Nursery Study 1

FINAL REPORT

Project Title:	Evaluate the Effects of Amino Acid Supplementation with Reduced Dietary Crude Protein on Nursery Performance: GHG Mitigation Technology Evaluation
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Key Words: **Protein level, Nursery, Growth performance, GHG mitigation**

Specific Objectives

- Determine the impact of sequential increases in crystalline amino acids in reduced crude protein diets on growth performance in phase 1- 3 of the nursery phase of production in wean-to-finish facilities.

- Perform experimental validation of the effectiveness of reduced dietary nitrogen as a mitigation technology to support development of a robust and accurate process-based Life Cycle Analysis model of GHG emission from swine production systems.

- Provide data which will allow coupling this model with Life Cycle Cost Analysis.

- Utilize this model as an education and outreach tool for evaluation of the environmental footprint of swine production.

Justification

Nitrogen compounds from manure and urine are oxidized/reduced by soil and air, with some nitrogen being released into the atmosphere as nitrous oxide (N_2O). The greenhouse effect of N_2O is about 288 times that of CO_2; therefore, N_2O has the next largest impact on total global warming after CO_2 and methane. Maximizing crystalline amino acid use and reducing dietary crude protein in swine diets has been shown to dramatically reduce nitrogen excretion in nursery pigs (Hinson, et al., 2009). These studies suggest that the maximum level of crude protein reduction, in conjunction with the optimum amino acid inclusion rate, has not been sufficiently determined for widespread acceptance by the swine industry. Therefore, we propose to utilize wean-to-finish facilities at the University of Arkansas to develop three phase nursery diets that maximize use of crystalline amino acids and minimize crude protein without negatively impacting growth performance.

Procedures

A nursery study involving 320 pigs (PIC C-29 X 380) was conducted at the University of Arkansas wean-to-finish facilities to establish the practical limits of crude protein reduction with amino acid replacement in nursery pigs fed reduced crude protein diets that meet the ideal SID amino acid recommended ratios. This experiment was carried out in accordance with the Protocol **#11023** for swine experiments issued by the University of Arkansas Interdepartmental Animal Care and Use Committee.

Nursery Study:

Approximately 320 weaned pigs (21.2 days of age, PIC C-29 females x PIC 380 sires) were blocked by initial BW into five weight blocks, and within blocks, allotted to pens with 8 pigs/pen. Pens within a given block contained equal numbers of barrows and gilts and were randomly assigned to 1 of 5 dietary treatments (8 reps/treatment).

Treatments:

- **Phase 1: 6-8 kg (10 d) 1 of 5 experimental diets (pellet)**
- **Phase 2: 8-12 kg (14 d) 1 of 5 experimental diets (pellet)**
- **Phase 3: 12-23 kg (14 d) 1 of 5 experimental diets (pellet)**

Diet Formulation, requirements, Mixing, Sampling

Dietary formulation was provided by the University of Arkansas. Diets for this study are presented in Tables 1, 2, and 3 for phase 1 through 3, respectively. Diets were formulated to meet, or exceed standardized ileal digestible (SID) amino acid requirements for all phases of production (PIC Nutrient Specifications Manual, 2011), and were consistent with standard industry dietary ingredients. Diets were formulated to meet the 95 % of the SID lysine requirement for nursery pigs. **Note: Lysine levels were reduced to 0.95 % SID lysine to ensure that diets were not formulated at levels in excess of the lysine requirement.**

During phase 1, crude protein was reduced by replacing equal amounts of fish meal and poultry meal with increasing amounts of crystalline lysine and amino acids, and in phase 2 crude protein was reduced by replacing increasing amounts of fish meal with lysine and appropriate crystalline amino acids, while in phase 3, crystalline lysine and amino acids replaced decreasing levels of soybean meal.

Treatments during Nursery Phase 1 through 3:

***Treatment 1*:** Control: Conventional phase 1 through 3 diets formulated to contain no crystalline lysine. Diets were formulated to meet 95% of the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for nursery pigs, PIC Nutrient Specifications Manual, 2011). All other indispensable amino acids were added at 2.00 percentage units above the SID ideal amino acid ratio requirement to ensure that these amino acids are not deficient (PIC Nutrient Specifications Manual, 2011) for all phases of production.

