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Effects of diet complexity and dietary lactose levels during three starter phases on postweaning pig performance[1,2,3]

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ABSTRACT: Four experiments involving 1,005 crossbred pigs weaned at 19 ± 2 d of age evaluated the effect of diet complexity and lactose level on starter pig performances. Experiment 1 was a randomized complete block (RCB) conducted in nine replicates with 135 pigs. A complex diet using several protein sources, a semicomplex diet with fewer protein sources, and a simple diet of corn and soybean meal comprised the three treatment groups. All diets contained 25% lactose (as-fed basis) with lysine (total) constant from d 0 to 14 (1.55%) and d 14 to 28 (1.45%), respectively. Gain, feed intake, and feed efficiency ($P < 0.05$) improved as diet complexity increased during both periods. In Exp. 2, 240 pigs in eight replicates in a RCB design were fed complex diets, but dietary lactose (total; as-fed basis) levels ranged from 10 to 35% in 5% increments from 0 to 14 d after weaning. From 14 to 30 d, a common 17% lactose diet was fed to evaluate the effects of early lactose level on subsequent responses. Gains ($P < 0.05$) increased for the 0- to 7- and 0- to 14-d periods as lactose increased to 30%. Similar gains resulted for all treatment groups from 14 to 30 d after weaning, with no evidence of compensatory responses to early lactose levels. In Exp. 3, 330 pigs were fed complex diets. From 0 to 7 d after weaning, the diets contained 25% lactose (as-fed basis), and from 7 to 21 d postweaning, the lactose levels ranged from 7 to 31% in 5% increments. Gain ($P < 0.01$) and feed efficiency ($P < 0.05$) increased from 7 to 21 d to the 17% lactose level. In Exp. 4, 300 pigs were fed 25 and 17% (as-fed basis) lactose diets from 0 to 7 and 7 to 21 d postweaning, respectively. From 21 to 35 d postweaning, lactose levels of 0 to 20% in 5% increments were added to a corn-soybean meal diet. The experiment was conducted as a RCB design in 12 replicates. Gain ($P < 0.05$) and feed intake ($P < 0.05$) increased to 10 to 15% lactose. When the data from Exp. 4 were partitioned into lighter (15.0 kg) and heavier (17.7 kg) pig weight replicates, only the lighter replicates had significant improvements in gain, feed intake, and feed efficiency ($P < 0.05$) in response to dietary lactose. These results demonstrated that starter pigs performed better when fed complex diets, that dietary lactose levels of 25 to 30% (to 7 kg BW) during the initial week postweaning, 15 to 20% lactose during d 7 to 21 (to 12.5 kg BW), and 10 to 15% lactose during d 21 to 35 postweaning (to 25 kg BW) resulted in maximum performance.

Key Words: Diets, Lactose, Pigs, Weaning

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Introduction

With the advent of improved feed processing technologies and the introduction of new feedstuffs, there is a wide array of dietary feed sources of high nutritional quality that are available for nursery pig diets. Rather than attaining the traditional 18 kg of BW pigs at 56 d of age that was a common goal before 1980, it is not uncommon today to achieve average pig weights >25 kg of BW at 56 d, an increase of approximately 40%. An overall improvement of health status, increased lean growth, and other factors (management, facilities, environment) have each contributed to superior nursery pig performance. The effect of new feeds, some with immunological properties, is widely recognized as a possible major factor in the success of early weaning programs. Some researchers have investigated diet complexity for weanling pigs and have generally concluded that complex diets improved nursery pig performance during the early postweaning period, but these early

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diets seemed to have had a minimal affect during the grower-finisher period (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003).

Dried whey is a major feed ingredient added to weanling pig diets that has been shown to increase pig growth (Graham et al., 1981, Tokach et al. 1989; Mahan, 1993; Nessmith et al., 1997). Although high protein digestibility and high AA quality enhances the value of whey, its lactose seems to be a primary factor in achieving good performance responses from this product (Mahan, 1992). Most researchers have, however, incorporated it only during the early phase after weaning. This series of experiments evaluated the effects of diet complexity and the effects of various dietary levels of lactose provided during each of three commonly used starter phases on weanling pig performance.

