Effects of Conditioners (Standard, Long-Term and Expander) on Pellet Quality and Growth Performance in Nursery and Finishing Pigs[a]

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

ABSTRACT : A series of experiments were conducted to determine the effects of standard (ST), long-term (LT), and expander (EX) conditioners on nutritional value of phase-three nursery and finishing swine diets. In Exp. 1, 180 pigs (average initial BW of 11.7 kg) were fed corn-soybean meal based diets (1.3% lysine) during a 28 d growth assay. Gain/feed was improved (p<0.004) with pelleting and pellet durability index (PDI) increased with degree of conditioning (LT>ST). However, there was no advantage for LT vs ST conditioning in rate or efficiency of gain (p>0.5). In Exp. 2, 180 pigs (average initial BW of 10.4 kg) were fed con-soybean meal based diets (0.9% lysine) during a 28 d growth assay. Pelleted diets tended to support greater ADG (p<0.08) and gain/feed (p<0.002) with no marked advantage from EX vs ST conditioning. In Exp 3, a total of 70 barrows (average initial BW of 54 kg) was used in a growth assay to determine the effects of feeding a corn-soybean meal based diet processed with a standard (ST) steam conditioner, a long-term (LT) steam conditioner, and an expander (EX) conditioner. The conditioned diets were fed as mash (M) or pellets (P) to give a 2×3 factorial plus a meal control. PDI increased with degree of conditioning (EX>LT>ST). There was a trend (p<0.07) for greater ADG in pigs fed diets that had been thermally conditioned. Also, there was a general advantage in gain/feed with pelleting (p<0.04), but this advantage was pronounced only with standard conditioning. Indeed, the greatest gain/feed was observed for pigs fed the expander treatments (p<0.03) and the expander mash was used as efficiently as the expander pellets. There was no difference in backfat thickness among pigs fed the treatments (p>0.3), but the more extreme the processing technique, the greater the incidence and severity of stomach lesions (p<0.04). These results suggest maximum rate and efficiency of growth with pelleting after standard steam conditioning or simply feeding an expanded mash. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 558-564)*

Key Words : Nursery Pigs, Finishing Pigs, Conditioners, Expander, Pellet Quality, Growth Performance

INTRODUCTION

Expansion (high shear conditioning) is a technology that is entering the U.S. from Europe. It appears to increase pellet quality and starch gelatinization of feed and improve growth performance of pigs when used to process swine feed. Wondra (1993) obtained a 5% increase in growth rate and a 7% increase in efficiency of gain in finishing pigs when corn-based swine rations were pelleted. Stark (1994) showed that finishing pigs fed an increasing amount of fines had a decrease in efficiency of gain. Long-term conditioning has been used in the aquaculture industry to increase pellet durability. While Stark (1994) suggested that increased animal efficiency from pelleting resulted primarily from a decrease in feed wastage of the pelleted form of the diet, increased nutrient digestibility is often associated with pelleted diets. Stark (1994) showed increased nutrient digestibility with pelleting, which did not decrease as fines increased. This would seem to indicate that the conditioning prior to pelleting might be at least partially responsible for increase in efficiency. However, this was not supported by Moran (1989) who fed a reground pelleted diet to turkeys and saw an increase of only 1% in efficiency over the mash diet while feeding the whole pellet increased efficiency by 16%. Traylor (1997) reported increased pellet durability and increased starch gelatinization as prepelleting processing conditions changed in a corn-based diet. Chiang and Johnson (1977) showed that increased gelatinization in extruded diets increased enzymatic susceptibility. It has been suggested that conditioning alone, expanding but not pelleting, of swine and poultry feed, might be as beneficial to the animal as expanding and pelleting (Peisker, 1994). Elstner (1996) reported production of 1.5 million tons of unpelleted expandate per year, mostly in Northern Europe being fed to swine, chickens, and turkeys. However, very little research has been done to compare the effects of various conditioning technologies and whether conditioned diets need to be pelleted to impact animal performance. Thus, this series of experiments was conducted to determine the effects of standard, long-term, and expander conditioning, fed in mash and pellet form, on performance of nursery and finishing swine.

