Nursery Study 2

Final Report:

Evaluate the Effects of Amino Acid Supplementation with Reduced Dietary Crude Protein on Growth Performance in Nursery Pigs: GHG Mitigation Technology Evaluation-ME vs. NE.

Starting Date: 09/25/2014 (~6 to 7 kg, 21 d of age)
Ending Date: 11/03/2014 (~24 kg)

Title:

Effects of aggressive feed-grade amino acid supplementation with reduced dietary CP on growth performance nursery pigs.

Objective:

1) Evaluate the effect of aggressive feed-grade amino acid supplementation with reduced CP on growth performance in nursery pigs fed NE or ME based diets.
2) Compare performance in pigs fed diets with small dietary modifications compared to diets from nursery study 1.
3) 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.
4) Provide data which will allow coupling this model with Life Cycle Cost Analysis.
5) Utilize this model as an education and outreach tool for evaluation of the environmental footprint of swine production.

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INTRODUCTION

This study represents a continuation of efforts to determine the limitations in N reduction in swine diets. 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. Pigs fed reduced CP diets also have been shown to dramatically reduce nitrogen (N) excretion (Kerr and Easter, 1995; Kendall, 2000; Figueroa et al., 2002, Hinson, et al., 2009). However, there was variability in growth performance and carcass characteristics when reduced crude protein (CP) diets were fed (Dourmad et al., 1993; Kerr er al., 1995; Figueroa et al., 2003; Yue and Qiao, 2008). These studies suggest that the maximum level of CP reduction in conjunction with the optimum amino acid inclusion rate had not been sufficiently determined for widespread acceptance by the swine industry.

Studies to date involving the N reduction objective of the USDA NIFA AFRI grant have determined that the inclusion level for amino acids in swine diets without impacting growth performance is higher than levels currently employed in the swine industry in both nursery (Bass et al., 2013) and growing/finishing pigs (Apple et al., 2013). Therefore, increasing the inclusion level of feed-grade amino acids may offer an opportunity to improve profitability in the swine industry as well as reduce GHG emissions. It should be noted, however, that feed efficiency was negatively impacted at the highest amino acid inclusion level in nursery pigs and during the phase 1 growing period. In addition, feed intake and carcass lean gain was negatively impacted and fat depth and percent ham fat increased at the highest level of aggressive feed-grade amino acid supplementation. This suggest that further efforts are needed to determine factors limiting feed intake and lean tissue growth at the highest level of feed-grade amino acid substitution.

In all the initial studies, diets were formulated on a ME basis which results in diets with a reduced Lys/NE ratio compared to diets formulated on an NE basis. This may explain some of the negative impact on growth performance and/or the increase in fat deposition in pigs fed diets at the highest amino acid inclusion level. A recent study (unpublished data form the University of Arkansas) with diets formulated on an NE basis, resulted in similar growth performance at all levels of amino acid supplementation with the exception of the highest level. ADG, ADFI, and HCW, but not G:F, of pigs again decreased at the highest level of feed-grade amino acid supplementation. In addition, pigs fed the NE based diets had similar back fat thickness at the highest inclusion level of feed grade amino acids which is not consistent with the increase in back fat observed in earlier studies in pigs fed ME based diets.

Relatively few studies have been devoted to effects of aggressive feed-grade amino acids supplementation (ME or NE basis) on growth performance in nursery pigs. Therefore, the objective of this study was to determine the effects of reduced CP diet formulated on an ME vs. NE basis with a high inclusion of feed-grade amino acids.

MATERIALS AND METHODS

Nursery phase:

Weanling pigs (n=147, 21 d) at the University of Arkansas Animal Science Research Farm were selected and transferred to University of Arkansas Conventional Nursery Facility.

Allotment to Treatments:

The pigs were individually weighed and sorted. To avoid the confounding effect of initial weight, the pigs were assigned to 7 blocks by weight as determined by the experimental facility (7 blocks of 21 pigs per block). There were a total of 7 replicates per treatment in each phase, with pigs housed 7 pigs/pen in each block. An attempt was made to balance sex within block such that each treatment was represented by an equal number of each sex within block. Pigs remained in the same pens throughout the experiment.

Dietary Phases:

The treatments will be consisted of three dietary phases:

- Phase 1: 6.5-7 kg (8 d)
- Phase 2: 7-13 kg (13 d)
- Phase 3: 13-24 kg (18 d)

Treatment Regime: Pigs will be fed one of three treatments over the three nursery phases. Diets for phase 1, 2 and 3 are listed in Tables 1, 2 and 3, respectively.

Treatment 1: **Control**: Conventional phase 1, 2, and 3 diets formulated to contain L-Lys HCL, DL-Met, L-Thr, and L-Trp to meet all amino acid requirements. The amino acid inclusion level at the expense of soybean meal was selected to be the typical level currently used in the swine industry and were the same as the initial level of CP reduction (Treatment 2) in nursery study 1. Diets were formulated on an ME basis and to meet the SID lysine requirement (Standardized Ileal Digestible Amino Acid Recommendations for nursery pigs, PIC Nutrient Specifications Manual, 2011).

Treatment 2: **RCP-ME**: Reduced CP diet formulated to meet the histidine requirement without added feed-grade histidine (control with reduced crude protein and 0.55, 0.72, and 0.84% added feed-grade Lys HCL in phase 1, 2, and 3, respectively) with supplemental Met, Thr, Trp, Ile, and Val. Diets were formulated on the same ME basis as the control and to meet the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for Nursery Pigs, PIC Nutrient Specifications Manual, 2011).

