Effects of Expander Conditioning of Complex Nursery Diets on Growth Performance of Weanling Pigs[a]

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ABSTRACT : Three experiments were conducted to determine the effects of conditioning a complex (20% whey, 10% lactose, 4% plasma protein, 4% wheat gluten and 2% blood meal) diet on growth performance of weanling pigs. In Exp. 1, 180 pigs (average initial BW of 6.4 kg) were fed the experimental diet (1.7% lysine) during a 7-d growth assay. Treatments were a meal control (M), standard (ST), and expander (EX) conditioned mash or pellets. Rate and efficiency of gain were decreased by 39% and 21% ($p<0.005$) respectively, for pigs fed EX diets compared to those fed the ST diet. In Exp. 2, 196 pigs (average initial BW of 6.5 kg) were used to determine the effects of EX operating conditions on nutritional value of a pelleted complex diet. When steam conditioning temperature (prior to expanding) was 54℃, increasing cone pressure of the EX from 0 to 7 to 14 kg/cm2 resulted in linear decreases in rate of gain of weaned pigs ($p<0.006$), suggesting heat damage of the diet. Increasing conditioning temperature (i.e., adding steam) of the diets from 46 to 54 to 63℃ (cone pressure at 12 kg/cm^2) resulted in improved rate of gain ($p<0.04$) of the pigs. However, none of the pigs fed expanded diets compared favorably to the pigs fed the conditioned (54℃) pellets processed with no cone pressure. In Exp. 3, 168 pigs (average initial BW of 6.6 kg) were used to determine the effects of expanding the various components of the diet. Treatments were M and ST pellets as controls, EX-corn, EX-corn soybean-meal, EX corn-soybean meal-oil, and EX-complete diet. Efficiency of gain was increased by 13% with EX portions of the diet compared to the mash control, but there was a marked decrease in performance when the complete diet was expanded ($p<0.001$). Expanded corn-soybean meal-oil supported the greatest ADG with a 19% increase compared to the average of the EX corn and EX corn-soybean meal treatments ($p<0.005$). In conclusion, our results suggest no benefit from expanding complete phase-I diets. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 3 : 395-399)*

Key Words : Weanling Pigs, Expander, Growth Performance, Nursery Diet

INTRODUCTION

Expander technology has recently entered the United States from Europe and is beginning to be utilized by the poultry and swine industries. Peisker (1994a) reported that the expansion of complete diets for 35 d old nursery pigs containing wheat bran improved the average daily gain of the pigs by 10% while expanding only the wheat bran portion of the diet resulted in improvements of 24%. Nursery diets used in the US tend to contain less fiber and more specialized protein and dairy products. Traylor et al. (1997) suggested that benefits of expander technology shown in simple diets might not be seen in complex diets for the same age of pig. One of the benefits of expander technology is an increase in pellet quality (Traylor, 1997), however, 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. Piesker (1994b) suggested that feeding expanded crumbles might show increased efficiencies of gain while not requiring the use of a pellet mill. Hongtrakul et al. (1996) showed an increase in growth performance in segregated early weaned (SEW) pigs when only the corn portion of the diet was extruded, in both simple and complex nursery formulations, as compared to expanding the complete diets. Thus, this series of three experiments was designed to determine the effects of expander conditioning and feed form, expander processing parameters, and expansion of various dietary components of a complex nursery diet on the growth performance of weanling pigs.

MATERIALS AND METHODS

1. Experiment 1

One hundred-eighty piglets (PIC L326 sires×C15 dams, 22 d of age and 6.4 kg average initial BW) were weaned, 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 one pen within each block (6 blocks, 5 pens/block, 6 pigs/pen). The experimental design was a 2×2 factorial arrangement of treatments with a meal control, with pen as the experimental unit. Pens were 1.2 m×1.5 m, with woven wire flooring over Y-flush pits and equipped with a nipple waterer and a self-feeder to allow pigs *ad libitum* access to water and feed. The experimental diet (table 1) was formulated to 1.7% lysine, 0.9% Ca, and 0.8% P, and to meet or exceed NRC (1988) requirements for all other nutrients and fed for 7 d. Standard conditioned diets were steam conditioned to 60℃ using a California Pellet Mill® conditioner with a retention time of 10 seconds. Expander conditioned diets were steam conditioned prior to expanding to 54℃ and expanded at

