VALIDATION OF CONTROL DIETS FOR LACTOSE AND FISH MEAL REPLACEMENT STUDIES IN NURSERY PIGS

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Summary

The objective of this study was to develop and validate control test diets to be used for lactose and fish meal replacement studies in nursery pigs. A total of 180 nursery pigs (PIC, initially 16.6 lb and 28 ± 2 d of age) were blocked by initial weight and randomly allotted to 1 of the following 6 dietary treatments: (1) negative control (NC) diet based on corn-soybean meal, (2) NC + 10% food-grade whey, (3) NC + 10% feed-grade whey, (4) Diet 2 + 4.5% select menhaden fish meal, (5) Diet 2 + 2.25% select menhaden fish meal and 1.25% spray-dried blood cells, and (6) Diet 2 + synthetic amino acids. Diets 4 to 6 also contained 10% food-grade whey. Each treatment had 5 pigs per pen and 6 replications (pens). Diets were formulated to contain 1.37% standardized ileal digestible lysine and 1,495 kcal ME/lb and were fed in meal form. Newly-weaned pigs (21 ± 2 d of age) were fed a common segregated early weaning and transition diet for 7 days then fed the experimental phase 2 diets for 21 d. From d 0 to 7 and 0 to 14, pigs fed the diet containing 10% feed-grade whey tended to have greater ADG ($P < 0.07$) and heavier ($P < 0.08$) BW than pigs fed the negative control diet, with pigs fed the diet containing 10% food-grade whey being intermediate. Pigs fed the negative control diet with either added food- or feed-grade whey tended to have better ($P < 0.06$) F/G than pigs fed the phase 2 diet solely based on corn and soybean meal. Pigs fed phase 2 diets containing either 4.5% select menhaden fish meal or the combination of 2.25% select menhaden fish meal and 1.25% spray-dried blood cells tended to have greater ADG ($P < 0.07$) and BW ($P < 0.07$) than pigs fed the diet containing 10% food-grade whey. Pigs fed the diet with increased synthetic amino acids had similar ($P > 0.36$) ADG and BW compared with pigs fed the diet containing the same food-grade whey without specialty proteins but tended to have poorer ($P < 0.09$) F/G than pigs fed the diet containing food-grade whey during d 0 to 7. Overall (d 0 to 21), only numerical differences ($P > 0.15$) were observed in ADG, ADFI, F/G, and pig BW among the dietary treatments. More research is needed to evaluate the use of synthetic amino acids as a replacement for high quality protein ingredients in nursery diets. When reviewing data from previous studies, it is apparent that further development of the control diets for testing lactose and fish meal sources is needed so that the predicted response is consistent.

Key words: lactose, protein sources, synthetic amino acids, weanling pigs

Introduction

Success in feeding nursery pigs relies mainly on the proper selection and use of high

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quality feed ingredients. However, rising costs of typical feed ingredients used for starter diets has increased motivation to reduce cost, which many times can lead to using lower quality ingredients. Recent studies at Kansas State University (KSU) and observations in the field seem to indicate that lower quality feed ingredients are being utilized in nursery pig diets. Therefore, it is vital to assess potential protein and energy sources that can be used as effective substitutes for typical specialty feed ingredients without affecting nursery growth performance. However, to successfully determine potential alternatives, the formulation of the control diets for both lactose and fish meal replacement must be validated. Therefore, the objective of this study was to develop and validate control test diets to be used for studies investigating potential feed ingredients that can replace lactose and fish meal in nursery pig diets.

Procedures

A total of 180 nursery pigs (PIC, initially 16.6 lb and 28 ± 2 d of age) were used in a 21-d growth assay. Pigs were blocked by initial weight and randomly allotted to 1 of 6 experimental treatments in a randomized complete block design. Each treatment had 5 pigs per pen and 6 replications (pens). Each pen was 4 ft × 4 ft and contained a 4-hole self-feeder and 1 cup waterer to provide ad libitum access to feed and water. Pigs were housed at the KSU Segregated Early Weaning (SEW) Research Facility.