MATERIALS AND METHODS

1. Nursery experiment 1

One hundred-eighty (PIC L326 sires×C15 dams) nursery pigs (average initial BW of 11.9 kg) were blocked by weight and sex, sorted by ancestry and allotted to 30 pens. There were six pigs per pen and six pens per treatment, with three blocks each of gilts and barrows. Treatments of meal, standard conditioned mash, standard conditioned pellets, long-term conditioned mash, and long-term conditioned pellets were randomly assigned to each pen within each block for a complete

* Address reprint request to R. H. Hines.
[a] This study was partially funded by the Korea Science and Engineering Foundation (KOSEF) and Kansas Agricultural Experiment Station. Experiment Station Contribution No. 99-282-J.
[2] Dept. of Grain Sci. & Industry, Kansas State Univ., USA.
Received December 7, 1998; Accepted January 23, 1999

Table 1. Composition of basal nursery diet[a,b]

Ingredient	%
Corn	54.55
Soybean meal (46.5 % CP)	37.98
Lysine · HCl	0.03
Methionine	0.14
Monocalcium phosphate	1.62
Limestone	0.89
Soy oil	3.00
Salt	0.30
Vitamin premix[c,d]	0.25
Trace mineral premix[e]	0.15
Copper sulfate	0.09
Antibiotic[f]	1.00

[a] Chromic oxide was added at 0.20% as an indigestible marker.

[b] All diets were formulated to 1.30% lys, 0.80% Ca, and 0.70% P (calculated values).

[c] Supplied (per kilogram of diet) 11,023 IU of vitamn 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}.

[d] 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; 298 mg I, and 298 mg Se.

[f] Provided 55 mg carbadox per kilogram of diet.

randomized block design, with pen as the experimental unit. Pigs were housed environmentally controlled building in 1.2 m×1.5 m pens with wire flooring and equipped with a nipple waterer and a self-feeder to allow pigs *ad libitum* access to water and feed. Treatments of a phase-III nursery diet (table 1) were started on d 16 postweaning (average initial BW 11.7 kg, age 37 d) and fed for 28 d. The diet was formulated to 1.30 % lys, 0.80 % Ca, and 0.70 % P and to meet or exceed NRC (1988) requirements for all other nutrients. Chromic oxide was added at 0.2% to all treatments and 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 were determined by atomic absorption spectrophotometry (Williams et al., 1962) to allow calculation of apparent digestibilities of N, DM, and GE. Data were analyzed with the GLM procedure of SAS (1985) using the following contrasts: 1) meal vs all others; 2) mash vs pellet; 3) standard conditioning vs long-term conditioning; 4) mash vs pellet×long-term conditioning vs expander conditioning with d 16 weight, weight block, and treatment as sources of variation, and pen as the experimental unit.

2. Nursery experiment 2

One hundred-eighty (PIC L326 sires×C15 dams) pigs, were sorted by sex and ancestry, blocked by weight and allotted to 30 pens. Treatments of meal, standard conditioned mash, standard conditioned pellets, expander conditioned mash, and expander conditioned pellets, were randomly assigned to each pen within each block (3 blocks each of gilts and barrows, 5 pens/block, 6 pigs/pen). Therefore, experimental design was a 2×2 factorial arrangement of treatments with a meal control, with pen as the experimental unit. Facilities and apparent digestibility analysis were the same as the first experiment. The phase-III nursery treatments (table 1) were started at d 14 postweanling (average initial BW 10.4 kg, age 36 d) and fed for 28 d. Because of potential for vitamin degradation in the expander, expanded treatments were fortified at 1.25 times the vitamins added to the basal diet. Data were analyzed as in experiment one with expander conditioning replacing long-term conditioning and using d 14 weight as a source of variation.

3. Finishing experiment

A total of seventy (average initial BW of 54 kg) terminal-cross barrows (PIC line 326 boars×C15 sows) were blocked by weight, sorted by ancestry and allotted to 35 pens. There were two pigs per pen and five pens per treatment. Treatments of meal, standard conditioned mash, standard conditioned pellets, long-term conditioned mash, long-term conditioned pellet, expanded conditioned mash, and expanded conditioned pellet. Pigs were randomly assigned to one pen within each block for a calculation of apparent digestibilities of protein, dry matter, and gross energy using the following equation (Arentson and Zimmerman, 1992) :

$$\text{Percent apparent digestibility} = \{N_d/C_d - N_s/C_s\}/\{N_d/C_d\} \times 100$$

C_d = percent Cr_2O_3 in feed
C_s = percent Cr_2O_3 in sample
N_d = percent nutrient in feed
N_s = percent nutrient in sample.