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a cone pressure of 12 kg/cm^2 using a 100 hp expander (Model OE15.2, Amandus-Kahl, Hamburg, Germany). After conditioning and drying 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, with a die 38 mm thick and 4 mm diameter openings. Changes in starch gelatinization was measured by using a glucose release procedure (Xiong et al., 1990). Pigs and feeders were weighed at the initiation and conclusion of the experiment in order to determine ADG, ADFI, and G/F. Data were analyzed with the GLM procedure of SAS (1985) using the following orthogonal contrasts: 1) meal vs all others; 2) mash vs pellet; 3) standard conditioned vs expander conditioned; 4) mash vs pellet×standard vs expander conditioned, with weight block and treatment as sources of variation.

Table 1. Diet composition for Exp. 1, 2, and 3 (as fed basis)[a]

Ingredient	%
Corn	26.69
Soybean meal (46.5% CP)	26.62
Whey	20.00
Lactose	10.00
Porcine plasma protein	4.00
Blood meal	2.00
Wheat gluten	4.00
Soy oil	2.00
Monocalcium phosphate	1.50
Limestone	0.94
Lysine-HCl	0.22
Methionine	0.16
Salt	0.10
Vitamin premix[b,c]	0.25
Trace mineral premix[d]	0.15
Zinc oxide	0.37
Antibiotic[e]	1.00

[a] Formulated to 1.7% lysine, 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 vitamin E; 4.4 mg of vitamin K (as menadione); 8.3 mg of riboflavin; 28.7 ng of pantothenic acid (as d-calcium pantothenate); 49.6 mg niacin ; 165.3 mg of choline, and 0.03 mg of vitamin B_{12}.

[c] Expanded diets were fortified at 1.25 times of the vitamins of the basal diet.

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

[e] Supplied per kilogram of diet; 34 mg apramycin.

2. Experiment 2

One hundred ninety six pigs (PIC L326 sires×C15 dams, 21 d of age, BW of 6.5 kg) were sorted by sex, ancestry, blocked by weight and allotted to 28 pens (4 blocks, 7 pens/block, 7 pigs/pen). Treatments of meal, meal conditioned to 54℃ expanded at 0, 7 and 14 kg/cm^2 and pelleted, and meal conditioned to 46, 54, and 63℃ and expanded at a cone pressure of 12 kg/cm^2 and pelleted were randomly assigned to one pen within each block, and fed for 10 d. Nursery facilities, diet formulation, feed processing equipment, and response criteria were the same as in experiment one. Data were analyzed with the GLM procedure of SAS (1985) using the following contrasts: 1) meal vs 54℃×kg/cm^2: 2) linear for changing pressure; 3) quadratic for changing pressure; 4) meal vs 12 kg/cm^2; 5) linear for changing temperature; 6) quadratic for changing temperature.

3. Experiment 3

One hundred sixty eight pigs (PIC L326 sires×C15 dams, 22 d, BW 6.6 kg) were weaned, sorted by sex and ancestry blocked by weight and allotted to 30 pens (5 blocks, 6 pens/block, 5-6 pigs/pen) Two blocks had 5 pigs/pen with 3 gilts and 2 barrows while the remaining 3 blocks had 6 pigs/pen with equal numbers of gilts and barrows.

Treatments of meal, standard conditioned pellet, the corn portion of the diet expanded, the corn-soybean meal portion expanded, the corn-soybean meal-oil portion expanded, and the complete diet expanded and pelleted. Therefore, the experimental design was a 1×4 factorial arrangement of treatments with negative (meal) and positive (standard conditioned pellet) controls, with pen as the experimental unit. The expander was operated at 10 kWh/t of electrical energy inputs for the expanded portions of the diets.