Initially, all pigs were fed a commercial SEW diet with a budget of 1 lb/pig followed by a commercial transition diet with a budget of 2.5 lb/pig for the first 7 d postweaning. Both diets were pelleted and based on KSU specifications. At d 7 postweaning (d 0 of the experiment), phase 2 diets (1 of the 6 experimental diets; Table 1) were fed to the pigs. The negative control diet was solely based on corn and soybean meal as the main energy and protein sources. For the lactose replacement controls, 10% feed-grade and food-grade whey from 2 different sources were added to the negative control diet at the expense of corn. Soybean meal content of these diets was maintained at the same level as in the negative control, with synthetic amino acids being altered to adjust diets to a constant lysine level. For the fish meal replacement controls, 4.5% select menhaden fish meal or a combination of 2.25% select menhaden fish meal and 1.25% spray-dried blood cells were added to the diet containing 10% food-grade whey to replace amino acids provided by soybean meal and corn. For the sixth dietary treatment, synthetic amino acids (L-lysine, DL-methionine, L-threonine, and L-valine) replaced the specialty protein sources in the fish meal replacement controls. All the experimental diets contained 1% soybean oil. Diets were formulated to contain 1.37% standardized ileal digestible (SID) lysine and 1,495 kcal ME/lb and were fed in meal form.

Pigs and feeders were weighed on d 0, 7, 14, and 21 to calculate ADG, ADFI, and F/G. Data were analyzed as a randomized complete block design by using the MIXED procedure of SAS with pen as experimental unit. Treatment means were separated by using the LSMEANS statement and the PDIFF option of SAS.

Results and Discussion

From d 0 to 7 of the study, pigs fed the diet containing 10% feed-grade whey tended to have greater ADG (17%; $P < 0.08$) and BW at d 7 (3.4%; $P < 0.07$) than pigs fed the negative control diet, with pigs fed the diet containing 10% food-grade whey being intermediate (Table 2). There were no differences ($P > 0.23$) in ADFI between pigs fed diets containing either of the 2 whey sources and the negative control diet. Pigs fed the negative control diet with either added food- or feed-grade whey had improved ($P < 0.04$) F/G compared with pigs fed the negative control diet solely based on corn and soybean meal. There were no differences (*P* > 0.40) in F/G between the two whey sources.

For the fish meal replacement controls, pigs fed the diet containing 4.5% select menhaden fish meal tended to have greater ADG (16%; *P* < 0.07) and BW (3.3%; *P* < 0.07) at d 7 than pigs fed the diet containing 10% food-grade whey, with pigs fed the diet containing the combination of 2.25% select menhaden fish meal and 1.25% spray-dried blood cells being intermediate. The increase in ADG in pigs fed the diet containing select menhaden fish meal was due to a numerical improvement (8%; *P* < 0.11) in F/G. Pigs fed the diet with increased synthetic amino acids had similar (*P* > 0.36) ADG and BW but tended to have poorer (*P* < 0.09) F/G than pigs fed the diet containing food-grade whey. However, ADG, F/G, and BW at d 7 of pigs fed the diet with synthetic amino acids were lower (*P* < 0.02) than those of pigs fed the diets containing select menhaden fish meal and the fish meal-blood cells combination. There were no differences (*P* > 0.53) in ADFI across all the dietary treatments.

From d 7 to 14 and d 14 to 21, there were no differences (*P* > 0.22) in ADG, ADFI and F/G among the dietary treatments. Because of the improvements in performance from d 0 to 7, pigs fed the diet containing 10% feed-grade whey tended to have greater (15.4%; *P* < 0.08) ADG from d 0 to 14 and heavier (5.8%; *P* < 0.08) BW at d 14 than pigs fed the negative control diet, with pigs fed the diet containing 10% food-grade whey being intermediate. Pigs fed diets containing either of the 2 whey sources had a tendency for better (7 to 10%; *P* < 0.06) F/G than pigs fed the negative control diet. Likewise, feeding the diets containing 4.5% select menhaden fish meal or the combination of 2.25% select menhaden fish meal and 1.25% spray-dried blood cells to nursery pigs tended to have improved (16%; *P* < 0.06) ADG and increased (6.5%; *P* < 0.06) BW at d 14 compared with pigs fed the diet containing 10% food-grade whey. However, pigs fed the diet containing either of the specialty protein sources had similar (*P* > 0.36) F/G compared with pigs fed the diet containing food-grade whey. The difference in daily gains with pigs fed the diets containing either of the specialty protein sources was due to a slight increase (7 to 11%; *P* > 0.13) in ADFI. There were no differences (*P* > 0.49) in ADG, F/G, and BW at d 14 between pigs fed the diet containing select menhaden fish meal and those fed the fish meal-blood cells combination. Pigs fed the diet containing a high concentration of amino acids had similar (*P* > 0.90) ADG and BW at d 14 compared with pigs fed the diet containing food-grade whey; however, they were lower (*P* < 0.05) than pigs fed diets containing either of the specialty protein sources. Feed efficiency of pigs fed the diet containing synthetic amino acids was similar (*P* > 0.26) to that of pigs fed the diets containing food-grade whey or either of the specialty protein sources. No differences (*P* > 0.25) in ADFI were observed among dietary treatments.