Materials and Methods

General

Four experiments were conducted at The Ohio State University Swine Research Farm in Columbus. The crossbred pigs ([Yorkshire × Landrace] × PIC 280) used in each experiment were weaned at an average 19 ± 2 d of age, allotted on the basis of weight, sex, and litter, and immediately placed in nursery pens (n = 5 per pen) that provided 0.30 m^2 of woven-wire floor space per pig, one nipple waterer, and a four-hole stainless steel feeder. Diets were mixed in a horizontal paddle drum mixer at the Ohio Agriculture Research Center feed mill in Wooster in meal form, preweighed into bags, transported to the Columbus Swine Farm, and fed to pigs within 30 d of mixing. All diets met or exceeded NRC (1998) nutrient requirements. The room temperature was initially set at 28°C and adjusted downward as needed to meet the comfort zone of the pigs.

Experiment 1

A randomized complete block (**RCB**) experiment conducted in nine replicates used a total of 135 crossbred pigs and evaluated the effects of diet complexity during both d 0 to 14 and d 14 to 28 postweaning. Diets were formulated with various combinations of protein sources for each treatment group during each of two nursery phases. All diets contained corn and soybean meal, but the percentage of soybean meal was reduced as the diets became more complex. In the initial d-0 to -14 period, the complex treatment diet contained dried whey, blood cells, soy protein concentrate, blood plasma, fish meal, and synthetic AA (lysine and methionine). A second treatment diet (semicomplex) contained dried whey and blood plasma, whereas the third treatment group (simple diet) was formulated with corn and soybean meal. During d 14 to 28, the diets contained the same ingredients as in the initial phase except that plasma protein was eliminated in the d-0 to -14 period of the complex and semicomplex diets, and the percentage of contribution from each protein source varied from the initial phase. The calculated lysine (total) content of diets was 1.55 and 1.45% during the initial 0- to 14- and 14- to 28-d periods, respectively. Because of the presence of ileitis in the herd, a high level of antibiotic was included in the nursery diets as a preventative for the disease. The composition of treatment diets is presented in Table 1. Pig weights and feed intake were recorded at 7-d intervals during the experiment.

Experiment 2

A RCB experiment conducted in eight replicates evaluated the effect of lactose (total) levels during the initial period postweaning. A complex dietary scheme similar to that followed in Exp.1 was provided during d 0 to 14 postweaning (Table 2). Lactose (total) levels ranged from 10 to 35%, in 5% increments, in six treatment groups. Lactose was provided from dried whey (70% lactose), with crystalline lactose added to attain the desired dietary lactose (total) treatment levels. Lactose was added at the expense of corn, with corn gluten meal also added to replace the corn protein component lost from this replacement. From d 14 to 30 postweaning, the pigs were fed a common diet containing 17% lactose (total). This part of the experiment was conducted to evaluate whether the lactose levels provided during the initial period could affect and influence later growth and feed intake responses. The composition of the basal diet for the 0- to 14-d period and the common diet during the second phase is presented in Table 2. A total of 240 crossbred pigs was allotted to treatment pens with pig weights and feed intakes collected at d 7, 14, and 30 of the experiment.

Experiment 3

The length of feeding the Phase 1 diet in most commercial and research conditions is normally 5 to 14 d after weaning. The pigs of this experiment were fed a 25% lactose diet during the initial week postweaning, whereupon this experiment was initiated. Lactose (total) levels ranging from 7 to 31%, in 5% increments, in six treatment groups were evaluated during the 7- to 21-d postweaning period. Dried whey was included in all treatment diets at 10% (i.e., 7% lactose), with crystalline lactose added to attain the desired treatment lactose (total) levels. The replacement of the added lactose to the diets was the same as in Exp. 2 by using lactose and corn gluten meal at the expense of the corn component. The composition of the basal diet is presented in Table 2. This RCB experiment was conducted in 11 replicates and involved a total of 330 pigs. Pigs were allotted at weaning into the six treatment pens with the lactose treatment diets started on test at d 7 postweaning. Subsequent pig weights and feed intakes were collected at 7-d intervals to 21 d postweaning.