Treatment 3: **RCP-NE**: Reduced CP diet formulated to meet the His requirement without added feed-grade His (control with reduced crude protein and 0.55, 0.72, and 0.84% added crystalline Lys HCL in phase 1, 2, and 3, respectively) with supplemental Met, Thr, Trp, Ile, and Val. Diet was formulated to meet the same amino acid requirements as Treatment 2 except the diet was formulated on a NE basis, and again, the diet was formulated to meet the SID ideal recommended amino acid ratio requirement (Standardized Ileal Digestible Amino Acid Ratio Recommendations for Nursery Pigs, PIC Nutrient Specifications Manual, 2011).

Housing and Environment:

Pigs were housed in a conventional nursery facility, with totally slatted pens and equipped with propane-fueled heaters, a two-hole nursery feeder and a two-nipple waterers in each pen. Ambient minimum room temperature was initially set at 84°F and dropped 2°F weekly until temperature reached 78°F. Pigs had free access to water and feed.

Standard 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 measured in order to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F) 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 ship with proper identification of the ration number and batch size for complete amino acid analysis.

Animal Care:

The pigs in this study were cared for according to typical commercial management procedures. This experiment was carried out in accordance with the Animal Care Protocol #13060 for swine experiments issued by the University of Arkansas Animal Care Committee. Any animal suffering from minor illness was reported to the Study Director and treated. All medical treatments were recorded. Any animal that died or became ill was weighed and removed from the study. An animal removal form was completed detailing the reason for removal, date, time and animal disposition.

Data Analysis

The performance data were analysed using the PROC MIXED procedures of SAS. Treatment was the fixed effect. Probability values of $P < 0.05$ was considered statistical significant.

Results and Discussion

Analyzed amino acid composition are in presented in Table 4 and are similar to calculated values.

No differences were observed in ADG, ADFI, or G:F in any phase or for the overall study (Table 5) in pigs fed diets formulated on an aggressive feed grade amino acid inclusion based on ME (RCP-ME) or NE (RCP-NE) compared to pigs fed amino acid inclusion levels currently used in swine industry (Control). Figure 1 illustrated how similar growth performance was among the three treatments in overall performance. These results indicate that in nursery pigs, one should be able to use a His set point in formulating amino acid based diets and allow computer simulated formulation to ensure the addition of the selected SID AA:Lys ratio without concern for animal performance. The simulation would be on a least cost diet formulation when considering minimizing nitrogen excretion in nursery pigs fed diets with the higher level of feed-grade amino acids. No differences in pig performance were observed when the diets were formulated based on either an ME or NE basis.

A previous study (Bass et al., 2013) conducted to evaluate the feeding reduced CP diet with the highest levels of feed-grade amino acids to nursery pigs resulted in poor growth performance, especially Gain:Feed in phase 3 and the overall nursery period. In the previous study, experimental diets were formulated to meet the 95% of SID Lys requirement for nursery pigs. The diets, as well as calculated and analyzed composition of diets are presented in Tables 6, 7, and 8, respectively. Comparative calculated amino acid values comparing amino acid levels used by Bass et al., (2013) and levels used in the current study are presented in Table 9. Note that Treatment 5, which was formulated with the highest level of feed-grade amino acid addition, did not meet the His :Lys or Phe+Tyr:Lys minimum ratio requirement (Table 9).

In conclusion, unlike the previous study, growth performance of nursery pigs was not affected by the higher level of feed-grade amino acids and low dietary CP. It may due to different SID His:Lys and SID Phe+Tyr:Lys in diet formulation or different protein source used in each pf the studies (Table 9). In the current study, all diets were formulated based on 100 % of the SID Lys requirement for nursery pigs, and were formulated to meet the His and Phe+Tyr requirement (Table 1, 2, & 3), which differed from the diet formulation of the previous study as I mentioned above (Table 9). Also, soy protein concentrate (SPC) was used in the current study during phase 1 and 2 which replaced menhaden fish meal used in the previous study.

Appendix

1) Personnel:

	Name and Phone number	Email
Research site Principal investigator	Charles Maxwell 479-575-2111	cmaxwell@uarc.edu
Research site diet preparation	Howard Lester (Nursery)	hlester@uark.edu
Research site animal supervisor	Chris Hart 479-387-1577	clhart@uark.edu
Research site statistician (if applicable)	Jeff Chewning	Chewning@ipa.net
Research site Veterinarian:	Michael Lunsford 479-361-9417	
Research site report preparation (if applicable)	Charles Maxwell 479-575-2111	

2) Responsibilities of research site:

Feed raw material purchase and diet preparation as detailed in protocol
Animal purchase: Animals produced by university
Housing and care of animals and all associated labor and management costs

Report preparation if requested

3) Materials and Methods - Detailed

Nursery Study	
Animal	Pig
Age of Pig	Weaning to 37 days post-weaning
Genetics	PIC C-29 X PIC 380
Vaccinations Used	Circovirus, Mycoplasma
Health Status	PRRS free
Individual Pig Identification	Yes
Animals Per Pen	7
Treatments	3
Replicates	7
Total No of Animals	147
Initial Expected Weight/days	5.0 kg at day 21 (Weaning)
Initial End Weight/days	22 kg at day 36 (57 days)
Sex	Mixed Sex Per Pen if applicable
Pen Dimensions	1.49 X 1.2 m
Feeder Type	2-hole dry feeder-Farmweld
Feeder Space/Animal	2 spaces/6 or 8 animals
Water Type Nipple/Cup/Bowl etc	Bowl
Water Availability (No. Per Pen)	1
Diet Form – Phase 1 (meal/pellet size)	Pellet (3/16 in.)
Diet Form – Phase 2 (meal/pellet size)	Pellet (3/16 in.)
Diet Form – Phase 3 (meal/pellet size)	Pellet (3/16 in.)