***Treatment 2*:** Reduced CP diet (control with reduced crude protein and 0.19, 0.22, and 0.25% added crystalline Lys-HCL in phase 1, 2, and 3, respectively) with supplemental threonine, methionine, and tryptophan. Diets were formulated at 2.00 percentage units above the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for Nursery Pigs, PIC Nutrient Specifications Manual, 2011) for threonine, Methionine, and Tryptophan using crystalline amino acids.

Treatment 3: Reduced CP diet (control with reduced crude protein and 0.37, 0.44, and 0.50% added crystalline Lys HCL in phase 1, 2, and 3, respectively) with supplemental threonine, methionine, tryptophan, valine and isoleucine. Diets were formulated at 2.00 percentage units above the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for

Nursery Pigs, PIC Nutrient Specifications Manual, 2011) for threonine, methionine, tryptophan, valine and -isoleucine using synthetic amino acids.

Treatment 4: Reduced CP diet (control with reduced crude protein and 0.56, 0.67, and 0.75% added crystalline Lys HCL in phase 1, 2, and 3, respectively) with supplemental threonine, methionine, tryptophan, valine, and isoleucine. Diets were formulated at 2.00 percentage units above the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for Nursery Pigs, PIC Nutrient Specifications Manual, 2011) for threonine, methionine, tryptophan, valine, and isoleucine using synthetic amino acids.

Treatment 5: Reduced CP diet (control with reduced crude protein and 0.750, 0.900, and 1.00% added crystalline Lys HCL in phase 1, 2 and 3, respectively) with supplemental threonine, methionine, tryptophan, valine, and isoleucine. Diets were formulated at 2.00 percentage units above the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for Nursery Pigs, PIC Nutrient Specifications Manual, 2011) for threonine, methionine, tryptophan, valine, and isoleucine, using synthetic amino acids.

Housing and Environment:

Pigs were housed in a wean-to-finish facility in totally slatted pens (1.52 m x 3.05 m; 0.39 m^2/pig) equipped with radiant heaters, a two-hole nursery feeder and a wean-to-finish cup waterer. Ambient room temperature was maintained at 78°F. In addition, a radiant heater oriented above a fiberboard mat provided supplemental heat to a 1.8 m diameter area covering two pens/heater during the nursery phase. The wean-to-finish barn is curtain-sided and naturally ventilated, and contains a pit fan for minimum ventilation. The temperature was reduced gradually over the course of the nursery phase according to established procedures (no more than 2°F per week). Water and feed was available ad libitum throughout the study.

Measurements:

At the start of the study and at the end of each phase throughout the study, individual pig weights and pen feed intake were collected in order to calculate average daily gain, feed intake, and gain to feed ratio by phase.

Feed samples

Feed samples were obtained for each batch of feed mixed and sent to the swine research farm. These were accumulated for each phase, subsampled to one composite sample/treatment/phase, and shipped with proper identification of the ration number and batch size to Evonik for complete amino acid analysis.

Data Analysis

Performance data were analyzed as a randomized complete block design, blocks based on initial BW as the random effect, and pen as the experimental unit. The ANOVA was generated using the mixed models procedure of SAS (SAS Institute, Inc.,

Cary, NC). Least squares means will be calculated for all dependent variables, and mean separation will be accomplished using *F*-protected, *t*-tests (PDIFF option).

Results

Growth performance data for Phase 1, 2 and 3 are presented in table 7. During phase 1, ADG, and G:F increased with increasing inclusion of synthetic dietary amino acids at the lower inclusion levels, then declined at the highest level of inclusion (Quadratic effect, $P < 0.01$). It should be noted that gain and G:F in pigs fed treatment 4 (0.56% inclusion of LYS HCL) did not differ from pigs fed the control diet devoid of synthetic amino acids (Treatment 1), or pigs fed 0.19 and 0.37% LYS HCL (Treatments 2 and 3, respectively). Average daily feed intake was similar among treatments during phase 1.

During phase 2, ADG and ADFI increased with increasing inclusion of synthetic amino acids and declined at the highest level of inclusion (Quadratic effect, $P < 0.002$). As observed in phase 1, gain and ADFI in pigs fed treatment 4 (0.67% inclusion of LYS HCL in phase 2) did not differ from pigs fed the control diet (Treatment 1), or pigs fed 0.22 and 0.44% LYS HCL (Treatments 2 and 3, respectively). Gain:Feed was not significantly affected by dietary treatment, however, there was a trend ($P < 0.07$) for a reduction in G:F with increasing inclusion of synthetic amino acids, although once again G:F in pigs fed treatment 4 (0.67% LYS HCL) did not differ from G:F in pigs fed the control diet devoid of synthetic amino acids (Treatment 1).