Overall (d 0 to 21), pigs fed the diet containing 10% feed-grade whey had 8.4% greater ADG, 11.6% better F/G, and were 4.9% heavier at d 21 than pigs fed the negative control diet or the diet containing 10% food-grade whey; however, differences were not significant (*P* > 0.15). There were no differences (*P* > 0.34) in ADFI among the dietary treatments. The difference in performance between pigs fed diets containing food- and feed-grade whey, especially during the initial 2 weeks of the study, was in contrast with a previous trial in which pigs had a greater growth response with food-grade whey. This may be due to variations in the quality of whey regardless of the grade, not only between each type but also within sources. This also indicates that food-grade whey is not always higher quality than feed-grade whey. However, the improvements in growth rates and F/G are consistent with previous studies evaluating the effects of adding spray-dried whey in corn-soybean meal diets fed to nursery pigs.

Dried whey consistently improved growth performance in all of the studies in KSU Swine Day Reports of Progress from 1986 to 2008 in which the effects of spray-dried whey additions to phase 2 diets were measured (Table 3). Adding dried whey to the phase 2 diet numerically increased ADG in 24 of the 27 comparisons, and about 80% of these comparisons resulted in at least 5% improvement in daily gains. In the 15 comparisons in which 10% spray-dried whey was added to phase 2 diets, ADG improved by an average of 7.5% with smaller improvements in ADFI (2.7%) and F/G (-3.5%). However, the level of response to the addition of spray-dried whey also varied across and within studies. In a previous study in which 7 different sources of food-grade whey were compared, responses for ADG, ADFI, and F/G ranged from 4.6 to 18.5%, -1.2 to 11%, and -1.3 to -8.4%, respectively (Bergstrom et al., 2007). The variability in whey responses may be a result of differences in the type, source, or inherent variation in the quality of whey used in the diets. Whey is a by-product of the cheese industry, and the method of production and aggressiveness of drying may affect its biological value. Under high temperatures during the drying of whey, either lactose can form complexes with proteins or whey proteins become denatured. The aggressiveness of processing may also result in the loss of biologically active proteins such as immunoglobulins, which are the most heat sensitive.

For the fish meal replacement controls, pigs fed the diets containing 4.5% select menhaden fish meal or the combination of 2.25% select menhaden fish meal and 1.25% spray-dried blood cells had in numerical ($P > 0.15$) improvements in ADG (9.5%), and pig weights at d 21 (5.5%) compared with pigs fed the diet containing food-grade whey. Pigs fed the diet containing select menhaden fish meal also had slightly better (6%; $P > 0.19$) F/G. There were no differences ($P > 0.34$) in ADFI among the dietary treatments. Select menhaden fish meal is generally regarded as one of the highest quality animal protein sources used in the feed industry. However, responses to select menhaden fish meal in phase 2 diets have been inconsistent, which may reflect variations in quality (Table 4). Across 10 studies in which 4 to 5% select menhaden fish meal was added as a replacement for soybean meal, ADG, ADFI, and F/G were improved by an average of 3.9, 1.8, and 2.6%, respectively.

Spray-dried blood cells, a coproduct of animal plasma production, are another animal protein source commonly used in piglet diets. In 3 other studies, the addition of 2.5% spray-dried blood cells in phase 2 diets improved ADG and ADFI by an average of 10.8 and 4.1%, respectively (Table 5). The inclusion rate for spray-dried blood cells is limited because of low isoleucine content. Thus, a combination of select menhaden fish meal and spray-dried blood cells is often used in phase 2 diets.

Pigs fed the diet with increased synthetic amino acids had similar ($P > 0.80$) ADG, ADFI, and F/G compared with pigs fed the diet containing the same level of food-grade whey. This result is consistent with previous studies in which feeding high concentrations of synthetic amino acids to replace specialty protein sources in phase 2 diets containing dried whey failed to improve nursery growth performance (Table 6). It is speculated that either an essential amino acid other than those considered may be affecting amino acid balance or the required amino acid ratios for phase 2 pigs may have not been met. As reflected in the feed efficiency response, the addition of the specialty protein sources, such as select menhaden fish meal and spray-dried blood cells, to a diet based on soy and whey proteins may have met the animal's requirement more closely than the diet with increased synthetic amino acids. The use of high concentrations of synthetic amino acids to replace specialty protein sources in phase 2 diets did not improve nursery growth performance; therefore, more research is needed to evaluate the use of synthetic amino acids as a replacement for high quality protein ingredients in nursery diets.

