements of Swine (9th Ed.). National Academy Press, Washington, DC.

SAS. 1985. SAS User's Guide: Statistics (Version 5 Ed.). SAS Inst, Inc., Cary, NC.

Sorrell, P., J. D. Hancock, L. L. Burnham, I. H. Kim, G. A. Kennedy, and R. H. Hines. 1995. Effects of crowding and intermittent feed intake on growth performance and development of stomach lesions in finishing pigs. Kansas Agric. Exp. Sta. Rep. of Prog. No. 746. p 117.

Stark, C. R. 1994. Pellet quality. Ph. D. Dissertation, Kansas State Univ., Manhattan, KS.

Traylor, S. L. 1997. Effects of feed processing on diet characteristics and animal performance. M.S. Thesis. Kansas State Univ., Manhattan, KS.

Traylor, S. L., S. L. Johnston, K. C. Behnke, J. D. Hancock, P. Sorrell, F. J. Fairchild, and R. H. Hines. 1997. Conditions during expander processing affect nutrient digestibility in finishing pigs fed corn- and sorghum-based diets. J. Anim. Sci. 75(Suppl. 1):64.

Tribble, L. F., W. F. Stansbury, and J. J. McGlone. 1975. Grain comparisons for growing-finishing swine. Texas Tech. Univ. Agric. Sci. Tech. Rep. T-5-111. p. 29.

Williams, C. H., D. J. David, and D. Iismaa. 1962. The determination of chromic oxide in feces samples by atomic absorption spectrophotometry. J. Agric. Sci. 59:381.

Wondra, K. J., J. D. Hancock, K. C. Behnke, R. H. Hines, and C. R. Stark. 1995. Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. Anim. Sci. 73:757.

Xiong, Y., S. J Bartle, and R. L. Preston. 1990. Improved enzymatic method to measure processing effects and starch availability in sorghum grain. J. Anim. Sci. 68:3861.