Pelleting Temperature	160º F or less
Conditioner time (seconds)/temp	Varies with diet/type (15 to 25 sec.)
Steam Pressure (bars)	220
Cooling Method/Time	Air lifted through draft cooler
Samples collected per diet/quantity per sample	Collect 3 grab samples of 500g each per diet from start, mid-point and end of diet manufacture run. Samples to be collected post cooler if diets are pelleted. Blend the 1.5kg together then send 500g to.

Premixes

Detailed composition of the mineral premix Nutra Blend LLC # NB-6508 Guaranteed Analysis Iron, Minimum % 11.0 Zinc, Minimum % 11.0 Manganese, Minimum % 2.64 Copper, Minimum % 1.10 Iodine, Minimum PPM 200.0 Selenium, Minimum PPM 200.0	Mineral mix supplies per kg of diet : Supplies 165 ppm Fe as Ferrous Sulfate, 165 ppm Zn as Zinc Sulfate, 0.30 ppm Se as Sodium Selenite, 40 ppm Mn as Manganous Sulfate, 16.5 ppm Cu as Copper Sulfate, and 0.30 ppm I as Calcium Iodate per kilogram of feed.
Detailed composition of the vitamin premix Nutra Blend LLC #NB-8534 Guaranteed Analysis Vitamin A, (Min) 2,000,000.0 IU/LB Vitamin D3, (Min) 300,000.0 IU/LB Vitamin E, (Min) 8,000.0 IU/LB Vitamin B12 (Min) 8.0 MG/LB Menadione, Min) 800.0 MG/LB Riboflavin, (Min) 1,800.0 MG/LB D-Pantothenic Acid, (Min) 6,000.0 MG/LB Niacin, (Min) 10,000.0 MG/LB	Vitamin mix supplies per kg of diet: Supplied 11000 IU of vitamin A, 1375 IU of vitamin D_3, 44 IU of vitamin E, 4.4 mg of vitamin K as menadione Dimethylpyrimidinol Bisulfite complex, 27.5 mg of pantothenic acid as D-calcium Pantothenate, 49.5 mg niacin, 8.25 mg of riboflavin, and 38.5 µg of vitamin B_{12} per kilogram of feed.

1) Data Analysis

A copy of all methods used or a detailed reference must be available on request.
Statistical analysis (if applicable)

Analytical software used	SAS
Observational unit	Pen
Method of analysis used	Mix
Model employed	Block, Treatment, Interactions
Means separation technique	PDIFF
Probability level employed	0.05
Treatment of missing values	No adjustment for missing values
Y values investigated	
Randomization plan – specify what blocks represent if present	four pens/block/Treatment

Literature Cite:

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Table 1. Nursery Phase 1 diets composition

University of Arkansas	Treatment 1		Treatment 2		Treatment 3	
PIC C29 x PIC380	**Control**		**RCP-ME**		**RCP-NE**	
Trial:	BW(lb)	12-16	BW(lb)	12-16	BW(lb)	12-16
Delivery Date:	14	lb Ave.	14	lb Ave.	14	lb Ave.
Ingredients	lbs	%	lbs	%	lbs	%
Corn, Yellow Dent	767.91	38.40	888.97	44.45	899.53	44.98
Soybean meal, 48%, high pr	247.000	12.350	188.500	9.425	188.000	9.400
Corn DDGS, >6 and <9% Oi	100.000	5.000	100.000	5.000	100.000	5.000
Poultry Fat	68.000	3.400	60.000	3.000	50.000	2.500
Poultry Byproduct	80.000	4.000		0.000		0.000
Milk, Whey Powder	400.000	20.000	400.000	20.000	400.000	20.000
Plasma (AP-920)	100.000	5.000	100.000	5.000	100.000	5.000
Fish Meal, Menhaden		0.000		0.000		0.000
Soycomil-P_ADM	100.000	5.000	100.000	5.000	100.000	5.000
Monocalcium P	12.850	0.643	17.800	0.890	17.800	0.890
Limestone	16.300	0.815	24.100	1.205	24.100	1.205
Salt	5.000	0.250	5.000	0.250	5.000	0.250
L-Lysine	**6.040**	**0.302**	**10.900**	**0.545**	**10.900**	**0.545**
DL-Methionine	**3.600**	**0.180**	**5.050**	**0.253**	**5.030**	**0.252**
L-Threonine	**0.900**	**0.045**	**3.040**	**0.152**	**3.030**	**0.152**
L-Tryptophan		**0.000**	**0.590**	**0.030**	**0.590**	**0.030**
L-Isoleucine		**0.000**	**1.850**	**0.093**	**1.820**	**0.091**
L-Valine		**0.000**	**1.800**	**0.090**	**1.800**	**0.090**
Milk, Lactose	70.000	3.500	70.000	3.500	70.000	3.500
ZnO	6.000	0.300	6.000	0.300	6.000	0.300
Trace Mineral Premix (NB-8!	3.000	0.150	3.000	0.150	3.000	0.150
Vitamin Premix (NB-6508)	5.000	0.250	5.000	0.250	5.000	0.250
Ronozyme P CT	0.300	0.015	0.300	0.015	0.300	0.015
Ethoxiquin (Quinguard)	0.600	0.030	0.600	0.030	0.600	0.030
Denaguard 10	3.500	0.175	3.500	0.175	3.500	0.175
Chlortetracycline 100 (ADM)	4.000	0.200	4.000	0.200	4.000	0.200
Tylan 40 Sulfa-G						
Tylan 40 Elanco						
Total	2000.0	100.0	2000.0	100.0	2000.0	100.0
Calculate						
NSNG ME (Mcal/lb)	1.584	1.542	1.584	1.584	1.574	
NSNG NE (Mcal/lb)	1.191		1.202		1.191	1.191
NSNG ME (kcal/kg)	3492		3493		3469	
CP (%)	22.9		20.0		20.1	
SID Lysine (%)	1.460	1.460	1.460	1.460	1.460	1.460
Total P (%)	0.705	PIC 2011	0.652	PIC 2011	0.653	PIC 2011
Available P (%)	0.455	0.550	0.455	0.550	0.455	0.550
Aval. P (%) with phytase	0.550		0.550		0.550	
Ca (%)	0.850	0.850	0.850	0.850	0.850	0.850
SID M+C:Lys	**58**	58	**58**	58	**58**	58
SID Thr:Lys	**60**	60	**60**	60	**60**	60
SID Trp:Lys	**17**	17	**17**	17	**17**	17
SID Ile:Lys	**57**	55	**55**	55	**55**	55
SID Val:Lys	**68**	65	**65**	65	**65**	65
SID Leu:Lys	**123**	100	**110**	100	**110**	100
SID His:Lys	**36**	32	**32**	32	**32**	32
SID Arg:Lys	**84**	42	**69**	42	**69**	42
SID Phe:Lys	**64**	60	**56**	60	**56**	60
SID Tyr:Lys	**47**		**42**		**42**	
SID Phe+Tyr:Lys	**111**	95	**98**	95	**98**	95