Table 1. Composition of experimental diets, % (as-fed basis; Exp. 1)

	Day 0 to 14[a]			Day 14 to 28[b]		
Ingredient	Complex	Semicomplex	Simple	Complex	Semicomplex	Simple
Corn	33.95	23.80	18.15	40.10	27.45	24.52
Soybean meal, 48% CP	14.00	35.60	50.00	20.00	42.00	46.25
Dried whey	15.00	15.00	—	12.00	12.00	—
Blood cell[c]	0.50	—	—	1.50	—	—
Soy protein concentrate	5.00	—	—	2.00	—	—
Blood plasma[c]	4.00	4.00	—	—	—	—
Fish meal, select	6.50	—	—	6.50	—	—
L-Threonine	—	—	—	0.10	—	0.03
Lysine·HCI	0.10	—	—	0.15	—	—
DL-Methionine	0.15	0.15	0.15	0.20	0.15	0.15
Lactose	15.00	15.00	25.00	10.00	10.00	20.00
Fat, choice white grease	3.00	3.00	3.00	5.00	5.00	5.00
Dicalcium phosphate	1.25	1.45	1.60	0.80	1.30	1.65
Limestone	0.35	0.80	0.90	0.45	0.90	0.90
Se premix[d]	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix[e]	0.10	0.10	0.10	0.10	0.10	0.10
Salt	0.40	0.40	0.40	0.40	0.40	0.70
Vitamin premix[f]	0.25	0.25	0.25	0.25	0.25	0.25
ZnO, 72% Zn	0.25	0.25	0.25	0.25	0.25	0.25
Antibiotic[g]	0.05	0.05	0.05	0.05	0.05	0.05

[a]Diets (d 0 to 14) calculated to contain 1.55% lysine (total), 0.95% Met + Cys, 1.03% Thr, 0.90% Ca, 0.70% P, and 25% lactose (total).
[b]Diets (d 14 to 28) calculated to contain 1.45% lysine (total), 0.89% Met + Cys, 0.95% Thr, 0.90% Ca, 0.70% P, and 20% lactose (total).
[c]Blood plasma (APC-920) and blood cell (301G) were obtained from American Protein Corp., Ames, IA.
[d]Sodium selenite in a limestone carrier provided 0.3 mg of Se/kg of diet.
[e]Supplied per kilogram diet: 8 mg of Cu (copper sulfate); 90 mg of Fe (ferrous sulfate); 0.2 mg of I (calcium iodate); 20 mg of Mn (manganese oxide); and 100 mg of Zn (zinc sulfate) with rice hull carrier.
[f]Supplied per kilogram diet: 2,450 IU of vitamin A (acetate); 245 IU of vitamin D_3; 0.6 mg of vitamin K (menadione sodium bisulfate); 18 IU of vitamin E (DL-α tocopheryl acetate); 4.5 mg of riboflavin; 13.5 mg of d-pantothenic acid; 22.3 mg of niacin; 0.3 mg of folacin; 1.7 mg of thiamine; 2.8 mg of pyridoxine; 0.1 mg of d-biotin; 22.3 μg of vitamin B_{12}; 0.70 g of choline; and 66 mg of butylated hydroxytoluene (BHT) as an antioxidant.
[g]Supplied 50 mg of tylosin/kg of diet.