Starch gelatinization was measured by using a glucose release (Xiong et al., 1990) procedure. Retention time in the conditioning units was measured by adding dye to the feed as it entered the conditioner and measuring the time until it exited. Standard conditioned diets were steam conditioned to 79℃ using a California Pellet Mill® conditioner with a retention time of 10 seconds. Long-term conditioned diets were conditioned with a California Pellet Mill®, two-pass conditioner which had a retention time of 2 min 40 sec and a conditioning temperature of 79℃. After conditioning, the mash diets were processed through a three high roller mill (Roskamp Manufacturing, Cedar Falls, IA). Pelleted diets were formed by a California Pellet Mill® (Crawfordsville, IN) 1000 series "Master HD" model pellet mill with a die 38 mm thick and 4 mm diameter openings. Pellet quality (PDI) was measured on the pellets using the standard determination for pellet durability index S269.3 (ASAE, 1987) and by modifying the procedure with the addition of five 13-mm hexagonal nuts prior to tumbling. Pigs and feeders were

Table 2. Composition of basal finishing diet[a]

Ingredient	%
Corn	80.37
Soybean meal (46.5 % CP)	15.42
Lysine-HCl	0.30
Threonine	0.05
Methionine	0.05
Tryptophan	0.01
Monocalcium phosphate	1.07
Limestone	1.03
Soy oil	1.00
Salt	0.30
Vitamin premix[b,c]	0.15
Trace mineral premix[d]	0.10
Corn starch	0.04
Antibiotic[e]	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 times 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, 0.2mg I, and 0.2 mg Se.
[e] Provided 110 mg tylosin per kilogram of diet.

weighed at the beginning and end of the experiment to allow calculation of gain, feed intake, and efficiency of gain. Data were analyzed with the GLM procedure of SAS (1985) using randomized complete block design. Thus, the experiment was arranged in a 3×2 factorial with a meal control with pen as the experimental unit.

The diet was corn-soybean meal-based (table 2) and formulated to 0.9% lysine, 0.65% Ca, and 0.55% P. The diets for the standard and long-term conditioned treatments were conditioned to a temperature of 79℃ using the same processing equipment as in the nursery experiment. The expander (Amandus-Kahl, high-shear) conditioner had a cone pressure of 14kg/cm^2 and the diet was preconditioned prior to expanding to a temperature of 77℃. The conditioned diets were fed as a mash or after pelleting through a 5 mm×4 cm die (California Pellet Mill®).

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 feed and water. The pigs and feeders were weighed at initiation 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 38, diets were weighed back and feeds containing chromic oxide (0.20%) as an indigestible marker was fed. After 5 d a grab sample of feces was taken from all pigs and pooled by pen. Apparent digestibilities analyses were calculated as in the nursery experiments. Data were analyzed using the GLM procedure of SAS (1985) using the following orthogonal contrasts: 1) meal vs all others; 2) mash vs pellet; 3) standard conditioning vs long-term and expander conditioning; 4) long-term conditioning vs expander conditioning; 5) mash vs pellet×standard conditioning vs long term and expander conditioning; 6) mash vs pellet ×long-term conditioning vs expander conditioning with weight block and treatment as sources of variation. A block of pigs were slaughtered when a pen within the block reached 118 kg (average final BW 115 kg). Last rib fat depth was measured at the mid-line on both sides of a split carcass and averaged and data analyzed with final body weight, block, and treatment as sources of variation. Stomachs 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), a row mean scores differ test for categorical data.

RESULTS AND DISCUSSION

1. Nursery experiment 1

Pellet durability was increased when comparing standard conditioned pellets to long term conditioned pellets (table 3).

Table 3. Processing characteristics in nursery diets (Exp. 1)

Item	Standard pellet	Long-term pellet
Pelleting, kWh/t	5.9	8.3
Pellet durability index, %		
Standard[a]	69.5	92.0
Modified[b]	56.5	90.0

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

Growth performance of the phase-III pigs (table 4) indicated no advantage for long-term conditioned mash and pellets compared to standard conditioned for rate ($p>0.24$) or efficiency of gain ($p>0.52$). However, pelleting of the conditioned mash diets improved gain to feed by 15% ($p<0.004$). There were noteworthy interactions of conditioning type and feed form as feed intake was dramatically higher for the long-term conditioned mash and lower for the long-term conditioned pellets than for the standard conditioned treatments ($p<0.02$). Rate of gain increased 5% ($p<0.02$) when the standard conditioned diets were pelleted, but pelleting the long-term conditioned diets showed a decrease of 3% for ADG.