During phase 3, ADG and ADFI responded to increasing inclusion of synthetic amino acids as in phase 2 (Quadratic response, $P < 0.01$) and once again a reduction was not observed until pigs were fed the highest level of synthetic amino acids (Treatment 5, 1.00 % LYS HCL), and pigs fed up to 0.75% inclusion of synthetic amino acids (Treatment 4) had similar performance when compared to those fed the control diet devoid of synthetic amino acids (Treatment 1) or those fed lower inclusion levels of 0.25 and 0.50% (Treatments 2 and 3, respectively). Gain:Feed in phase 3, however, declined linearly ($P < 0.001$) with increasing amino acid inclusion, although the magnitude of decline was small.

Overall, ADG and ADFI improved with lower inclusions of synthetic amino acids and declined at the highest inclusion (Quadratic effect, $P < 0.001$). Overall ADG and ADFI were higher in pigs fed treatments 2, 3 and 4 before declining in pigs fed treatment 5 which is consistent with the earlier observation that pigs can be fed up to 0.56, 0.67, and 0.75% inclusion of LYS HCL without impacting performance in phase 1, phase 2 and phase 3, respectively. Overall, a small but significant decrease in efficiency was observed with increasing inclusion of LYS HCL.

As might be expected based on ADG, pig weight at the end of each phase increased with increasing level of dietary LYS HCL at the lower inclusion levels (Treatments 2, 3 and 4) and declined at the highest inclusion level (Treatment 5; Quadratic effect, $P < 0.01$). Once again, pig weight at the end of each phase was similar among pigs fed treatments 1, 2, 3, and 4 which suggests that an inclusion of synthetic amino acids up to 0.56, 0.67, and 0.75% inclusion of LYS HCL without impacting performance in phase 1, phase 2 and phase 3, respectively. One should note that all other indispensable amino acids including methionine, tryptophan, isoleucine, and

valine were also included by adding the individual synthetic amino acids to meet the SID amino acid requirement for young nursery pigs.

The results of this study establishes that a high inclusion of synthetic LYS HCL at the expense of intact proteins can be fed without decreasing ADG and ADFI as long as the SID requirement for all indispensable amino acids are met. The maximum level established in this study of 0.56, 0.67 and 0.75% LYS HCL, with inclusion of other synthetic amino acids to meet the requirements for optimum growth performance, is higher than traditionally utilized in the swine industry. This information is timely since the cost of soybean meal is approaching record levels which make substitution of synthetic amino acids for intact protein more economically feasible. The ultimately goal of this research is to establish the impact of the reduction in dietary N on nitrogen excretion and on GHG emissions. These data will be utilized in research to conduct a nitrogen balance study using the levels established in this study. This will then be validated in a large pen wean-to-finish facility at Purdue University that is consistent with industry systems. All these data will be utilized by our modeling group to expand and enhance the LCA model to create a user-friendly tool to identify economical swine production system options which will provide swine producers options with potential for minimizing GHG emissions and increasing sustainability of swine production systems.

Literature Cited

Hinson, R. B., A. P. Schinckel, J. S. Radcliffe, G. L. Allee, A. L. Sutton and B. T. Richert. 2009. Effect of feeding reduced crude protein and phosphorus diets on weaning-finishing pig growth performance, carcass characteristics, and bone characteristics. J. Anim. Sci. 87:1502-1517.

National Swine Nutrition Guide. 2010. U. S. Pork Center of Excellence. David Meisinger, Editor.

Nutrient Requirements of Swine. 1998. National Research Council (10th Edition). National Academy Press. 2101.Constitution Ave., NW. Washington, D.C. 20418.

Nutrient Specification Manual. 2011. Pig Improvement Corporation.

Table 1. Composition of nursery phase 1 diets.

