MAXIMIZING SYNTHETIC AMINO ACIDS IN SWINE DIETS

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With feed costs rising rapidly over the past months, everyone is looking to formulation to do its part in helping to ease some of the pain. One area of continued scrutiny is the optimum or maximum level of synthetic amino acids. With today's cost structure aggressive synthetic usage can greatly reduce nursery, finisher and sow feed costs. Many of us would consider their usage a given, but discrepancies still lie in the extent one should push the upper limits. With current feed cost even increasing L-Lysine inclusions by a half a pound can contribute to the bottom line. The goal of this paper is to focus on the most current and most aggressive practical synthetic amino acid research.

AMINO ACIDS IN FORMULATION

Amino acids are the building blocks of proteins; as protein synthesis takes place there is a need for given amount of each amino acid. The amino acid present in the lowest amount relative to the requirement is known as the first limiting and thus, responsible for limiting protein synthesis. In the growing pig being fed a corn and soybean meal based diet lysine is first limiting followed by sulfur amino acids, threonine and tryptophan (not necessarily in that order). The balance of needed amino acids that meet the pig's requirement is referred to as the ideal protein. Using the ideal protein concept to aid in formulation, lysine, the first limiting in most swine diets, is set at 100%. All other amino acid needs are expressed as a percentage of the lysine, thus allowing ease of formulation if the lysine requirement is known. This concept becomes very important as the limiting amino acids become more readily available in synthetic forms. When conducting trials to investigate the optimum ratios to lysine it is important to be at or below the lysine requirement. Note that it is not the intention of this paper to suggest the below trials are designed to determine the appropriate ratios for all amino acids; however inferences and validation of previous work can be made.

MAXIMUM L-LYSINE HCL INCLUSIONS

Nursery Diets

Nursery diets are often separated into two categories: 1) from weaning to 25 lbs, which often contain specialty ingredients and 2) diets from 25 to 50 lbs which are most always corn and soybean meal based.

Diets for pigs from weaning to 25 lbs often contain alternative protein ingredients such as fishmeal and/or poultry meal. These animal proteins are often expensive and have potential to pose a risk for bacterial contamination. Ratliff et al., 2005, evaluated the effect of replacing 6% fishmeal with all synthetic amino acids in diets fed from 17 to 30 lbs of body weight. L-Lysine was incrementally increased from 5.5 to 12.5 lbs with dietary standardized ileal digestible (SID) lysine formulated at 1.42%, the requirement previously reported by Gaines et al., 2003. Utilizing

DL-Methionine, L-Threonine, L-Tryptophan, L-Valine and L-Isoleucine SID ratios to lysine were maintained at a minimum of 60, 65, 17, 67 and 60% respectfully. Growth performance was maintained across all diets (Table 1). A subsequent trial re-evaluated the 5.5 vs. 12.5 lb L-Lysine diets and then removed independently each L-Tryptophan, L-Isoleucine and L-Valine to further refine the necessary amino acid ratios (Table 2). Performance was maintained as both L-Tryptophan and L-Isoleucine were removed, but was reduced with the removal of L-Valine (Table 3). These data would suggest minimum SID ratios to lysine of 65, 50 and 14% for Valine, Isoleucine and Tryptophan for 25 to 50 lb pigs. However, these ratios should be considered minimal only when blood products (specifically blood cells) are not included in the diet. With 3% blood cells in the diet SID Iso:Lys is likely much greater.

In today's production systems it is often from 25 to 50 lbs that the pig is moved to a "simple" corn and soybean meal based diet. Fu et. al., 2004, indicated with current genetics the SID lysine requirement to maximize growth was 1.32%. However, formulating to this level of lysine utilizing soybean meal has potential to decrease performance and cause increased diarrhea. Thus, the use of synthetic amino acids is of utmost importance in this phase of growth. Following this lysine requirement study Kendall (2004) evaluated the maximum inclusion of L-Lysine with the addition of DL-Methionine and L-Threonine. The SID M+C:Lys and Thr:Lys ratios were maintained at a minimum of 60 and 65%, respectfully, in all diets. Performance data indicated no reduction in growth performance with increased L-Lysine inclusions (Figure 1).