Nursery facilities, feed processing equipment, and response criteria were the same as in experiment 1. Chromic oxide (Cr_2O_3) was added to the diet (table 1) at 0.20% as an indigestible marker. Fecal samples were collected on d 8 and concentrations of Cr (Williams et al., 1962) in the diet and the feces were determined to allow calculation of apparent digestibilities of N, DM, and GE. Pigs and feeders were weighed at the initiation and conclusion of the experiment and data were analyzed with the GLM procedure of SAS(1985) using the following orthogonal contrasts: 1) meal vs others; 2) standard conditioned pellet vs expanded-corn, expanded-corn soybean-meal, expanded corn-soybean meal-oil, and expanded complete diet; 3) expanded-corn, expanded-corn soybean-meal, expanded corn-soybean meal-oil vs expanded-complete diet; 4) expanded-corn and expanded-corn soybean-meal vs expanded corn-soybean meal-oil, 5) expanded-corn vs expanded-corn soybean-meal.

RESULTS AND DISCUSSION

1. Experiment 1

There was no difference ($p>0.3$) between the meal treatment and the average of the conditioned treatments for ADG, ADFI, or G/F (table 2). This lack of response was mainly due to the very low growth performance of the pigs fed the expanded treatments rather than a lack of response by pigs fed the standard conditioned mash and pellets. Pigs fed the expanded conditioned treatments had a 39% decrease ($p<0.001$) in rate of gain, a decrease ($p<0.002$) in feed consumption of 25%, and a decrease of 21% in efficiency of gain ($p<0.005$) when

Table 2. Effect of standard and expander conditioning on growth performance of weanling pigs[a]

Item	Meal	Standard		Expander		SE
		Mash	Pellet	Mash	Pellet	
ADG, g	210	241	253	146	154	15
ADFI, g	236	282	201	176	186	17
G/F	0.89	0.86	1.26	0.85	0.83	68
Starch gelatinization, %	46.9	48.6	52.9	48.6	68.6	-
Contrast[b]	1	2	3	4		
ADG, g	-[c]	-	0.001	-		
ADFI, g	-	-	0.002	0.02		
G/F	-	0.02	0.005	0.006		
Starch gelatinization, %	-	-	-	-		

[a] One hundred-eighty pigs (6.4 kg avg initial BW) were used.
[b] 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 expanded.
[c] Dashes indicate p>0.15.

compared to pigs fed the standard conditioned diet. The pelleted diets were not significantly different from the mash diets for ADG (p>0.5), or ADFI (p>0.1), however, G/F was improved (p<0.02) when the conditioned mash was pelleted. There were interactions for feed intake (p<0.02), with intake decreasing as the standard mash was pelleted and increasing as the expanded mash was pelleted. Pigs fed the standard pellet had the highest efficiency, a 41% improvement over the meal control and a 45% increase over the standard conditioned mash. The pelleted expandate had the lowest efficiency of gain. This would agree with Traylor (1997) who showed that phase II nursery pigs fed expanded complex nursery diets tended to have lower rate of gain.

2. Experiment 2

As cone pressure was increased from 0 to 14 kg/cm^2, rate of gain (p<0.06) and daily feed intake (p<0.001) decreased for pigs fed the expander conditioned and pelleted diets compared to those fed the unconditioned meal control (table 3).

Efficiency of gain was higher (p<0.04) for pigs fed the conditioned pelleted treatments. Pigs fed the conditioned but unexpanded (cone pressure-0 kg/cm^2) pellet had higher ADG than those fed the meal control. As cone pressure increased (0 to 7 to 14 kg/cm^2) there was a dramatic linear decrease (p<0.001) in rate of gain. Piglets also showed a marked decrease in feed intake (p<0.001), and efficiency of gain (p<0.006) as cone pressure increased. When pressure was held constant (12 kg/cm^2) and temperature was increased from 46 to 63℃, the pigs fed the control diet had better rate of gain (p<0.008) and higher feed intake (p<0.001) than those fed the expanded diets. Feed efficiency was higher for the expanded diets (p<0.02) than for the control diet. More steam was used in the preconditioning process to raise the temperature to 63℃, likely having the effect of lubricating the feed as it past through the expander, decreasing the probability of heat damage.