University of Arkansas	Nursery Phase 1 Diets									
PIC C29XPIC380	Trt. 1 Control		Trt. 2 C+0.188 % Lys HCL		Trt 3. C+0.375 % Lys HCL		Trt. 4 C+0.563 % Lys HCL		Trt. 5 C+0.75 % Lys HCL	
Ingredients	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**
Corn	643.67	32.18	720.98	36.05	795.17	39.76	868.31	43.42	942.25	47.11
SBM 48%	386.50	19.33	337.00	16.85	288.00	14.40	239.00	11.95	190.00	9.50
DDGS	200.00	10.00	200.00	10.00	200.00	10.00	200.00	10.00	200.00	10.00
Poultry meal	60.00	3.00	45.00	2.25	30.00	1.50	15.00	0.75	0.00	0.00
Poultry Fat	50.00	2.50	52.00	2.60	54.00	2.70	55.00	2.75	55.00	2.75
Dicalcium Phosphate	0.00	0.000	6.60	0.330	13.30	0.665	19.90	0.995	26.60	1.330
Limestone	5.75	0.288	8.50	0.425	11.00	0.550	13.50	0.675	16.10	0.805
Salt	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300
L-Lysine HCL	0.00	0.000	3.75	0.188	7.50	0.375	11.25	0.563	15.00	0.750
DL-Methionine	1.11	0.056	2.33	0.117	3.56	0.178	4.80	0.240	6.05	0.303
L-Threonine	0.00	0.000	0.37	0.019	1.95	0.098	3.51	0.176	5.10	0.255
L-Tryptophan	0.00	0.000	0.50	0.025	0.97	0.049	1.47	0.074	1.96	0.098
L-Valine	0.00	0.000	0.00	0.000	0.70	0.035	2.64	0.132	4.55	0.228
L-Isoleucine	0.00	0.000	0.00	0.000	0.88	0.044	2.65	0.133	4.42	0.221
Whey	400.00	20.00	400.00	20.00	400.00	20.00	400.00	20.00	400.00	20.00
Plasma	80.00	4.00	80.00	4.00	80.00	4.00	80.00	4.00	80.00	4.00
Fish Meal, Menhaden	120.00	6.00	90.00	4.50	60.00	3.00	30.00	1.50	0.00	0.00
Lactose	12.00	0.60	12.00	0.60	12.00	0.60	12.00	0.60	12.00	0.60
ZnO	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300
UArk VITAMINS	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250
UArk TRACE MINERAL	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150
Ronozyme	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019
Ethoxiquin (Quinguard)	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030
Neo-Terramycin 10/5	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000
Calculated analysis										
NSNG ME (Mcal/lb)	1.55		1.55		1.55		1.55		1.55	
CP (%)	25.83		23.85		21.96		20.15		18.34	
SID Lysine (%)	1.387	1.460	1.387	1.460	1.387	1.460	1.387	1.460	1.387	1.460
Total P (%)	0.75		0.74		0.73		0.72		0.72	
Available P (%)	0.53	0.550	0.53	0.550	0.53	0.550	0.53	0.550	0.53	0.550
Ca (%)	0.84	0.850	0.84	0.850	0.84	0.850	0.84	0.850	0.84	0.850
Na (%)	0.50		0.49		0.48		0.47		0.46	
Lactose	13.99	20.0	13.99	20.0	13.99	20.0	13.99	20.0	13.99	20.0
g SID Lysine/Mcal NRC ME	4.06	0.94	4.06	0.94	4.06	0.94	4.06	0.94	4.06	0.94
SID M+C:Lys	60.03	58	60.01	58	60.01	58	60.03	58	60.09	58
SID Thr:Lys	66.35	60	62.08	60	62.08	60	62.02	60	62.06	60
SID Trp:Lys	19.06	17	19.09	17	19.01	17	19.04	17	19.03	17
SID Ile:Lys	66.43	55	60.19	55	57.05	55	57.06	55	57.06	55
SID Val:Lys	77.92	65	71.26	65	67.01	65	67.07	65	67.03	65
SID Leu:Lys	143.97	100	134.41	100	124.78	100	115.12	100	105.48	100
SID His:Lys	43.63	32	39.81	32	35.98	32	32.14	32	28.31	32
SID Arg:Lys	96.05	42	85.60	42	75.16	42	64.72	42	54.28	42
SID Phe:Lys	75.51	60	69.20	60	62.87	60	56.53	60	50.20	60
SID Tyr:Lys	56.37		51.44		46.51		41.57		36.63	
SID Phe+Tyr:Lys	131.84	95	120.62	95	109.38	95	98.12	95	86.88	95
Ca/AP	1.60		1.61		1.60		1.60		1.60	