As evidenced by the differences in response between the feed- and food-grade whey exhibited in this study and the evaluation of responses in previous reports, it is important to use ingredients in the control test diets for both lactose and fish meal replacement that can result in a consistent response. It is apparent that further development of the control diets for testing alternative ingredients is needed so that consistency in the predicted response can be achieved.

Table 1. Diet composition (as-fed basis)

	Phase 2 diets[1,2]					
Ingredient, %	Negative Control	Food-grade whey	Feed-grade whey	SMFM + SDBC	SMFM	Synthetic amino acids
Corn	54.00	44.49	44.49	49.13	48.70	51.78
Soybean meal (46.5% CP)	40.02	40.01	40.01	32.21	32.13	32.17
Select menhaden fish meal	---	---	---	2.25	4.50	---
Spray-dried blood cells	---	---	---	1.25	---	---
Food-grade whey	---	10.00	---	10.00	10.00	10.00
Feed-grade whey	---	---	10.00	---	---	---
Soybean oil	1.00	1.00	1.00	1.00	1.00	1.00
Monocalcium phosphate (21% P)	1.90	1.55	1.55	1.30	1.03	1.60
Limestone	1.00	0.98	0.98	0.85	0.68	1.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30
Zinc oxide	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix with phytase	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Neo-terramycin	0.70	0.70	0.70	0.70	0.70	0.70
L-lysine HCl	0.23	0.15	0.15	0.15	0.15	0.40
DL-methionine	0.12	0.12	0.12	0.14	0.11	0.20
L-threonine	0.09	0.05	0.05	0.08	0.06	0.16
L-valine	---	---	---	---	---	0.04
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
SID[3] amino acids						
Lysine, %	1.37	1.37	1.37	1.37	1.37	1.37
Lysine:ME, g/Mcal	4.16	4.17	4.17	4.16	4.14	4.17
Isoleucine:lysine, %	66	68	68	62	65	58
Leucine:lysine, %	131	131	131	133	129	117
Methionine:lysine, %	32	32	32	34	34	35
Met & Cys:lysine, %	58	58	58	58	58	58
Threonine:lysine, %	62	62	62	62	62	62
Tryptophan:lysine, %	19	20	20	19	18	17
Valine:lysine, %	71	72	72	74	71	65
Total Lysine, %	1.53	1.53	1.53	1.52	1.52	1.51
ME, kcal/lb	1,498	1,493	1,493	1,497	1,506	1,495
Protein, %	23.54	23.85	23.85	23.20	23.37	21.19
Ca, %	0.88	0.88	0.88	0.88	0.88	0.88
P, %	0.83	0.80	0.80	0.78	0.78	0.77
Available P, %	0.48	0.48	0.48	0.48	0.48	0.48

[1] Fed for 21 d with d 7 postweaning as d 0 of the experiment; diets were in meal form.
[2] SMFM = select menhaden fish meal, SDBC = spray-dried blood cells.
[3] Standardized ileal digestible.

Table 2. Effects of lactose and fish meal replacement control diets on growth performance of nursery pigs during Phase 2[1]