Table 2. Nursery phase 2 diets composition

University of Arkansas	Treatment 1		Treatment 2		Treatment 3	
PIC C29 x PIC380	**Control**		**RCP-ME**		**RCP-NE**	
Trial:	BW(lb)	17-24	BW(lb)	17-24	BW(lb)	17-24
Delivery Date:	21	lb Ave.	21	lb Ave.	21	lb Ave.
Ingredients	lbs	%	lbs	%	lbs	%
Corn, Yellow Dent	736.30	36.82	926.83	46.34	945.42	47.27
Soybean meal, 48%, high prote	457.000	22.850	299.500	14.975	298.000	14.900
Corn DDGS, >6 and <9% Oil	300.000	15.000	300.000	15.000	300.000	15.000
Poultry Fat	76.700	3.835	67.000	3.350	50.000	2.500
Poultry Byproduct	50.000	2.500		0.000		0.000
Milk, Whey Powder	240.000	12.000	240.000	12.000	240.000	12.000
Plasma (AP-920)	30.000	1.500	30.000	1.500	30.000	1.500
Fish Meal, Menhaden		0.000		0.000		0.000
Soycomil-P_ADM	50.000	2.500	50.000	2.500	50.000	2.500
Monocalcium P	3.700	0.185	8.000	0.400	8.000	0.400
Limestone	19.850	0.993	25.150	1.258	25.150	1.258
Salt	7.000	0.350	7.000	0.350	7.000	0.350
L-Lysine	**7.550**	**0.378**	**14.360**	**0.718**	**14.360**	**0.718**
DL-Methionine	**3.150**	**0.158**	**5.140**	**0.257**	**5.100**	**0.255**
L-Threonine	**1.350**	**0.068**	**4.360**	**0.218**	**4.360**	**0.218**
L-Tryptophan		**0.000**	**1.050**	**0.053**	**1.050**	**0.053**
L-Isoleucine		**0.000**	**1.750**	**0.088**	**1.730**	**0.087**
L-Valine		**0.000**	**2.460**	**0.123**	**2.430**	**0.122**
Milk, Lactose		0.000		0.000		0.000
ZnO	6.000	0.300	6.000	0.300	6.000	0.300
Trace Mineral Premix (NB-853	3.000	0.150	3.000	0.150	3.000	0.150
Vitamin Premix (NB-6508)	5.000	0.250	5.000	0.250	5.000	0.250
Ronozyme P CT	0.300	0.015	0.300	0.015	0.300	0.015
Ethoxiquin (Quinguard)	0.600	0.030	0.600	0.030	0.600	0.030
Denaguard 10		0.000		0.000		0.000
Chlortetracycline 100 (ADM)		0.000		0.000		0.000
Tylan 40 Sulfa-G	2.500	0.125	2.500	0.125	2.500	0.125
Tylan 40 Elanco						
Total	2000.0	100.0	2000.0	100.0	2000.0	100.0
NSNG ME (Mcal/lb)	1.582	1.542	1.582	1.542	1.563	
NSNG NE (Mcal/lb)	1.171	1.171	1.189		1.171	1.171
NSNG ME (kcal/kg)	3488		3487		3446	
CP (%)	24.4		20.6		20.6	
SID Lysine (%)	1.420	1.420	1.420	1.420	1.420	1.420
Total P (%)	0.575	PIC 2011	0.526	PIC 2011	0.528	PIC 2011
Available P (%)	0.306	0.400	0.306	0.400	0.306	0.400
Available P (%) with phytase	0.400		0.400		0.400	
Ca (%)	0.750	0.750	0.750	0.750	0.750	0.750
SID M+C:Lys	**58**	58	**58**	58	**58**	58
SID Thr:Lys	**60**	60	**60**	60	**60**	60
SID Trp:Lys	**17**	17	**17**	17	**17**	17
SID Ile:Lys	**61**	55	**55**	55	**55**	55
SID Val:Lys	**69**	65	**65**	65	**65**	65
SID Leu:Lys	**133**	100	**115**	100	**115**	100
SID His:Lys	**39**	32	**32**	32	**32**	32
SID Arg:Lys	**93**	42	**70**	42	**70**	42
SID Phe:Lys	**70**	60	**57**	60	**57**	60
SID Tyr:Lys	**51**		**42**		**42**	
SID Phe+Tyr:Lys	**120**	95	**99**	95	**99**	95