To further push the upper limit, Ratliff et al., 2004b, titrated L-Lysine from 6 to 14 lbs with all diets above 8 lbs containing added L-Valine, L-Isoleucine and L-Tryptophan to maintain the same amino acid ratios present in the 8 lb L-Lysine diet (Table 4). Results validated the previous research showing no reduction in performance with 8 lbs of L-Lysine when DL-Methionine and L-Threonine were added. Additionally, performance was maintained with 10 lbs of L-Lysine when L-Valine, L-Isoleucine and L-Tryptophan were added (Table 5).

These data indicate in early nursery diets animal protein (in diets without blood products) can be replaced with up to 12.5 lbs of L-Lysine w/ added DL-Methionine, L-Threonine and L-Valine to maintain SID ratios of 60, 65 and 65%, respectively. Furthermore, in 25 to 50 lbs pigs up to 8 lbs of L-Lysine with only added DL-Methionine and L-Threonine or 10 lbs of L-Lysine, when L-Valine, L-Isoleucine and L-Tryptophan are also available, can be added without compromising growth performance.

Growing/Finishing Diets

As L-Lysine became commercially available the question of how much could be added was asked. One of the most recent and comprehensive experiments was conducted at Kansas State University (De la Llatta et al., 2002). In this study, corn and soybean meal based diets were formulated with incremental increases in L-Lysine from 0 to 6 lbs. A negative control diet, with 0.0 lbs of L-Lysine, was formulated at 0.10% less lysine to ensure all other diets were at or below the requirement. The results (Figure 2) indicated superior growth performance in pigs from 65 to 265 lbs of body weight when diets contained 3 lbs of L-Lysine or less. As lysine is the first limiting amino acid one can assume the respective amino acid ratios at 3 lbs L-Lysine inclusion would be adequate (Table 6). This trial and others have provided means of cost effectively reducing soybean meal use by close to 100 lbs per ton by replacing it with approximately 97 lbs of corn and 3 lbs of L-Lysine. The 3 lbs per ton rule of thumb has been in place for many years, but with the increased production and reduced cost of L-Threonine and multiple methionine sources it needs to be re-evaluated.

A series of studies were conducted at University of Missouri evaluating the maximum L-Lysine inclusion with the use of a synthetic methionine source and L-Threonine. In all studies pigs were fed at or below the lysine requirement based on previous lysine requirement studies. In the first experiment, Ratliff et al. (2005) increased L-Lysine inclusion from 3 to 8 lbs with added Alimet (maintaining a SID M+C:Lys ratio of 60%) and L-Threonine (maintaining a SID Thr:Lys of 65%) for pigs weighing from 50 to 190 lbs. Data indicated up to 8 lbs of L-Lysine could be added from 50 to 100 lbs and 7 lbs from 100 to 190 lbs. Note that at these inclusion levels the SID Trp:Lys was allowed to drop to 15.5% from 50 to 150 lbs and a 14.5% from 150 to 180 lbs (Table 7). Srichana et al., 2005, validated the 150 to 190 lb data and further evaluated L-Lysine addition in 190 to 230 lb pigs. Similarly, in his experiment Alimet and L-Threonine were added to maintain minimum TID ratios to lysine of 60 and 65%, respectfully. Data indicated that up to 6 lbs of L-Lysine could be utilized. This usage resulted in a SID Trp:Lys ratio of 15.5% (Table 7).

Gaines et al. (2004) compared 2 vs. 6 lbs of L-lysine in late finishing diets fed Paylean; maintaining minimum SID M+C:Lys and SID Thr:Lys ratios of 58% and 70%, respectfully. Performance data indicated no difference between 2 and 6 lbs added L-Lysine (Table 7). The trail was validated by Ratliff et al. (2005) by titrating L-Lysine up to 10 lbs with the same respective ratios. This data indicated no performance lag going from 2 to 8 lbs of L-Lysine (Table 7). Sustained performance at 8 lbs of L-Lysine would suggest a minimum SID Trp:Lys ratio of 15.0%.