Table 2. Composition of nursery phase 2 diets.										
University of Arkansas	Nursery Phase 2 Diets									
PIC C29XPIC380	Trt. 1 Control		Trt. 2 C+0.225 % Lys HCL		Trt 3. C+0.45 % Lys HCL		Trt. 4 C+0.675 % Lys HCL		Trt. 5 C+0.90 % Lys HCL	
Ingredients	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**
Corn	648.98	32.45	752.67	37.63	855.10	42.76	949.78	47.49	1044.37	52.22
SBM 48%	571.00	28.55	498.00	24.90	425.00	21.25	352.50	17.63	280.00	14.00
DDGS	300.00	15.00	300.00	15.00	300.00	15.00	300.00	15.00	300.00	15.00
Poultry meal	60.00	3.00	45.00	2.25	30.00	1.50	15.00	0.75	0.00	0.00
Poultry Fat	50.00	2.50	50.00	2.50	50.00	2.50	50.00	2.50	50.00	2.50
Dicalcium Phosphate	0.00	0.000	0.00	0.000	0.10	0.005	6.90	0.345	13.60	0.680
Limestone	0.55	0.028	7.00	0.350	13.40	0.670	16.10	0.805	18.80	0.940
Salt	6.10	0.305	6.90	0.345	7.00	0.350	7.50	0.375	8.00	0.400
L-Lysine HCL	0.00	0.000	4.50	0.225	9.00	0.450	13.50	0.675	18.00	0.900
DL-Methionine	0.40	0.020	1.84	0.092	3.30	0.165	4.74	0.237	6.20	0.310
L-Threonine	0.00	0.000	0.70	0.035	2.60	0.130	4.50	0.225	6.42	0.321
L-Tryptophan	0.00	0.000	0.42	0.021	1.05	0.053	1.66	0.083	2.28	0.114
L-Valine	0.00	0.000	0.00	0.000	0.48	0.024	2.82	0.141	5.15	0.258
L-Isoleucine	0.00	0.000	0.00	0.000	0.00	0.000	2.03	0.102	4.22	0.211
Whey	208.00	10.40	208.00	10.40	208.00	10.40	208.00	10.40	208.00	10.40
Fish Meal, Menhaden	120.00	6.00	90.00	4.50	60.00	3.00	30.00	1.50	0.00	0.00
ZnO	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300	6.00	0.300
UArk VITAMINS	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250
UArk TRACE MINERAL	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150
Ronozyme	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019
Ethoxiquin (Quinguard)	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030
Neo-Terramycin 10/5	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000
Calculated Analysis										
NRC ME (Mcal/lb)	1.55		1.55		1.55		1.55		1.55	
CP (%)	27.30		24.93		22.62		20.43		18.25	
SID Lysine (%)	1.350	1.420	1.350	1.420	1.350	1.420	1.350	1.420	1.350	1.420
Total P (%)	0.72		0.65		0.57		0.56		0.55	
Available P (%)	0.44	0.400	0.38	0.400	0.32	0.400	0.32	0.400	0.32	0.400
Ca (%)	0.70	0.750	0.70	0.750	0.70	0.750	0.70	0.750	0.70	0.750
Na (%)	0.30		0.31		0.30		0.30		0.30	
g SID Lysine/Mcal NRC ME	3.95		3.95		3.95		3.95		3.95	
SID M+C:Lys	60.05	58	60.05	58	60.11	58	60.04	58	60.03	58
SID Thr:Lys	66.43	60	62.06	60	62.06	60	62.03	60	62.07	60
SID Trp:Lys	19.76	17	19.03	17	19.07	17	19.03	17	19.01	17
SID Ile:Lys	73.27	55	65.41	55	57.54	55	57.02	55	57.07	55
SID Val:Lys	81.88	65	73.61	65	67.05	65	67.08	65	67.08	65
SID Leu:Lys	153.18	100	141.38	100	129.55	100	117.54	100	105.52	100
SID His:Lys	46.69	32	41.94	32	37.18	32	32.39	32	27.60	32
SID Arg:Lys	111.27	42	98.00	42	84.71	42	71.41	42	58.09	42
SID Phe:Lys	82.18	60	74.17	60	66.15	60	58.08	60	50.00	60
SID Tyr:Lys	61.37		55.09		48.80		42.48		36.17	
SID Phe+Tyr:Lys	143.57	95	129.30	95	115.01	95	100.64	95	86.26	95
Ca/AP	1.58		1.83		2.19		2.19		2.19	