Table 3. Nursery Phase 3 diets composition

University of Arkansas	Treatment 1		Treatment 2		Treatment 3	
PIC C29 x PIC380						
Trial:	BW(lb)	25-50	BW(lb)	25-50	BW(lb)	25-50
Delivery Date:	38	lb Ave.	38	lb Ave.	38	lb Ave.
Ingredients	lbs	%	lbs	%	lbs	%
Corn, Yellow Dent	892.35	44.62	1135.70	56.78	1162.84	58.14
Soybean meal, 48%, high	567.000	28.350	308.000	15.400	306.000	15.300
Corn DDGS, >6 and <9%	400.000	20.000	400.000	20.000	400.000	20.000
Poultry Fat	80.000	4.000	70.000	3.500	45.000	2.250
Poultry Byproduct		0.000		0.000		0.000
Milk, Whey Powder		0.000		0.000		0.000
Plasma (AP-920)		0.000		0.000		0.000
Fish Meal, Menhaden		0.000		0.000		0.000
Soycomil-P_ADM		0.000		0.000		0.000
Monocalcium P	4.300	0.215	6.850	0.343	6.800	0.340
Limestone	23.500	1.175	24.500	1.225	24.500	1.225
Salt	10.000	0.500	10.000	0.500	10.000	0.500
L-Lysine	**8.680**	**0.434**	**16.760**	**0.838**	**16.770**	**0.839**
DL-Methionine	**2.470**	**0.124**	**4.700**	**0.235**	**4.650**	**0.233**
L-Threonine	**1.820**	**0.091**	**5.310**	**0.266**	**5.300**	**0.265**
L-Tryptophan	**0.480**	**0.024**	**1.945**	**0.097**	**1.945**	**0.097**
L-Isoleucine		**0.000**	**2.430**	**0.122**	**2.430**	**0.122**
L-Valine		**0.000**	**4.410**	**0.221**	**4.370**	**0.219**
Milk, Lactose		0.000		0.000		0.000
ZnO		0.000		0.000		0.000
Trace Mineral Premix (NB	3.000	0.150	3.000	0.150	3.000	0.150
Vitamin Premix (NB-6508	5.000	0.250	5.000	0.250	5.000	0.250
Ronozyme P CT	0.300	0.015	0.300	0.015	0.300	0.015
Ethoxiquin (Quinguard)	0.600	0.030	0.600	0.030	0.600	0.030
Denaguard 10		0.000		0.000		0.000
Chlortetracycline 100 (ADM)		0.000		0.000		0.000
Tylan 40 Sulfa-G		0.000		0.000		0.000
Tylan 40 Elanco	0.500	0.025	0.500	0.025	0.500	0.025
		0.000		0.000		0.000
		0.000		0.000		0.000
Total	2000.0	100.0	2000.0	100.0	2000.0	100.0
Calculate						
NSNG ME (Mcal/lb)	1.581		1.581	1.549	1.554	
NSNG NE (Mcal/lb)	1.166		1.193		1.166	1.167
NSNG ME (kcal/kg)	3486		3486		3426	
CP (%)	23.350		19.140		19.201	
Crude fat(%)	7.764		7.490		6.286	
SID Lysine (%)	1.281	1.281	1.281	1.281	1.281	1.281
Total P (%)	0.483	PIC 2011	0.449	PIC 2011	0.452	PIC 2011
Available P (%)	0.226	0.320	0.225	0.320	0.225	0.320
Aval. P (%) with phytase	0.320		0.320		0.320	
Ca (%)	0.650	0.650	0.650	0.650	0.650	0.650
Cost ($/ton)	57.712	152.71	231.166	326.17	222.539	317.54
Calculate						
gTotal Lysine/Mcal ME	4		4		4	
gSID Lysine/Mcal ME	4	3.750	4	3.750	4	3.750
SID M+C:Lys	**58**	58	**58**	58	**58**	58
SID Thr:Lys	**60**	60	**60**	60	**60**	60
SID Trp:Lys	**19**	17	**19**	17	**19**	17
SID Ile:Lys	**63**	55	**55**	55	**55**	55
SID Val:Lys	**70**	65	**70**	65	**70**	65
SID Leu:Lys	**142**	100	**118**	100	**119**	100
SID His:Lys	**41**	32	**32**	32	**32**	32
SID Arg:Lys	**99**	42	**69**	42	**69**	42
SID Phe:Lys	**76**	60	**57**	60	**58**	60
SID Tyr:Lys	**54**		**41**		**41**	
SID Phe+Tyr:Lys	**129**	95	**99**	95	**99**	95