Experiment 4

Pigs used in this experiment were fed a 25% lactose diet from 0 to 7 d postweaning, followed by a 17% lactose diet that was fed from 7 to 21 d after weaning, similar in composition to the diets of Exp. 2 and 3. Pigs were allotted to one of five treatment pens at 21 d postweaning. A total of 300 crossbred pigs was used in a RCB experiment conducted in 12 replicates to evaluate the effect of providing five lactose levels ranging from 0 to 20% lactose (total) in 5 % increments from 21 to 35 d postweaning. The basal diet was comprised of corn and soybean meal with no added lactose. Crystalline lactose was added to treatment diets at the expense of corn, with corn gluten meal added to replace the corn protein component removed by the lactose addition. The composition of the basal diet is presented in Table 2.

Statistical Methods

The performance responses within each experiment were analyzed as a RCB design (Steel and Torrie, 1980) using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). In all experiments, time was included in the model because replicates in each experiment were not conducted within the same group. In Exp. 1, treatments were contrasted by LSD after a significance level of $P < 0.05$ was obtained from the ANOVA. In Exp. 2, 3, and 4, regression analysis was conducted for the different lactose levels evaluated. In Exp. 4, the initial BW differed by replicate. It was of interest to know whether lighter weight pigs responded to the dietary lactose levels as those of a heavier BW. Consequently, seven replicates of pigs averaged 15.0 ± 0.8 kg at 21 d of age, and five replicates of pigs averaged 17.7 ± 0.9 kg BW and were analyzed separately. In each experiment, the pen was considered the experimental unit.

Results

Experiment 1

Daily gains increased during each postweaning period when the starter diets became more complex (Table 3). Feeding the complex diet resulted in greater ($P < 0.05$) gains during both d 7 to 14 and d 14 to 21, and for the overall period of 0 to 28 d. Although there was a numerical decline in daily gain response during the initial week when the simple diet was fed, the data

Table 2. Composition of experimental basal diets, % (as-fed basis; Exp. 2, 3, 4)

	Exp. 2[ab]		Exp. 3[c]	Exp. 4[d]
	Days 0 to 14	Days 14 to 30	Days 7 to 21	Days 21 to 35
Ingredient Lactose, %:	12	17	8	0
Corn	49.20	37.70	50.10	58.90
Soybean meal, 48% CP	14.00	31.50	31.25	29.00
Corn gluten meal	±	2.00	±	±
Soy protein concentrate	5.00	—	—	5.00
Dried whey	15.00	10.00	10.00	—
Blood plasma[e]	4.00	—	—	—
Blood cell[e]	0.50	2.00	2.00	—
Fish meal, select	6.50	—	—	—
Lysine·HCI	0.05	0.15	0.15	0.15
DL-Methionine	0.10	0.10	0.10	0.10
Lactose	±	10.00	±	±
Fat, choice white grease	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.25	1.45	1.45	1.60
Limestone	0.35	0.90	0.90	1.00
Se premix[f]	0.15	0.15	0.15	0.15
Trace mineral premix[g]	0.10	0.10	0.10	0.10
Salt	0.25	0.40	0.25	0.45
Vitamin premix[h]	0.25	0.25	0.25	0.25
ZnO, 72% Zn	0.25	0.25	0.25	0.25
Antibiotic[i]	0.05	0.05	0.05	0.05

[a]The basal diet (0 to 14 d) was calculated to contain 1.55% lysine (total), 0.95% Met + Cys, 1.03% Thr, 0.90% Ca, 0.70% P, 0.40% Na, 0.50% Cl, and 10% lactose. Treatment lactose levels were added at the expense of corn with corn gluten meal replacing the corn protein component.
[b]The diet (14 to 30 d) was calculated to contain 1.45% lysine (total), 0.95% Thr, 0.90% Met + Cys, 0.90% Ca, 0.70% P, 0.40% Na, 0.50% Cl, and 17% lactose.
[c]The basal diet (7 to 21 d) was calculated to contain 1.55% lysine (total), 0.95% Met + Cys, 1.03% Thr, 0.90% Ca, 0.70% P, 0.40% Na, 0.50% Cl, and 10% lactose. Treatment lactose levels were added at the expense of corn with corn gluten meal replacing the corn protein component (±).
[d]The basal diet (21 to 35 d) was calculated to contain 1.35% lysine (total), 0.80% Met + Cys, 0.85% Thr, 0.90% Ca, 0.70% P, 0.20% Na, and 0.34 % Cl. Treatment lactose levels were added at the expense of corn with corn gluten meal replacing the corn protein component.
[e]Blood plasma (APC-920) and blood cell (301G) were obtained from American Protein Corp., Ames, IA.
[f]Sodium selenite in a limestone carrier provided 0.3 mg of Se/kg of diet.
[g]See the trace mineral premix in Table 1 for composition.
[h]See the vitamin premix in Table 1 for composition.
[i]Supplied 50 mg of tylosin/kg of diet.