Table 4. The effect of standard and long-term conditioning of feed on growth performance of phase III nursery pigs and nutrient digestibility

Item	Meal	Standard		Long-term		SE
		Mash	Pellet	Mash	Pellet	
ADG, g	563	562	595	589	571	10
ADFI, g	1,001	995	979	1,104	876	41
G/F	0.56	0.57	0.61	0.53	0.65	0.24
Apparent digestibility, %						
GE	89.9	89.1	91.2	85.6	90.4	0.93
DM	89.3	87.8	90.0	86.8	88.8	0.72
N	89.7	88.7	90.9	87.2	90.0	0.41
DE, kcal/kg	3,656	3,623	3,709	3,482	3,675	38
Starch gelatinization, %	26.1	25.0	34.9	37.2	38.1	-

Contrasts[a]	1	2	3	4
ADG, g	0.10	-[b]	-	0.02
ADFI, g	-	0.006	-	0.02
G/F	-	0.004	-	0.11
Apparent digestibility, %				
GE	-	0.002	0.04	0.002
DM	-	0.009	0.13	0.009
N	-	0.001	0.05	0.001
DE, kcal/kg	-	0.002	0.04	0.002
Starch gelatinization, %	-	-	-	-

[a] Contrasts were: 1) meal vs others; 2) mash vs pellet; 3) standard conditioning vs long-term; and 4) the interaction of mash vs pellet × standard vs long-term.

[b] Dashes indicate p>0.15.

Table 5. Processing characteristics in nursery diets (Exp. 2)

Item	Standard conditioning	Expander conditioning	
	Pellet	Mash	Pellet
Energy, kWh/t			
Pelleting	8.6	-	11.2
Expanding	-	36.6	36.6
Total	8.6	36.6	47.8
Pellet durability index, %			
Standard[a]	70.6	-	87.0
Modified[b]	57.8	-	71.0
Production rate[c], kg/h	2,645	-	920

[a] ASAE (1987).

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

[c] Screened pellets.

When nutrient digestibility of the diets was compared, there was no difference between the unconditioned meal and the conditioned treatments. Pelleting of the conditioned diets increased digestibility of GE, N, DM, and DE of the diet (p<0.009) with increases for both the standard and long-term pellets. Standard conditioned diets had higher digestibilities for GE, DM, and DE than did the long-term conditioned diets.

2. Nursery experiment 2

Pellet durability was increased for expander conditioned pellets compared to standard conditioned pellets (table 5). Feed intake of pigs was lower (table 6)

Table 6. The effect of standard and expander conditioning of feed on growth performance of phase III nursery pigs and nutrient digestibility (Experiment 2)

Item	Meal	Standard		Expander		SE
		Mash	Pellet	Mash	Pellet	
ADG, g	563	562	560	521	540	13
ADFI, g	905	897	848	830	786	22
G/F	0.62	0.59	0.66	0.63	0.69	0.16
Apparent digestibility, %						
GE	87.2	86.0	88.4	89.1	90.2	0.82
DM	85.2	83.8	85.1	86.6	88.2	0.94
N	86.3	85.7	87.5	88.1	89.0	0.57
DE, kcal/kg	3,623	3,572	3,672	3,670	3,746	34
Starch gelatinization, %	26.1	25.0	34.9	41.9	40.5	-

Contrasts[a]	1	2	3	4
ADG, g	0.09	0.08	-[b]	-
ADFI, g	0.03	0.07	0.09	-
G/F	-	0.001	-	-
Apparent digestibility, %				
GE	-	0.05	0.008	0.05
DM	-	0.14	0.006	0.14
N	-	0.04	0.003	0.04
DE, kcal/kg	-	0.05	0.008	0.05
Starch gelatinization, %	-	-	-	-

[a] Contrasts were: 1) meal vs others; 2) mash vs pellet; 3) standard conditioning vs expander conditioning; and 4) the interaction of mash vs pellet × standard vs expander.

[b] Dashes indicate p>0.15.

for all of the conditioned diets (p<0.03) compared to the unconditioned meal control.