Table 4. Analyzed amino acids composition in nursery diets

	Dietary Treatments					
	CON		RCP-ME		RCP-NE	
Item	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
Nursery Phase 1						
CP (%)	22.94	21.48	20.04	19.05	20.07	19.18
Total Lysine (%)	1.62	1.42	1.59	1.43	1.59	1.40
Total Met (%)	0.52	0.48	0.54	0.50	0.54	0.50
Total M+C (%)	0.96	0.87	0.94	0.87	0.94	0.86
Total Threonine (%)	1.04	0.97	1.01	1.01	1.01	0.99
Total Tryptophan (%)	0.28	0.27	0.27	0.27	0.27	0.27
Total Isoleucine (%)	0.94	0.87	0.89	0.83	0.89	0.83
Total Valine (%)	1.15	1.07	1.07	1.02	1.07	1.02
Total Leucine (%)	2.02	1.85	1.79	1.68	1.80	1.70
Total Histidine (%)	0.60	0.54	0.52	0.48	0.53	0.47
Total Arginine (%)	1.33	1.28	1.08	1.05	1.08	1.04
Total Phenylalanine (%)	1.07	0.99	0.93	0.86	0.93	0.88
Nursery Phase 2						
CP (%)	24.41	23.13	20.60	19.87	20.63	20.03
Total Lysine (%)	1.61	1.46	1.57	1.49	1.57	1.41
Total Met (%)	0.54	0.53	0.58	0.54	0.58	0.56
Total M+C (%)	0.95	0.91	0.93	0.88	0.93	0.91
Total Threonine (%)	1.03	0.99	1.00	0.96	1.00	0.93
Total Tryptophan (%)	0.28	0.28	0.27	0.26	0.27	0.27
Total Isoleucine (%)	1.01	0.93	0.89	0.86	0.89	0.87
Total Valine (%)	1.16	1.09	1.07	1.03	1.07	1.05
Total Leucine (%)	2.16	1.98	1.85	1.77	1.86	1.81
Total Histidine (%)	0.63	0.58	0.52	0.49	0.52	0.49
Total Arginine (%)	1.44	1.37	1.10	1.08	1.10	1.09
Total Phenylalanine (%)	1.15	1.06	0.94	0.90	0.94	0.91
Nursery Phase 3						
CP (%)	23.35	23.51	19.14	19.39	19.20	19.74
Total Lysine (%)	1.47	1.43	1.44	1.44	1.44	1.44
Total Met (%)	0.50	0.48	0.55	0.53	0.55	0.52
Total M+C (%)	0.87	0.86	0.85	0.84	0.86	0.83
Total Threonine (%)	0.94	0.94	0.90	0.90	0.91	0.90
Total Tryptophan (%)	0.28	0.27	0.27	0.25	0.27	0.26
Total Isoleucine (%)	0.94	0.97	0.82	0.82	0.82	0.84
Total Valine (%)	1.08	1.11	1.05	1.00	1.05	1.01
Total Leucine (%)	2.10	2.14	1.75	1.75	1.76	1.78
Total Histidine (%)	0.62	0.62	0.48	0.48	0.48	0.49
Total Arginine (%)	1.39	1.48	0.99	1.06	0.99	1.11
Total Phenylalanine (%)	1.13	1.15	0.87	0.87	0.87	0.90

Table 5. Growth performance of nursery pigs

Item	Treatment[1]			SEM	*P*-value
	Control	RCP-ME	RCP-NE		
ADG, kg					
Phase 1	0.142	0.149	0.152	0.009	0.7393
Phase 2	0.426	0.428	0.449	0.024	0.6736
Phase 1-2	0.318	0.322	0.337	0.016	0.6607
Phase 3	0.631	0.590	0.614	0.022	0.2954
Overall	0.461	0.445	0.468	0.016	0.4035
ADFI, kg					
Phase 1	0.188	0.181	0.193	0.008	0.5432
Phase 2	0.578	0.578	0.596	0.030	0.8775
Phase 1-2	0.430	0.427	0.442	0.020	0.8207
Phase 3	1.071	1.012	1.047	0.035	0.4538
Overall	0.726	0.697	0.721	0.025	0.6511
Gain:Feed					
Phase 1	0.754	0.821	0.798	0.040	0.4925
Phase 2	0.736	0.740	0.754	0.016	0.6847
Phase 1-2	0.740	0.756	0.762	0.143	0.5587
Phase 3	0.593	0.583	0.588	0.020	0.9268
Overall	0.637	0.639	0.650	0.015	0.7655
BW, kg					
D 0	6.43	6.41	6.44	0.47	0.8077
D 8	7.57	7.60	7.65	0.44	0.5785
D 21	13.13	13.16	13.49	0.69	0.6133
D 39	24.45	23.80	24.66	0.99	0.4039

[1]Control: The diet with L-Lys HCL, DL-Met, and L-Thr in Phase 1 & 2, and with L-Lys HCL, DL-Met, L-Thr, and L-Trp in Phase 3; RCP-ME: Reduced CP ME based diet formulated to meet the histidine requirement without added feed-grade histidine; and RCP-NE: Reduced CP NE based diet formulated to meet the histidine requirement without added feed-grade histidine.

Table 6. Composition of nursery diets formulated by Bass et al. (2013).

Ingredients	Phase 1					Phase 2					Phase 3				
	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5
Corn	32.18	36.05	39.76	43.42	47.11	32.45	37.63	42.76	47.49	52.22	35.76	43.25	50.61	57.61	64.00
SBM 48%	19.33	16.85	14.40	11.95	9.50	28.55	24.90	21.25	17.63	14.00	38.55	30.75	22.95	15.20	7.45
DDGS	10.00	10.00	10.00	10.00	10.00	15.00	15.00	15.00	15.00	15.00	20.00	20.00	20.00	20.00	20.00
Poultry meal	3.00	2.25	1.50	0.75	-	3.00	2.25	1.50	0.75	-	-	-	-	-	-
Poultry Fat	2.50	2.60	2.70	2.75	2.75	2.50	2.50	2.50	2.50	2.50	2.50	2.43	2.30	2.15	2.23
Dicalcium Phosphate	-	0.33	0.67	1.00	1.33	-	-	0.01	0.35	0.68	0.22	0.27	0.32	0.37	0.43
Limestone	0.29	0.43	0.55	0.68	0.81	0.03	0.35	0.67	0.81	0.94	0.93	0.96	1.00	1.03	1.06
Salt	0.30	0.30	0.30	0.30	0.30	0.31	0.35	0.35	0.38	0.40	0.50	0.50	0.50	0.50	0.50
Potassium sulfate	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10	0.55
L-Lysine HCL	-	0.19	0.38	0.56	0.75	0.00	0.23	0.45	0.68	0.90	-	0.25	0.50	0.75	1.00
DL-Methionine	0.06	0.12	0.18	0.24	0.30	0.02	0.09	0.17	0.24	0.31	-	0.04	0.12	0.19	0.27
L-Threonine	-	0.02	0.10	0.18	0.26	0.00	0.04	0.13	0.23	0.32	-	0.01	0.12	0.23	0.34
L-Tryptophan	-	0.03	0.05	0.07	0.10	0.00	0.02	0.05	0.08	0.11	-	-	0.04	0.09	0.13
L-Valine	-	-	0.04	0.13	0.23	0.00	0.00	0.02	0.14	0.26	-	-	-	0.12	0.26
L-Isoleucine	-	-	0.04	0.13	0.22	0.00	0.00	0.00	0.10	0.21	-	-	-	0.11	0.25
Copper sulfate	-	-	-	-	-	-	-	-	-	-	0.10	0.10	0.10	0.10	0.10
Whey	20.00	20.00	20.00	20.00	20.00	10.40	10.40	10.40	10.40	10.40	-	-	-	-	-
Plasma	4.00	4.00	4.00	4.00	4.00	-	-	-	-	-	-	-	-	-	-
Fish Meal, Menhaden	6.00	4.50	3.00	1.50	0.00	6.00	4.50	3.00	1.50	0.00	-	-	-	-	-
Lactose	0.60	0.60	0.60	0.60	0.60	-	-	-	-	-	-	-	-	-	-
ZnO	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	-	-	-	-	-
UArk VITAMINS	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
UArk TRACE MINERAL	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Ronozyme	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Ethoxiquin (Quinguard)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Neo-Terramycin 10/5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 7. Calculated Analysis of dietary treatments formulated by Bass et al. (2013).