Table 3. Composition of nursery phase nursery 3 diets.										
University of Arkansas	Nursery Phase 3 Diets									
PIC C29XPIC380	Trt. 1 Control		Trt. 2 C+0.25 % Lys HCL		Trt 3. C+0.50 % Lys HCL		Trt. 4 C+0.75 % Lys HCL		Trt. 5 C+1.00 % Lys HCL	
Ingredients	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**	**lbs**	**%**
Corn	715.23	35.76	865.02	43.25	1012.22	50.61	1152.25	57.61	1279.94	64.00
SBM 48%	771.00	38.55	615.00	30.75	459.00	22.95	304.00	15.20	149.00	7.45
DDGS	400.00	20.00	400.00	20.00	400.00	20.00	400.00	20.00	400.00	20.00
Poultry Fat	50.00	2.50	48.50	2.43	46.00	2.30	43.00	2.15	44.50	2.23
Dicalcium Phosphate	4.30	0.215	5.30	0.265	6.40	0.320	7.40	0.370	8.50	0.425
Limestone	18.50	0.925	19.20	0.960	19.90	0.995	20.60	1.030	21.25	1.063
Salt	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500	10.00	0.500
Potassium sulfate	0.00	0.000	0.00	0.000	0.00	0.000	2.00	0.100	11.00	0.550
L-Lysine HCL	0.00	0.000	5.00	0.250	10.00	0.500	15.00	0.750	20.00	1.000
DL-Methionine	0.00	0.000	0.82	0.041	2.32	0.116	3.84	0.192	5.40	0.270
L-Threonine	0.00	0.000	0.14	0.007	2.33	0.117	4.55	0.228	6.75	0.338
L-Tryptophan	0.00	0.000	0.05	0.003	0.86	0.043	1.74	0.087	2.58	0.129
L-Valine	0.00	0.000	0.00	0.000	0.00	0.000	2.40	0.120	5.15	0.258
L-Isoleucine	0.00	0.000	0.00	0.000	0.00	0.000	2.25	0.113	4.97	0.249
copper sulfate	2.00	0.100	2.00	0.100	2.00	0.100	2.00	0.100	2.00	0.100
UArk VITAMINS	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250	5.00	0.250
UArk TRACE MINERAL	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150	3.00	0.150
Ronozyme	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019	0.37	0.019
Ethoxiquin (Quinguard)	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030	0.60	0.030
Neo-Terramycin 10/5	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000	20.00	1.000
Calculated Analysis										
NRC ME (Mcal/lb)	1.55		1.55		1.55		1.55		1.55	
CP (%)	26.76		24.00		21.36		18.88		16.37	
SID Lysine (%)	1.217	1.283	1.217	1.283	1.217	1.283	1.218	1.283	1.217	1.283
Total P (%)	0.54		0.52		0.50		0.47		0.45	
Available P (%)	0.22	0.320	0.22	0.320	0.22	0.320	0.22	0.320	0.22	0.320
Ca (%)	0.60	0.650	0.60	0.650	0.60	0.650	0.60	0.650	0.60	0.650
Na (%)	0.26	0.250	0.26	0.250	0.26	0.250	0.26	0.250	0.26	0.250
Lactose	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
g SID Lysine/Mcal NRC ME	3.56	3.75	3.56	3.75	3.56	3.75	3.56	3.75	3.56	3.75
SID M+C:Lys	62.86	58	60.09	58	60.07	58	60.05	58	60.10	58
SID Thr:Lys	70.34	60	62.04	60	62.03	60	62.11	60	62.04	60
SID Trp:Lys	22.43	17	19.19	17	19.00	17	19.10	17	19.01	17
SID Ile:Lys	80.50	55	69.67	55	58.82	55	57.02	55	57.04	55
SID Val:Lys	89.88	65	79.16	65	68.41	65	67.13	65	67.13	65
SID Leu:Lys	173.18	100	157.88	100	142.53	100	126.97	100	111.07	100
SID His:Lys	51.93	32	45.69	32	39.44	32	33.16	32	26.81	32
SID Arg:Lys	128.75	42	109.80	42	90.83	42	71.86	42	52.80	42
SID Phe:Lys	95.51	60	84.02	60	72.52	60	60.96	60	49.29	60
SID Tyr:Lys	71.85		62.71		53.56		44.39		35.16	
SID Phe+Tyr:Lys	167.52	95	146.89	95	126.24	95	105.51	95	84.60	95
Ca/AP	2.73		2.73		2.72		2.73		2.72	