Table 7. Processing characteristics in finishing diets

Item	Standard pellet	Long-term	Expander
Energy, kWh/t			
Pelleting	17.6	9.7	11.0
Expanding	-	-	33.7
Total	18.1	8.8	43.7
Pellet durability index, %			
Standard[a]	68.1	73.3	91.2
Modified[b]	51.5	61.6	89.5
Production rate[c], kg/h	850	1,308	1,017

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

There was a tendency for a decreased rate of gain (p<0.09) in the conditioned diets with the standard conditioned treatments having a 4% decrease and the expanded treatments having a 6% decrease in ADG compared to the meal control. The standard conditioned diets tended (p<0.09) to have higher feed intakes than the expander conditioned diets.

However, growth performance of pigs showed no difference between the expanded diets (p>0.24) and the standard conditioned diets. This is in contrast with Traylor et al. (1997) who obtained increased efficiency of gain when a simple corn-based nursery diet (1.5% fish meal) were expanded. There was a trend, 5% improvement in gain, for pigs fed pelleted diets (p<0.08) compared to the conditioned mash diets. Pigs fed pelleted diets did have an improved efficiency of gain (p<0.001) when compared to those fed the conditioned mash diets.

Apparent nutrient digestibility was not significantly different for the conditioned diets when compared to the meal control for GE, N, or DE (p>0.2). When the conditioned diets were pelleted, apparent digestibility of GE, DM and DE increased (p<0.05) while digestibility of N was unaffected (p>0.13) with the greatest increases resulting from pelleting the standard conditioned mash (p<0.05). Digestibility was higher for expander conditioned diets than for standard conditioned diets (p<0.05).

Table 9. Probability table of feed conditioning on growth performance and nutrient digestibility in finishing pigs

Item	Contrasts[a]/Interaction					
	1	2	3	4	5	6
ADG, g	0.07	0.09	-[b]	-	-	0.13
ADFI, g	-	-	-	0.14		-
G/F	-	0.04	0.15	0.03	0.02	-
LRFD, mm	-	-	-	-	-	-
Apparent digestibility, %						
GE	0.005	0.001	0.004	0.001	0.003	-
DM	0.09	0.001	0.003	0.009	0.02	-
N	-	0.002	0.06	0.05	0.05	-
DE of diet, kcal/kg	0.005	0.001	0.004	0.001	0.003	-

[a] Contrasts were: 1) meal vs Thermal conditioning; 2) conditional mash vs pellet; 3) standard vs advanced conditioning; and 4) long-term vs expander conditioning; 5) conditioned mash vs pellet×standard vs advanced conditioning; 6) mash vs pellet×long-term vs expander conditioning.
[b] Dashes indicate p>0.15.

3. Finishing experiment

Pellet durability was increased from standard to long-term to expander preconditioning of the feed (table 7). There was a trend (p<0.07) for greater ADG (table 8) in pigs fed diets that had been thermally conditioned vs the unconditioned mash control. Pigs fed the expanded mash and the standard, long-term and expanded pellets grew faster than those fed the standard and long-term conditioned mash. Long-term and expander conditioning of the diet did not increase efficiency of gain compared to the standard diet (p>0.14). The standard pellet diet was as efficient as expanded while the long term diet had a lower G/F compared to the expanded diets (p<0.03). There was a general advantage in G/F with pelleting (p<0.04), but

Table 8. The effect of feed conditioning of feed on growth performance and nutrient digestibility in finishing pigs

Item	Meal	Standard		Long-term		Expander		SE
		Mash	Pellet	Mash	Pellet	Mash	Pellet	
ADG, g	905	913	990	931	994	985	962	28
ADFI, g	2,742	2,974	2,830	2,847	2,976	2,782	2,718	109
G/F	0.33	0.31	0.35	0.33	0.33	0.35	0.35	0.01
LRFD, mm	27.9	28.2	30.1	27.3	29.1	28.5	27.5	1.3
Apparent digestibility, %								
GE	89.2	87.5	92.7	90.0	91.3	92.0	94.0	0.6
DM	89.7	87.9	92.1	90.0	90.7	90.9	93.0	0.6
N	87.8	84.3	89.9	87.3	88.4	88.7	91.4	1
DE, kcal/kg	3,572	3,505	3,714	3,607	3,656	3,686	3,767	25
Starch gelatinization,%	19.4	24.2	28.1	25.4	34.1	39.1	43.8	