Item	Phase 1					Req.	Phase 2					Req.	Phase 3					Req.
	Trt 1	**Trt 2**	**Trt 3**	**Trt 4**	**Trt 5**		**Trt 1**	**Trt 2**	**Trt 3**	**Trt 4**	**Trt 5**		**Trt 1**	**Trt 2**	**Trt 3**	**Trt 4**	**Trt 5**	
ME (Mcal/lb)	1.55	1.55	1.55	1.55	1.55		1.55	1.55	1.55	1.55	1.55		1.55	1.55	1.55	1.55	1.55	
CP (%)	25.83	23.85	21.96	20.15	18.34		27.3	24.93	22.62	20.43	18.25		26.76	24	21.36	18.88	16.37	
SID Lysine (%)	1.39	1.39	1.39	1.39	1.39	**1.46**	1.35	1.35	1.35	1.35	1.35	**1.42**	1.217	1.217	1.217	1.218	1.217	**1.283**
Total P (%)	0.75	0.74	0.73	0.72	0.72		0.72	0.65	0.57	0.56	0.55		0.54	0.52	0.5	0.47	0.45	
Available P (%)	0.53	0.53	0.53	0.53	0.53		0.44	0.38	0.32	0.32	0.32		0.22	0.22	0.22	0.22	0.22	
Ca (%)	0.84	0.84	0.84	0.84	0.84		0.7	0.7	0.7	0.7	0.7		0.6	0.6	0.6	0.6	0.6	
Na (%)	0.5	0.49	0.48	0.47	0.46		0.3	0.31	0.3	0.3	0.3		0.26	0.26	0.26	0.26	0.26	**0.25**
SID M+C:Lys	60	60	60	60	60	**58**	60	60	60	60	60	**58**	63	60	60	60	60	**58**
SID Thr:Lys	66	62	62	62	62	**60**	66	62	62	62	62	**60**	70	62	62	62	62	**60**
SID Trp:Lys	19	19	19	19	19	**17**	20	19	19	19	19	**17**	22	19	19	19	19	**17**
SID Ile:Lys	66	60	57	57	57	**55**	73	65	58	57	57	**55**	81	70	59	57	57	**55**
SID Val:Lys	78	71	67	67	67	**65**	82	74	67	67	67	**65**	90	79	68	67	67	**65**
SID Leu:Lys	144	134	125	115	105	**100**	153	141	130	118	106	**100**	173	158	143	127	111	**100**
SID His:Lys	44	40	36	32	28	**32**	47	42	37	32	28	**32**	52	46	39	33	27	**32**
SID Arg:Lys	96	86	75	65	54	**42**	111	98	85	71	58	**42**	129	110	91	72	53	**42**
SID Phe:Lys	76	69	63	57	50	**60**	82	74	66	58	50	**60**	96	84	73	61	49	**60**
SID Tyr:Lys	56	51	47	42	37		61	55	49	42	36		72	63	54	44	35	
SID Phe+Tyr:Lys	132	121	109	98	87	**95**	144	129	115	101	86	**95**	168	147	126	106	85	**95**

Table 8. Analyzed amino acids composition in nursery diets conducted by Bass et al. (2013).

Treatment	1		2		3		4		5	
	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed	Calculated	Analyzed
	------------ Phase 1 Diets ------------									
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
	------------ Phase 2 Diets ------------									
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
	------------ Phase 3 Diets ------------									
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 9.Calculated amino acids composition in nursery diets from the previous study (Bass et al., 2013) and the current study