Table 4. Analyzed amino acids composition in nursery phase 1 diet.

Treatment	1		2		3		4		5	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	26.21	24.89	24.26	23.52	22.42	21.70	20.64	20.16	18.86	18.48
Total Lysine (%)	1.59	1.42	1.58	1.47	1.57	1.45	1.55	1.42	1.54	1.36
Total Met (%)	0.51	0.48	0.52	0.50	0.54	0.50	0.55	0.50	0.57	0.48
Total M+C (%)	0.97	0.90	0.96	0.92	0.95	0.90	0.94	0.87	0.93	0.83
Total Threonine (%)	1.13	1.08	1.04	1.04	1.03	1.01	1.02	1.00	1.01	0.96
Total Tryptophan (%)	0.31	0.31	0.31	0.31	0.30	0.29	0.30	0.28	0.30	0.28
Total Isoleucine (%)	1.04	1.01	0.95	0.96	0.91	0.90	0.90	0.87	0.89	0.82
Total Valine (%)	1.26	1.22	1.16	1.17	1.10	1.10	1.08	1.07	1.07	1.02
Total Leucine (%)	2.27	2.11	2.13	2.06	1.98	1.93	1.84	1.81	1.70	1.66
Total Histidine (%)	0.68	0.59	0.62	0.57	0.57	0.53	0.51	0.48	0.45	0.42
Total Arginine (%)	1.52	1.45	1.36	1.35	1.21	1.20	1.05	1.06	0.90	0.89
Total Phenylalanine (%)	1.20	1.14	1.10	1.08	1.01	0.99	0.91	0.91	0.82	0.81

Table 5. Analyzed amino acids composition in nursery phase 2 diet.

Treatment	1		2		3		4		5	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	27.65	27.62	25.30	24.84	23.05	23.66	20.89	20.86	18.75	18.48
Total Lysine (%)	1.55	1.42	1.54	1.44	1.52	1.49	1.50	1.42	1.49	1.42
Total Met (%)	0.52	0.48	0.54	0.49	0.56	0.53	0.58	0.52	0.60	0.52
Total M+C (%)	0.94	0.87	0.93	0.87	0.92	0.90	0.91	0.86	0.90	0.84
Total Threonine (%)	1.10	1.04	1.01	0.96	0.99	0.98	0.98	0.95	0.96	0.92
Total Tryptophan (%)	0.31	0.31	0.30	0.30	0.29	0.30	0.29	0.29	0.28	0.28
Total Isoleucine (%)	1.11	1.08	1.00	0.97	0.89	0.94	0.88	0.89	0.87	0.85
Total Valine (%)	1.27	1.22	1.15	1.11	1.06	1.09	1.05	1.05	1.03	1.00
Total Leucine (%)	2.34	2.22	2.17	2.08	2.00	2.01	1.82	1.81	1.65	1.64
Total Histidine (%)	0.71	0.63	0.64	0.59	0.57	0.57	0.50	0.51	0.43	0.44
Total Arginine (%)	1.70	1.62	1.51	1.48	1.32	1.39	1.12	1.18	0.93	0.97
Total Phenylalanine (%)	1.27	1.21	1.15	1.14	1.03	1.06	0.91	0.93	0.79	0.83

Table 6. Analyzed amino acids composition in nursery phase 3 diet.