did not differ significantly between the three treatment groups. Daily feed intakes were greater as diet complexity increased during d 0 to 7 ($P < 0.05$), d 14 to 21 ($P < 0.05$), and for the overall period of d 0 to 28 ($P < 0.05$), but not during d 14 to 28. Feed efficiency was greater ($P < 0.05$) during d 0 to 14, for the overall 0- to 28-d period ($P < 0.05$), but not for d 14 to 28. At 28 d postweaning, pigs fed the complex diet were 2.65 kg heavier (i.e., 12%) in BW ($P < 0.05$) than pigs fed the simple diet, whereas those fed the semicomplex diet had BW intermediate to the other two treatment groups.

Experiment 2

This experiment evaluated the effect of feeding a complex diet at dietary lactose levels ranging from 10 to 35% during the initial period postweaning, followed by the feeding of a common 17% dietary lactose (total) level from 14 to 30 d postweaning. The results presented in Table 4 indicated that daily gains increased linearly ($P < 0.05$) as dietary lactose level increased from d 0 to 7 and from d 0 to 14. Gain increased to the 30% lactose level but decreased at the 35% lactose level. There was no treatment group effect from d 7 to 14. Although feed intake numerically increased during d 0 to 7 and d 7 to 14 with dietary lactose level, the responses for each weekly period and for the period from 0 to 14 d were not significant. There was a linear increase ($P < 0.05$) in feed efficiency to lactose level during the 0- to 7-d period, but not during the subsequent week.

Feeding the constant dietary lactose level from d 14 to 30 postweaning evaluated the potential carryover or compensatory effect from the early lactose levels on later postweaning gain and feed intake responses. The results presented in Table 4 indicated that daily gains and feed intakes were similar for all treatment groups for the period from 14 to 30 d, suggesting that there was no compensatory gain. Pigs fed the basal diet had lighter BW at d 14 than pigs fed the 30% lactose diet, a difference of 0.44 kg, and this treatment weight difference remained at 30 d (0.57 kg) postweaning.

Experiment 3

Pigs were fed a common complex diet containing 25% lactose during the initial week postweaning, where-

Table 3. Effect of diet complexity on postweaning pig performance (Exp. 1)[a]

Item	Complex	Semicomplex	Simple	SEM
Weight, kg				
Weaning	6.34	6.32	6.35	0.04
7 d	7.18	7.03	6.92	0.12
14 d	10.18[x]	9.73[x]	9.23[y]	0.24
28 d	18.21[x]	16.91[y]	15.56[z]	0.30
Daily gain, g				
0 to 7 d	105	101	82	17
7 to 14 d	429[x]	383[x]	332[y]	20
0 to 14 d	266[x]	239[x]	205[y]	16
14 to 28 d	584[x]	522[y]	457[z]	10
0 to 28 d	422[x]	378[y]	328[z]	11
Daily feed, g				
0 to 7 d	198[x]	193[x]	163[y]	13
7 to 14 d	477	457	445	17
0 to 14 d	336	322	301	16
14 to 28 d	830[x]	772[y]	649[z]	20
0 to 28 d	579[x]	544[x]	473[y]	16
G:F, g/kg (as-fed basis)				
0 to 14 d	788[x]	756[xy]	685[y]	29
14 to 28 d	707	676	707	16
0 to 28 d	732[x]	696[y]	693[y]	12