Table 10. The effects of feed conditioning on stomach lesions in finishing pigs

Item	Meal	Standard		Long-term		Expander		SE
		Mash	Pellet	Mash	Pellet	Mash	Pellet	
Stomach keratinization[b]								
Total observations	10	9	10	10	9	10	10	
Normal	6	3	2	4	0	0	0	
Mild	1	3	3	4	3	4	4	
Moderate	3	2	4	2	6	1	5	
Severe	0	1	1	0	0	5	1	
Mean score	0.70	1.11	1.40	0.80	1.73	2.10	1.70	0.34
Stomach ulceration[c]								
Total observations	10	9	10	10	9	10	10	
Normal	10	8	7	9	6	2	5	
Mild	0	1	2	0	2	5	1	
Moderate	0	0	0	1	1	2	2	
Severe	0	0	1	0	0	1	2	
Mean score	0	0.13	0.50	0.20	0.46	1.20	1.10	0.37

Contrasts[a]	1	2	3	4	5	6
Stomach keratinization	0.005	-[d]	-	0.02	-	0.008
Stomach ulceration	0.04	-	0.08	0.003	-	-

[a] Contrasts were: 1) meal vs thermal conditioning; 2) conditioned mash vs pellets; 3) standard vs advanced conditioning; 4) long-term vs expander conditioning; 5) conditioned mash vs pellet × standard vs advanced conditioning; 6) mash vs pellet × long-term vs expander conditioning.

[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.

this advantage was pronounced only with standard conditioning which gave an improvement of 15% while long-term conditioning showed only 2% increase and expander conditioning showed no improvement In efficiency with pelleting ($p<0.02$). Gross energy and digestible energy of the diet were significantly increased ($p<0.005$) and dry matter digestibility tended ($p<0.09$) to increase with hydro-thermal processing.

Pelleting of the conditioned mash diets increased apparent nutrient digestibility ($p<0.002$) of GE, DM, N, and DE of the diet. The mean of the standard conditioned treatments was lower for GE, DM, and DE of the diet ($p<0.03$) and tended to be lower ($p<0.06$) for N digestibility. The expander conditioned treatments were more digestible than the long-term conditioned treatments ($p<0.05$), with both mash and pellet diets having a numerical advantage over either of the long-term conditioned diets. There was an interaction of mash vs pellet × standard vs advanced processing as the standard pellet showed dramatic increases in digestibility over the standard conditioned mash while pelleting the long-term or the expanded mash showed only slight increases.

Finally, steam conditioning of the diet increased the incidence and severity of stomach lesions ($p<0.04$) with pelleting of the standard and long-term diet minimally increasing stomach lesions (table 10) and the expander diets (mash or pellet) yielding the greatest increase in ulcers. Neither feed intake ($p>0.13$) nor last rib fat depth ($p>0.3$) was affected by any treatment.

In conclusion, no benefit in growth performance of nursery pigs with long-term or expander conditioning of diets was observed. Pelleting of the diet increased apparent digestibility of GE, DM, and DE of the diet in both experiments. Pellet durability was enhanced with long-term and expander conditioning. In the finishing experiment, diets that had been processed using standard, long-term, and expander (high shear) conditioning tended to support greater ADG than an unconditioned mash control diet. Pelleting was necessary to maximize efficiency of growth, but only with standard and long-term conditioning.

IMPLICATIONS

Both long-term and expander conditioning increased pellet durability which has been shown to increase animal performance. Feeding an expanded, mash diet to finishing pigs was shown to be an acceptable alternative to a standard or expanded pellets. Thus, the decision of which technology to adopt will depend on cost of processing via the two technologies, capital available to purchase the different equipment, and the time and degree of expertise available to operate the equipment.

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.

Arentson, R. and D. R. Zimmerman. 1991. True digestibilities ofamino acids and protein in pigs using ^{13}C as a label to determine endogenous amino acid excretion. p.38. ISU Swine Report ASL-R952. Iowa State Univ., Des Moines. IA.

Chiang, B. Y. and J. A. Johnson. 1977. Gelatinization of starch in extruded products. Cereal Chem. 54:436.

Elstner, F. E. 1996. Expanding without pelleting. Feed Management 47(6):23.

Moran, E. T. 1989. Effect of pellet quality on the performance of meat birds. In: Recent Advances in Animal Nutrition. Buttenvorths. London.

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

Peisker, M. 1994. Annular gap expansion technology and its effect on animal performance. In: Proc. 10th Annual Carolina Swine Nutr. Conf., Raleigh, NC. p. 53.

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

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.

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. 1993. Effects of particle size, mill type, and diet form on performance of finishing pigs and lactating sows. M.S. Thesis. Kansas State Univ., Manhattan, KS.

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.