3. Experiment 3

The meal (negative control) tended (p<0.06) to support greater ADG than did the average of the pelleted diets (table 4), primarily due to the very poor growth performance of the piglets fed the expanded complete diet.

The meal fed pigs had higher ADFI (p<0.002) and lower G/F than did those fed the pelleted diets. The standard conditioned pellets (positive control) had higher rate (p<0.02) and efficiency of gain (p<0.006) compared to the expanded treatments, again, due to the very poor performance of the pigs fed the complete expanded diet. When expanded components of the diet (expanded corn, expanded corn-soybean meal, and expanded corn-soybean meal-oil) were compared to the expanded complete diet, they supported higher rate of gain (p<0.001), higher feed intake (p<0.001), and higher efficiency of gain (p<0.001). This is supported by the work of Hongtrakul et al. (1996) who showed decreased ADG and G/F

Table 3. The effect of conditioning temperature and expander cone pressure on growth performance of weanling pigs

Item	Meal	Temperature, ℃						SE
		54	54	54	46	54	63	
		Cone pressure, kg/cm^2						
		0	7	14	12	12	12	
ADG, g	276	305	264	187	226	235	260	10
ADFI, g	316	286	263	213	229	231	253	9
G/F	0.87	1.07	1.00	0.88	0.99	1.02	1.03	42
Starch gelatinization, %	46.9	58.5	60.6	66.7	61.8	57.6	59.1	-
Contrasts[a]	1	2	3	4	5	6		
ADG, g	0.06	0.001	-[b]	0.008	0.04	-		
ADFI, g	0.001	0.001	-	0.001	0.09	-		
G/F	0.04	0.006	-	0.02	-	-		
Starch gelatinization, %	-	-	-	-	-	-		

[a] Contrasts were: 1) meal vs varying pressure; 2) linear varying pressure; 3) quadratic varying pressure ; 4) meal vs varying temperature; 5) linear varying temperature, and 6) quadratic varying temperature.
[b] Dashes indicate p>0.15.

Table 4. The effect of expanding various components on growth performance of weanling pigs and nutrient digestibility

Item	Meal	Pellet	Expanded feed components				SE
			C	C-SBM	C-SBM-O	Complete Diet	
ADG, g	377	382	346	359	420	193	17
ADFI, g	401	350	333	338	382	257	18
G/F	0.94	1.09	1.04	1.06	1.10	0.75	30
Apparent digestibility, %							
GE	80.7	81.3	86.0	87.3	86.1	85.7	0.54
DM	80.6	81.4	85.1	86.4	85.1	85.5	0.51
N	74.7	73.7	80.2	82.4	81.1	79.9	1.1
DE, kcal/kg	3,212	3,236	3,422	3,474	3,426	3,414	22
DE, kcal/d	1,288	1,133	1,140	1,174	1.309	877	51
Starch gelatinization, %	46.9	52.9	72.7	67.7	62.2	68.6	-

Contrasts[a]	1	2	3	4	5
ADG, g	0.06	0.02	0.001	0.005	-[b]
ADFI, g	0.002	-	0.001	0.05	-
G/F	0.05	0.006	0.001	-	-
Apparent digestibility, %					
GE	0.001	0.001	-	-	0.14
DM	0.001	0.001	-	-	0.14
N	0.001	0.001	-	-	-
DE, kcal/kg	0.001	0.001	-	-	0.14
DE, kcal/d	0.02	-	0.001	0.05	-
Starch gelatinization, %	-	-	-	-	-

[a] Contrasts were: 1) meal vs others; 2) standard pellet vs expanded treatments; 3) expanded-corn, expanded-corn soybean-meal, and expanded corn-soybean meal-oil vs the expanded-complete diet; 4) expanded-corn, expanded-corn-soybean meal vs expanded corn-soybean meal-oil; and 5) expanded corn vs expanded corn-soybean meal.