This set of experiments would indicate that in corn and soybean meal based diets with an added methionine source and L-Threonine that up to 8 lbs of L-lysine can be fed from 50 to 100 lbs, 7 lbs from 100 to 190 lbs, 6 lbs from 190 to 230 lbs and 8 lbs in Paylean diets. It is important to note that the reported minimal ratios present in Table 4 are generated using NRC (1998) nutrient profiles for all ingredients.

Sow Diets

There has been little research done looking at synthetic amino acid usage in gestating sows. The most recent work was conducted by Srichana et al., 2007a, to evaluate nitrogen retention when L-lysine inclusion was titrated from 0 to 6 lbs in corn and soybean meal based diets. Nitrogen retention was assessed in early (d 50-60), mid (d 80-90) and late (d 100-110) gestation in which sows were fed 11, 13 and 16 g of SID Lysine per day, which previous research indicated is below the requirement (Srichana et al., 2006). In all added L-Lysine diets, L-Threonine was added to maintained at a SID Thr:Lys ratio of 78% (the same as in a corn- soybean meal based diet). Nitrogen balance data indicated that up to 4 lbs of L-Lysine with only added L-Threonine did not statistically reduce nitrogen retention (Figures 3, 4 and 5). Furthermore, Srichana showed this was true regardless of feeding once or twice a day for gilts (Figure 6) and parity 2 females (Figure 7).

Research on the use of synthetic AA in lactation diets has been more prevalent. The decision to implement synthetics is largely dependent on ones view of the valine requirement. The NRC (1998) suggest a requirement of 0.82% total valine or a 85% Val:Lys ratio in a 0.97% total Lysine diet. Richert et al., 1996, showed a optimal Val:Lys of 120%, thus limiting any L-Lysine usage without L-Valine first being added. However, others would indicate an optimal ratio much lower (Trottier et al., 1997; Boyd et al., 1999; Carter et al., 2000; Moser et al., 2000; Kim et al., 2001 and Gaines et al., 2003). From a practical diet formulation perspective the most recent work was conducted by Srichana et al., 2007c. This work was conducted in first litter females with increasing levels of L-Lysine from 0 to 6 lbs per ton. Sows were fed a 1.2% total lysine which was previously determined to be below the requirement (Srichana et al., 2007b). As L-Lysine was increased, Alimet and L-Threonine were added to maintain minimal ratios of 58 and 65%, respectfully. Feeding diets containing 6 lbs of L-Lysine resulted in similar, if not superior, reproductive and litter performance in the first litter female (Table 8).

In corn and soybean meal based gestation diets up to 4 lbs of L-Lysine can be fed with the addition of supplemental L-Threonine (Thr:Lys of 78%). In lactation diets up to 6 lbs of L-Lysine can be utilized with the addition of a methionine source (M+C:Lys of 58%) and L-Threonine (Thr:Lys of 65%). This lactation data would further indicate a minimal Val:Lys of 71%. Schneider et al., 2007, would indicate a M+C:Lys no more than 50%, suggesting the need for only L-Threonine when using 6 lbs of L-Lysine. Note these minimal ratios are determined using NRC (1998) nutrient profiles for all ingredients.

TAKE-HOME MESSAGE

High levels of synthetic amino acids can be used in all phases of swine production with potential for substantial savings during periods of high feed costs. In early nursery diets costly animal protein products can be replaced with up to 12.5 lbs of L-Lysine and added DL-Methionine, L-Threonine and L-Valine (when blood products are not present in the diet). In late nursery, grow/finish and sow diets synthetics are used to solely reduce the level of SBM with the use of only L-Lysine, a methionine source and L-Threonine presenting practical and economical opportunities. With the use of these three synthetic amino acids the maximum L-Lysine inclusion in swine diets is 8 lbs from 25-105 lbs, 7 lbs from 105-190 lbs, 6 lbs from 190-230 lbs and 8 lbs when Paylean is fed. The respective SID Trp:Lys ratios are included in this paper when formulating using NRC (1998) nutrient analysis, however it is encouraged that each independent nutritionist utilize the maximum L-Lysine inclusion to determine these for their specific ingredient matrix.