[a]A total of 135 pigs (n = 45 per treatment group) was weaned at 19 ± 2 d of age.
[x,y,z]Means with different superscripts on the same row differ, $P < 0.05$.

upon various dietary treatment lactose levels added to a complex diet were fed during the ensuing 14-d postweaning period. Responses presented in Table 5 demonstrated that daily gains increased in a linear ($P < 0.01$) manner during the period from d 7 to 14, whereas gains during d 14 to 21 also tended to be greater ($P < 0.10$) when lactose levels increased. For the overall 7- to 21-d period, gains increased ($P < 0.01$) as lactose level increased, with a response plateau suggested at about 17% lactose. Feed intakes tended to be greater ($P < 0.10$) during the period of d 7 to 14 as dietary lactose level increased. Gain:feed ratio increased linearly ($P < 0.05$) for the 7- to 21-d period as dietary lactose level increased.

Experiment 4

Pigs were fed common complex diets containing 25 and 17% lactose levels during the d-0 to -7, and d-7 to -21 periods, respectively. During the 21- to 35-d experimental period, the diets were comprised of a corn-soybean meal mixture with lactose added at levels ranging from 0 to 20%. Crystalline lactose was added at the expense of corn, with corn gluten meal replacing the corn protein component. The results presented in Table 6 demonstrated that daily gains were greater ($P < 0.05$) as lactose level increased with a plateau suggested at the 15% lactose level. Daily feed intake increased ($P < 0.05$) to the 20% lactose level. There was no effect on feed efficiency to added lactose level during the period form d 21 to 35.

Replicates of pigs were separated into two weight groups and analyzed separately in order to evaluate the response effect when pigs differed in BW at the beginning of Phase 3. One set of replicates (n = 7) had lighter (15.0 ± 0.8 kg) initial BW, whereas the other replicate group (n = 5) had heavier (17.7 ± 0.9 kg) BW (Table 6). The results demonstrated that daily gains and feed intakes were greater ($P < 0.05$) when the level of lactose increased to the lighter-weight pigs. Although there was also a numerical increase in gain and feed intake response when the heavier-weight pigs were fed increasing lactose levels, the results were not significant.

Discussion

A simple diet comprised of corn and soybean meal can be formulated to meet the nutritional requirements of the weaned pig. However, feeding such a diet to 19-d-old weanling pigs did not result in maximum performance responses during the starter period. Simple diets contain high dietary soybean meal levels, resulting in villus hypersensitivity to the soybean protein that reportedly decreases pig gains (Li et al., 1990, 1991). However, this effect seemingly does not continue to market weight (Nessmith et al., 1997). With many commercial swine farms now weaning pigs at ≤21 d of age, the pig's ability to effectively respond with its immune system is lower (Blecha et al., 1983), its digestive tract is immature (Shields et al., 1980), the intestinal villi are more denuded than if weaned at a later age (Cera et al., 1988), and the use of high soybean meal levels is discouraged. Consequently, using feeds such as dried whey (Graham et al., 1981), spray dried plasma protein (Hansen et al., 1993), fish meal (Stoner et al., 1990), and other

Table 4. Effect of supplemental lactose level during phase 1 (0 to 14 d) weanling pig performance (Exp. 2)[a]