[b] Dashes indicate p>0.15.

when they expanded the complete diet for segregated early weaned pigs, but improved ADG and G/F when they extruded only the corn portion of the diet. This would suggest that expander processing was damaging to the high quality proteins and dairy sugars included in the complete diet. Apparent digestibilities of GE, DM, N, and DE of the diet, were significantly higher for the processed pelleted diets ($p<0.001$) than for the meal control, however, most of this increase was due to the increase in the digestibility of the expanded diets. No differences in apparent digestibilities were observed when the expanded corn and the expanded corn-soybean meal treatments were compared to the expanded corn-soybean meal-oil treatment ($p>0.32$) or when the expanded corn was compared to the expanded corn-soybean meal treatment ($p>0.13$). In addition, there was no difference in digestibility of GE, DM, N, or DE of the diet when the means of the expanded components were compared to the expanded complete diet ($p>0.33$). While expanding the total diet increased nutrient digestibilities, very low feed intake of the expanded complete diet may also be an explanation as a decrease in feed intake is often associated with an increase in nutrient digestibility.

Although expanding the total diet increased digestible energy of the diet by 202 kcal/kg, the decrease in feed intake of the expanded diet meant that piglets were consuming only 877 kcal/d, a 32% lower calorie intake than the meal control.

In conclusion, maximizing gain and getting newly weaned pigs to consume dry feed are prime concerns in the first phase of swine nursery feeding. In this series of experiments, expanding complete complex nursery diets was of no benefit. Expanding these diets was actually shown to be a detriment as evidenced by the sharp declines in rate of gain and very low feed intakes which occurred in the piglets fed the complete expanded diet in each experiment in this series. Under differing expander processing conditions the diet that would be most like a standard conditioned pellet gave the best results in growth performance. When the total diet and different components of the diet were expanded, apparent digestibility of nutrients in the diet was increased. However, expanding the complete diet caused a dramatic decline in feed intake which might account for the increase in digestibility.

While many things affect feed intake, the heat and pressure of extrusion processing is known to affect flavor. Maga (1989) reported that extrusion of nonvolatile flavor compounds associated with meats tie, porcine plasma and blood meal at 6% of the phase I diet were often bitter or astringent. Complex phase-I nursery diets have been carefully formulated to maximize feed intake in weanling pigs. A change in flavor may be the cause for the dramatic drop in intake of the expanded feeds.

IMPLICATIONS

In this series of experiments, expanding of complete complex nursery diets was detrimental to pig performance. The first experiment showed substantial decreases in rate and efficiency of gain and feed intake. The second experiment was conducted to determine whether or not the loss in growth performance observed in the first experiment could be avoided by varying either the cone pressure or the conditioning temperature. As operating conditions changed, the treatment that gave the highest numerical performance for growth criteria was the 54℃ cone pressure (i.e. a standard conditioned pellet). The third experiment showed that some benefit might be realized by expanding the corn-soybean meal-oil portion of the diet only.

REFERENCES

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

Hongtrakul, K., J. R. Bergstrom, R. D. Goodband, K. C. Behnke, I. H. Kim, W. B. Nessmith, M. D. Tokach, and J. L. Nelssen. 1996. The effect of ingredients processing and diet complexity on growth performance of the segregated early weaned pig. Kansas Agri. Exp. Sta. Rep. Prog. SRP 772. Kansas State Univ., Manhattan. KS. p. 43.

Maga, J. A. 1989. Flavor formation and retention during extrusion. In: Extrusion Cooking. C. Mercier, P. Linko, and J. M Harper, eds. Am. Assoc. Cereal Chem., St. Paul, MN.

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

Peisker, M. 1994a. An expander's effect on wheat bran in piglet rations. Extrusion Communique. 7(2):18.

Peisker, M. 1994b. 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.

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, J. R. Froetschner, F. J. Fairchild and R. H. Hines. 1997. Diet complexity and conditioning method affect growth performance and nutrient digestibility in nursery pigs. J. Anim. Sci. 75(Suppl. 1): 72.

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.

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.