	Dietary treatment[2]							
Item	Negative control	Food-grade whey	Feed-grade whey	SMFM + SDBC	SMFM	Synthetic amino acids	SED	*P* <
no. of pens	6	6	6	6	6	6	---	---
d 0 to 7								
ADG, lb	0.60[a]	0.64[ab]	0.70[bc]	0.72[bc]	0.74[c]	0.59[a]	0.05	0.03
ADFI, lb	0.91	0.86	0.90	0.94	0.92	0.88	0.04	0.53
F/G	1.53[a]	1.37[b]	1.31[b]	1.32[b]	1.26[b]	1.50[a]	0.07	0.01
d 7 to 14								
ADG, lb	0.97	0.99	1.10	1.15	1.15	1.02	0.09	0.22
ADFI, lb	1.32	1.31	1.40	1.49	1.42	1.33	0.08	0.23
F/G	1.38	1.33	1.28	1.31	1.25	1.30	0.06	0.43
d 0 to 14								
ADG, lb	0.78[a]	0.81[ab]	0.90[bc]	0.94[c]	0.94[c]	0.81[ab]	0.06	0.05
ADFI, lb	1.12	1.09	1.15	1.21	1.17	1.10	0.06	0.25
F/G	1.43[a]	1.33[b]	1.29[b]	1.31[b]	1.29[b]	1.37[ab]	0.05	0.06
d 14 to 21								
ADG, lb	1.29	1.21	1.31	1.25	1.29	1.27	0.07	0.76
ADFI, lb	1.69	1.67	1.50	1.69	1.64	1.64	0.14	0.69
F/G	1.32	1.38	1.13	1.35	1.25	1.29	0.10	0.24
d 0 to 21								
ADG, lb	0.95	0.95	1.03	1.04	1.04	0.96	0.05	0.20
ADFI, lb	1.31	1.28	1.27	1.37	1.33	1.28	0.05	0.34
F/G	1.38	1.35	1.22	1.33	1.27	1.34	0.06	0.15
Pig weight, lb								
d 0	16.5	16.6	16.6	16.6	16.6	16.6	0.01	0.22
d 7	20.7[a]	21.0[ab]	21.4[bc]	21.6[bc]	21.7[c]	20.7[a]	0.37	0.03
d 14	27.5[a]	28.0[ab]	29.1[bc]	29.7[c]	29.8[c]	27.9[ab]	0.87	0.05
d 21	36.5	36.5	38.3	38.4	38.5	36.7	1.13	0.19

[1] A total of 180 pigs (PIC, initially 16.6 lb and 28 ± 2 d of age), with 5 pigs per pen and 6 replications per treatment; Experimental diets were fed for 21 d with d 7 postweaning as d 0 of the experiment.

[2] SMFM = Select menhaden fish meal, SDBC = Spray-dried blood cells.

[abc] Within a row, means without a common superscript letter differ (*P* < 0.10).

Table 3. Swine day studies (1985-2008) evaluating the effects of spray-dried whey in phase 2 diets on overall growth performance of nursery pigs[1,2]

	Response vs. pigs fed the control diet (%)			
Reference	BW	ADG	ADFI	F/G
Sulabo et al., 2008				
10% Feed-grade whey	4.9	8.4	-3.1	-11.6
10% Food-grade whey	0	0	-2.3	-2.2
Bergstrom et al., 2007; Exp. 1				
10% Feed-grade whey	-2.5	-7.6	-7.1	0
10% Food-grade whey	2.5	5.1	3.0	-3.2
Bergstrom et al., 2007; Exp. 2				
10% Whey source 1	6.1	18.5	6.0	-8.4
10% Whey source 2	1.5	4.6	-1.2	-3.1
10% Whey source 3	3.4	10.8	3.5	-4.6
10% Whey source 4	1.1	4.6	1.2	-1.3
10% Whey source 5	6.1	18.5	11.0	-3.8
10% Whey source 6	3.4	10.8	7.0	-2.3
10% Whey source 7	2.3	7.7	1.2	-3.8
DeRouchey et al., 2001				
12.5% Food-grade whey	---	1.9	-3.6	-5.7
25.0% Food-grade whey	---	19.2	18.2	-0.9
12.5% Granular whey	---	11.5	5.5	-5.7
25.0% Granular whey	---	7.7	9.1	0.9
Lee et al., 1998				
20%	---	9.3	3.7	-5.9
Goodband and Hines, 1986				
10%	---	7.1	8.1	1.3
20%	---	19.1	19.4	-1.3
Thaler et al., 1986; Exp. 1				
10% Food-grade whey	---	9.3	2.0	-4.8
20% Food-grade whey	---	11.6	6.1	-4.2
Thaler et al., 1986; Exp. 2				
5% Food-grade whey	---	9.3	7.6	-1.4
10% Food-grade whey	---	9.3	11.5	1.4
15% Food-grade whey	---	7.0	11.5	6.1
20% Food-grade whey	---	10.5	12.2	2.7
Stoner et al., 1985; Exp. 1				
20%	---	-2.5	-12.6	-3.8
Stoner et al., 1985; Exp. 2				
10%	---	5.8	0	-6.5
20%	---	8.1	8.3	-1.9

Level in the diet	n	Average response, %			
5.0%	1	---	9.3	7.6	-1.4
10.0%	15	2.6	7.5	2.7	-3.5
12.5%	2	---	6.7	1.0	-5.7
15.0%	1	---	7.0	11.5	6.1
20.0%	6	---	9.4	6.2	-2.4
25.0%	2	---	13.5	13.7	0

[1] Spray-dried whey was added at the expense of corn and soybean meal in the control diet. Control diet was a corn-soybean meal diet. Studies varied from 14- to 21-d growth assays.