Treatment	1		2		3		4		5	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
CP (%)	27.18	27.47	24.41	24.44	21.77	21.58	19.31	19.33	16.78	16.31
Total Lysine (%)	1.43	1.41	1.41	1.37	1.39	1.38	1.37	1.37	1.35	1.28
Total Met (%)	0.45	0.43	0.45	0.42	0.48	0.48	0.51	0.47	0.55	0.47
Total M+C (%)	0.89	0.86	0.85	0.82	0.84	0.84	0.83	0.79	0.83	0.75
Total Threonine (%)	1.05	1.03	0.93	0.91	0.90	0.90	0.89	0.87	0.87	0.81
Total Tryptophan (%)	0.32	0.33	0.27	0.29	0.26	0.27	0.26	0.27	0.26	0.25
Total Isoleucine (%)	1.10	1.13	0.96	0.99	0.82	0.84	0.80	0.72	0.78	0.74
Total Valine (%)	1.24	1.27	1.11	1.13	0.97	0.99	0.95	0.96	0.94	0.89
Total Leucine (%)	2.38	2.36	2.18	2.18	1.98	1.97	1.78	1.79	1.56	1.50
Total Histidine (%)	0.71	0.71	0.63	0.64	0.55	0.56	0.47	0.49	0.38	0.38
Total Arginine (%)	1.77	1.78	1.52	1.54	1.27	1.30	1.02	1.09	0.77	0.78
Total Phenylalanine (%)	1.33	1.35	1.17	1.19	1.02	1.06	0.86	0.91	0.71	0.69

Table. 7. LS means of growth performance in nursery pigs fed diets with decreasing crude protein

	Treatments						P-Value			
							Diet	L-lysine level		
	1	2	3	4	5	SEM		Linear	Quadratic	Cubic
BW, kg										
d 0	6.49	6.51	6.52	6.53	6.50	0.37	0.405			
d 10	7.74	8.10	8.10	7.90	7.83	0.35	0.0198	0.922	0.003	0.0791
d 24	13.46	14.61	14.35	14.08	13.28	0.55	0.0007	0.2105	<0.0001	0.22
d 38	22.39	24.11	23.92	23.02	21.20	0.82	<0.0001	0.0017	<0.0001	0.3359
ADG, kg/d										
d 0-10	0.125	0.160	0.158	0.137	0.133	0.016	0.0269	0.8058	0.0056	0.0617
d 10-24	0.407	0.465	0.446	0.442	0.389	0.017	0.001	0.1488	0.0002	0.4891
d 0-24	0.290	0.338	0.326	0.315	0.282	0.011	0.001	0.1969	<0.0001	0.1966
d 24-38	0.638	0.679	0.684	0.633	0.566	0.029	<0.0001	0.0003	<0.0001	0.6881
d 0-38	0.418	0.463	0.458	0.434	0.387	0.015	<0.0001	0.0014	<0.0001	0.2988
ADFI, kg/d										
d 0-10	0.193	0.214	0.217	0.207	0.218	0.012	0.3726	0.1877	0.3642	0.2123
d 10-24	0.477	0.566	0.565	0.527	0.509	0.024	0.0108	0.6868	0.0015	0.0767
d 0-24	0.360	0.420	0.420	0.395	0.387	0.016	0.0146	0.4751	0.0027	0.0687
d 24-38	0.940	1.034	1.090	1.039	0.993	0.045	0.0454	0.3022	0.0046	0.6882
d 0-38	0.570	0.646	0.666	0.629	0.610	0.023	0.0042	0.2415	0.0004	0.1785
G:F										
d 0-10	0.645	0.736	0.725	0.658	0.611	0.047	0.0008	0.0374	0.0003	0.0788
d 10-24	0.852	0.827	0.792	0.844	0.766	0.028	0.151	0.0756	0.8604	0.1737
d 0-24	0.800	0.808	0.778	0.803	0.729	0.021	0.0388	0.0223	0.1329	0.3104
d 24-38	0.684	0.657	0.630	0.612	0.577	0.029	0.0058	0.0002	0.9338	0.785
d 0-38	0.732	0.717	0.689	0.686	0.637	0.019	0.0009	<0.0001	0.4377	0.4709

Data are LS means of eight replicates of 6 pigs each. Pigs were weaned at 21 day, and randomly allotted to one of five treatments for a 35 day trial. Treatment 1 was formulated to contain 26.2% CP in phase 1, 27.65% CP in phase 2 and 27.18% CP in phase 3 with no synthetic amino acids supplemented. Treatment 5 was formulated to contain 18.86% CP in phase 1, 18.75% CP in phase 2 and 16.78% CP in phase 3 with maximum lysine addition to a level where either histidine, arginine, or phenylalanine became limiting