	Previous study									Current Study								
	Phase 1			Phase 2			Phase 3			Phase 1			Phase 2			Phase 3		
Ingredients, %	CON	Trt 5	Req.	CON	Trt 5	Req.	CON	Trt 5	Req.	CON	RCP-NE	Req.	CON	RCP-NE	Req.	CON	RCP-NE	Req.
Calculated value of Total and SID AAs																		
Total Lysine	1.593	1.538		1.554	1.487		1.428	1.350		1.620	1.593		1.606	1.573		1.473	1.439	
SID Lysine	1.387	1.387	1.46	1.349	1.349	1.42	1.220	1.220	1.28	1.460	1.460	1.46	1.420	1.420	1.42	1.281	1.281	1.28
Total Met	0.509	0.567		0.523	0.599		0.450	0.547		0.524	0.537		0.544	0.576		0.504	0.550	
SID Met	0.457	0.531		0.466	0.560		0.399	0.508		0.480	0.505		0.492	0.533		0.451	0.501	
Total M+C	0.966	0.933		0.939	0.901		0.887	0.825		0.963	0.943		0.951	0.931		0.875	0.855	
SID M+C	0.834	0.834		0.811	0.811		0.764	0.734		0.847	0.847		0.824	0.823		0.749	0.743	
Total Threonine	1.132	1.005		1.098	0.963		1.050	0.872		1.040	1.014		1.026	0.997		0.940	0.906	
SID Threonine	0.937	0.861		0.913	0.838		0.876	0.757		0.876	0.876		0.853	0.852		0.775	0.769	
Total Trp	0.311	0.298		0.310	0.284		0.315	0.256		0.280	0.275		0.278	0.272		0.277	0.271	
SID Tryptophan	0.265	0.264		0.267	0.257		0.274	0.232		0.249	0.249		0.244	0.244		0.244	0.244	
Total Isoleucine	1.042	0.887		1.110	0.869		1.097	0.785		0.943	0.892		1.008	0.892		0.944	0.821	
SID Isoleucine	0.910	0.792		0.966	0.770		0.948	0.696		0.832	0.803		0.872	0.781		0.804	0.705	
Total Valine	1.261	1.072		1.269	1.033		1.245	0.937		1.145	1.075		1.163	1.069		1.080	1.051	
SID Valine	1.071	0.931		1.082	0.906		1.061	0.819		0.994	0.951		0.985	0.922		0.898	0.897	
Total Leucine	2.270	1.698		2.341	1.647		2.385	1.565		2.017	1.797		2.156	1.858		2.105	1.762	
SID Leucine	2.016	1.509		2.070	1.456		2.101	1.381		1.797	1.613		1.888	1.632		1.822	1.519	
Total Histidine	0.682	0.452		0.709	0.431		0.710	0.385		0.599	0.526		0.633	0.524		0.618	0.483	
SID Histidine	0.602	0.395		0.624	0.372		0.623	0.324		0.528	0.465		0.549	0.452		0.531	0.408	
Total Arginine	1.517	0.898		1.700	0.933		1.770	0.772		1.330	1.079		1.441	1.096		1.389	0.989	
SID Arginine	1.365	0.790		1.543	0.828		1.623	0.679		1.233	1.004		1.320	0.999		1.262	0.883	
Total Phe	1.197	0.815		1.266	0.792		1.325	0.706		1.067	0.933		1.148	0.942		1.128	0.868	
SID Phe	1.056	0.717		1.111	0.691		1.161	0.611		0.938	0.823		0.993	0.813		0.969	0.738	
Total Tyrosine	0.895	0.584		0.949	0.563		0.997	0.489		0.790	0.683		0.838	0.691		0.811	0.638	
SID Tyrosine	0.783	0.510		0.829	0.488		0.878	0.420		0.689	0.608		0.717	0.594		0.686	0.531	
Total Phe+Tyr	2.091	1.400		2.214	1.355		2.322	1.194		1.857	1.616		1.986	1.633		1.939	1.506	
SID Phe+Tyr	1.838	1.227		1.940	1.180		2.041	1.033		1.627	1.432		1.710	1.407		1.653	1.267	
Ratio between AAs and Lys																		
Total Met:Lys	32	37		34	40		32	40		32	34		34	37		34	38	
SID Met:Lys	33	38		35	42		33	42	**28**	33	35		35	38		35	39	**28**
Total M+C:Lys	61	61		60	61		62	61		59	59		59	59		59	59	
SID M+C:Lys	60	60		60	60		63	60	**58**	58	58		58	58		58	58	**58**
Total Thr:Lys	71	65		71	65		74	65		64	64		64	63		64	63	
SID Thr:Lys	68	62		68	62		72	62	**60**	60	60		60	60		60	60	**60**
Total Trp:Lys	20	19		20	19		22	19		17	17		17	17		19	19	
SID Trp:Lys	19	19		20	19		22	19	**17**	17	17		17	17		19	19	**17**
Total Ile:Lys	65	58		71	58		77	58		58	56		63	57		64	57	
SID Ile:Lys	66	57		72	57		78	57	**55**	57	55		61	55		63	55	**55**
Total Val:Lys	79	70		82	69		87	69		71	67		72	68		73	73	
SID Val:Lys	77	67		80	67		87	67	**65**	68	65		69	65		70	70	**65**
Total Leu:Lys	143	110		151	111		167	116		125	113		134	118		143	122	
SID Leu:Lys	145	109		153	108		172	113	**100**	123	110		133	115		142	119	**100**
Total His:Lys	43	29		46	29		50	28		37	33		39	33		42	34	
SID His:Lys	43	28		46	28		51	27	**32**	36	32		39	32		41	32	**32**
Total Arg:Lys	95	58		109	63		124	57		82	68		90	70		94	69	
SID Arg:Lys	98	57		114	61		133	56	**42**	84	69		93	70		99	69	**42**
Total Phe:Lys	75	53		81	53		93	52		66	59		71	60		77	60	
SID Phe:Lys	76	52		82	51		95	50	**60**	64	56		70	57		76	58	**60**
Total Tyr:Lys	56	38		61	38		70	36		49	43		52	44		55	44	
SID Tyr:Lys	56	37		61	36		72	34		47	42		51	42		54	41	
Total Phe+Tyr:Lys	131	91		143	91		163	88		115	101		124	104		132	105	
SID Phe+Tyr:Lys	133	89		144	87		167	85	**95**	111	98		120	99		129	99	**95**

Figure 1. Effect of aggressive feed-grade amino acid supplementation with reduced CP on in nursery pigs