Item / Crystalline lactose, %:	0	5	10	15	20	25	
Total lactose, %:	10	15	20	25	30	35	SEM
Weight, kg							
Weaning	6.29	6.37	6.32	6.32	6.34	6.26	0.02
7 d[b]	6.88	7.06	7.03	7.12	7.25	6.98	0.09
14 d[b]	9.31	9.51	9.79	9.77	9.75	9.36	0.15
30 d	15.02	15.31	15.54	15.37	15.59	14.86	0.32
Daily gain, g							
0 to 7 d[c]	84	99	103	114	130	103	11
7 to 14 d	346	349	370	360	359	339	13
0 to 14 d[b]	216	222	236	237	244	221	11
14 to 30 d	527	542	541	535	538	521	19
Daily feed, g							
0 to 7 d	190	207	202	214	225	194	12
7 to 14 d	401	412	423	428	421	409	16
0 to 14 d	296	308	313	321	323	302	12
14 to 30 d[b]	767	790	787	760	789	674	29
G:F, g/kg (as-fed basis)							
0 to 7 d[d]	442	478	509	533	577	530	36
7 to 14 d	863	853	880	841	855	832	21
0 to 14 d	724	725	754	738	755	734	15
14 to 30 d	686	680	686	697	710	742	11

[a]A total of 240 pigs (n = 40 per treatment, with five pigs per pen, in eight replicates, was weaned 19 ± 2 d of age. From 14 to 30 d after weaning, a common diet was fed that contained 17% lactose (total) and 1.45 % lysine (total).
[b]Quadratic response, $P < 0.05$.
[c]Linear response, $P < 0.05$.
[d]Linear response, $P < 0.01$.

feedstuffs used to formulate complex diets have been shown to be superior to a simple diet mixture. Our experiments differed from others reported in the literature, in that we used a constant level of lactose in our starter diets in Exp. 1 to more accurately compare complex vs. simple diet formulations.

The effect of varying the complexity of diets fed to nursery pigs (Dritz et al., 1996; Whang et al., 2000;

Table 5. Effect of supplemental lactose level during phase 2 (7 to 21 d) weanling pig performance (Exp. 3)[a]

Item / Crystalline lactose, %:	0	5	10	15	20	25	
Total lactose, %:	7	12	17	22	27	31	SEM
Weight, kg							
Weaning	6.41	6.41	6.39	6.38	6.43	6.42	0.03
7 d	7.34	7.20	7.34	7.35	7.29	7.15	0.10
21 d [b]	12.69	12.77	13.20	13.26	13.09	13.36	0.20
Daily gain, g							
7 to 14 d[c]	278	285	315	335	317	331	12
14 to 21 d[d]	507	509	525	514	529	540	15
7 to 21 d[c]	393	396	426	425	423	435	11
Daily feed, g							
7 to 14 d[d]	421	397	426	448	427	449	16
14 to 21 d	700	690	736	718	705	718	18
7 to 21 d	560	547	581	583	554	583	15
G:F, g/kg (as-fed basis)							
7 to 21 d[b]	709	724	737	730	741	748	13

[a]Eleven replicates were conducted using 330 pigs (n = 55 per treatment group), weaned at 19 ± 2 d of age. Pigs were fed a common diet containing 25% lactose and 1.55% lactose from 0 to 7 d postweaning.
[b]Linear response, $P < 0.05$.
[c]Linear response, $P < 0.01$.
[d]Linear response, $P < 0.10$.

Table 6. Effect of supplemental lactose level during phase 3 (21 to 35 d) weanling pig performance (Exp. 4)[a]

Item Lactose, %:	0	5	10	15	20	SEM
Weight, kg						
21 d	16.0	16.1	16.2	16.2	16.0	0.07
35 d	25.5	25.6	25.8	26.0	25.7	0.17
Daily gain, g[b]	673	690	692	706	697	9
Daily feed, g[b]	1,120	1,136	1,153	1,152	1,172	17
G:F, g/kg (as-fed basis)	601	609	600	614	596	6
	Light replicates[c]					
Weight, kg						
21 d	15.0	15.1	15.0	15.0	14.8	0.08
35 d	24.3	24.6	24.4	24.7	24.3	0.21
Daily gain, g[b]	657	685	678	695	686	10
Daily feed, g[b]	1,095	1,104	1,106	1,124	1,135	19
G:F, g/kg[d] (as-fed basis)	600	619	613	618	604	6
	Heavy replicates[e]					
Weight, kg						
21 d	17.5	17.5	17.8	17.8	17.7	0.11
35 d	27.2	27.3	27.7	27.9	27.7	0.31
Daily gain, g	694	698	711	722	712	17
Daily feed, g	1,155	1,179	1,218	1,189	1,222	34
G:F, g/kg (as-fed basis)	602	592	585	607	584	10