[2] Response, % = (Treatment – Control)/Control. Average response = average of the responses across all studies at each inclusion level. n = number of comparisons.

Table 4. Swine day studies (1986-2008) evaluating the effects of select menhaden fish meal in phase 2 diets on overall growth performance of nursery pigs[1,2]

		Response vs. pigs fed the control diet (%)			
Reference		BW	ADG	ADFI	F/G
Sulabo et al., 2008					
4.5%		5.5	9.5	1.5	-11.0
Frantz et al., 2004					
4.5%		-1.1	-2.7	1.0	1.4
Keegan et al., 2003a					
2.5%		---	6.8	4.0	-3.5
5.0%		---	5.7	2.0	-3.5
Keegan et al., 2003b					
2.5%		---	6.0	0.9	-5.2
5.0%		---	6.6	2.7	-5.2
Lawrence et al., 2002					
4.5%		---	8.5	5.3	-4.4
Young et al., 2001					
2.5%		-0.2	-1.5	1.1	2.2
5.0%		3.8	7.6	9.0	1.5
Moser et al., 1998					
2.5%		---	-5.5	-2.3	3.1
5.0%		---	-10.1	-7.9	1.2
Lee et al., 1998					
4.0%		---	1.9	3.7	0
Woodworth et al., 1996					
4.0%		---	3.2	0	-3.9
Stoner et al., 1989					
8.0%		---	19.5	8.0	-9.7
Stoner et al., 1986					
4.0%		---	8.5	0.9	-2.2
8.0%		---	12.2	16.2	4.5
Level in the diet	n	Average response, %			
2.5%	4	-0.2	1.5	0.9	-0.9
4.0-5.0%	10	2.7	3.9	1.8	-2.6
8.0%	2	---	15.9	12.1	-2.6

[1] Select menhaden fish meal was added at the expense of soybean meal in the control diet. Treatment and control diets contained equal amounts of dried whey. Studies varied from 14- to 28-d growth assays.
[2] Response, % = (Treatment – Control)/Control. Average response = average of the responses across all studies at each inclusion level. n = number of comparisons.

Table 5. Swine day studies (1996-2002) evaluating the effects of spray-dried blood cells in phase 2 diets on overall growth performance of nursery pigs[1,2]

Reference		Response vs. pigs fed the control diet (%)			
		BW	ADG	ADFI	F/G
Lawrence et al., 2002					
2.5%		---	8.5	7.0	-1.5
DeRouchey et al., 2000					
2.5%		7.2	17.4	2.7	11.7
5.0%		5.1	13.0	-5.3	16.0
7.5%		6.8	19.6	-5.3	19.6
Lee et al., 1998					
2.0%		---	7.4	2.5	-4.6
Woodworth et al., 1996					
2.5%		---	6.5	2.5	-3.9
Level in the diet	n	Average response, %			
2.0%	1	---	7.4	2.5	-4.6
2.5%	3	7.2	10.8	4.1	2.1
5.0%	1	5.1	13.0	-5.3	16.0
7.5%	1	6.8	19.6	-5.3	19.6

[1] Spray-dried blood cells were added at the expense of soybean meal in the control diet. Treatment and control diets contained equal amounts of dried whey. All studies were 14-d growth assays.
[2] Response, % = (Treatment – Control)/Control. Average response = average of the responses across all studies at each inclusion level. n = number of comparisons.

Table 6. Swine day studies (1996-2008) evaluating the effects of adding synthetic amino acids in phase 2 diets on overall growth performance of nursery pigs[1,2]

Reference	Response vs. pigs fed the control diet (%)			
	BW	ADG	ADFI	F/G
Sulabo et al., 2008	0.5	1.1	-2.3	-2.9
Frantz et al., 2004	0.9	1.4	-1.0	2.1
Woodworth et al., 1996	-	-4.8	-3.8	1.6
Average response	0.7	-0.8	-2.4	0.3

[1] Synthetic amino acids were added to replace amino acids provided by specialty protein sources. Treatment and control diets contained equal amounts of dried whey. Studies varied from 10- to 21-d growth assays.
[2] Response, % = (Treatment – Control)/Control. Average response = average of the responses across all studies.