[a]Twelve replicates using 300 pigs (n = 60 pigs per treatment group). Pig weaning weight averaged 6.45 kg BW at 19 ± 2 d of age.
[b]Linear response, $P < 0.05$.
[c]Seven replicates (n = 35 pigs per treatment group).
[d]Linear response, $P < 0.10$.
[e]Five replicates (n = 25 pigs per treatment group).

Wolter et al., 2003) and measuring the subsequent responses to market weight have resulted in responses that have been inconsistent. Some reports have indicated that diet complexity during the starter phase has had no effect on the length of time until grower-finisher pigs reach market weight (Dritz et al., 1996; Whang et al., 2000; Wolter et al., 2003), whereas others have shown that lighter-weight pigs at the end of the starter phase reach market weight at an older age (Chiba, 1995; Dritz et al., 1996). A tendency for a greater variation in pig weights by market weight has been reported when a simple nursery diet had been fed (Wolter et al., 2003). Our results demonstrated a 2.65 kg or an approximate 12% difference in BW at the end of a 28-d starter period when a complex vs. a simple diet was fed to 28 d postweaning. However, the subsequent long-term effects of these diets to market weight were not determined in these pigs.

Lactose is a major component of dried whey and has been shown to be a primary factor in enhancing starter pig performances (Mahan, 1992). The dietary level of lactose that was necessary to achieve maximum growth rates declined as pigs became older and heavier, probably because the pigs' digestive tracts became more mature and the digestive enzymes needed to hydrolyze the more complex components in cereal grains were adequately secreted. Our results suggest that lactose probably has a minimal carryover effect from one starter phase to another, but particularly during the early phases postweaning. When pigs in Phase 3 were fed various levels of lactose, there was a growth response to the lactose addition. Although the lighter-weight pigs in Phase 3 seemed to respond more to the dietary lactose levels than the heavier pigs, the data indicate that both groups responded in a positive manner to the lactose addition. This suggests that pigs at 21 d postweaning would probably benefit from dietary lactose to 25 kg BW, but pigs of a lighter weight would respond more than heavier weight pigs.

Lactose is the major substrate that enhances the growth of the *Lactobacillus* spp. (Kenworthy and Crabb, 1963), and its presence may help to suppress some of the hemolytic coliforms and other pathogens that decrease pig performance and their health status (De Mitchell and Kenworthy, 1976; Muralidhara et al., 1977[C1]). The *Lactobacillus* spp. present in the stomach and intestinal tract of the pig at weaning may be important in continuing to maintain a healthy intestinal tract environment throughout the postweaning nursery period (Krause et al., 1995).

Although lactose from either dried whey or crystalline lactose is beneficial during the postweaning period, other simple carbohydrates may be just as effective (Hongtrakul et al., 1998; Oliver et al., 2002). However, added fiber (Cheeke and Stangel, 1973), the inclusion of fat, and the pelleting of a high-lactose diet (Cheeke and Stangel, 1972) may reduce the effectiveness of the lactose addition on pig performances. In addition, certain breeds or genotypes may not tolerate high levels of whey or lactose, particularly if fed for an extended time (Ekstrom et al., 1976).

For optimal performance responses, our results suggest total inclusion levels of lactose of approximately 25 to 30% during the initial week postweaning or to a BW of 7 kg, followed by an approximately 20% level during the period from d 7 to 21 or to a BW of 12.5 kg, and a 10 to 15% level from d 21 to 35 postweaning or to a BW of 25 kg. The inclusion of lactose throughout the starter period may be important in maintaining a good intestinal environment and in decreasing the variability in pig market weights as reported by Wolter et al. (2003). The subsequent long-term effects of these lactose levels during the grower finisher period cannot be ascertained from our experiment.

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