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Table 1. Evaluation of replacing fish meal in the phase 3 nursery diet (19-30 lbs)[a]

L-lysine HCl, lbs	**5.5**	**7.25**	**9.00**	**10.75**	**12.50**			**P-Values**	
Fish meal, lbs/ton	**120**	**90**	**60**	**30**	**0**	**SEM**	**Trt**	**Linear**	**Quadratic**
D0 BW	18.98	19.16	19.15	19.09	19.07	0.25	0.99	0.89	0.66
D10 BW	30.64	30.55	30.62	30.50	30.80	0.47	0.99	0.86	0.75
ADG 0-10	1.17	1.14	1.15	1.14	1.17	0.030	0.88	0.91	0.94
ADFI 0-10	1.35	1.34	1.38	1.37	1.38	0.032	0.91	0.36	0.94
G:F 0-10	0.867	0.848	0.834	0.833	0.847	0.015	0.59	0.24	0.15
F:G 0-10	1.16	1.18	1.20	1.20	1.18	0.020	0.64	0.27	0.17

[a]Data represents the means of six replicate pens (800 pigs total). Trial was conducted at NEMO Pork; Moberly, MO.

Table 2. Experimental diet composition (Ratliff et al., 2005)						
L-Lysine, lbs	**5.5**	**12.5**	**12.5**	**12.5**	**12.5**	**12.5**
Treatment	**Cont +Fish**	**Cont -Fish**	**-Trp (14)**	**-Ile (50)**	**-Val (55)**	**+AA (14, 55, 65)**
Corn	969	1045	1045	1048	1048	1030
SBM 48%	600	600	600	600	600	600
Fat, CWG	60	60	60	60	60	60
Dical (18.5%)	18	37.25	37.25	37.25	37.25	37.25
Limestone	9	14.25	14.25	14.25	14.25	14.25
Salt	8.5	8.5	8.5	8.5	8.5	8.5
Dairy Lac 80	170	170	170	170	170	170
Fish Meal	120	---	---	---	---	---
L-Lysine	5.5	12.5	12.5	12.5	12.5	12.5
DL-Methionine	3.7	6.25	6.25	6.25	6.25	6.25
L-Threonine	3.55	6.35	6.35	6.35	6.35	6.35
L-Tryptophan	---	0.70	---	0.70	0.70	---
L-Isoleucine	---	3.35	3.35	---	3.35	1.65
L-Valine	---	3.3	3.3	3.3	---	2.85
Glutamic/Glycine	---	---	---	---	---	18
Other (VTM, Meds,	32.75	33.00	33.25	32.9	32.85	32.4
Calculated Composition						
NRC ME (Mcal/lb)	1.55	1.55	1.54	1.54	1.53	1.55
Calcium	0.85	0.85	0.85	0.85	0.85	0.85
Available Phosphorous	0.45	0.45	0.45	0.45	0.45	0.45
TID Lysine	1.42	1.42	1.42	1.42	1.42	1.42
TID M+C:Lys	60	60	60	60	60	60
TID Thr:Lys	65	65	65	65	65	65
TID Trp:Lys	16.8	16.8	14.4	16.8	16.8	14.4
TID Ile:Lys	60	60	60	50	60	55
TID Val:Lys	67	67	67	67	55	65

Table 3. Evaluation of replacing fish meal with synthetic amino acids and minimum amino acid ratios in Phase 3 diets.[a]

L-lysine, lbs	5.5	12.5	12.5	12.5	12.5	12.5		P Values
	Cont	Cont	-Trp	-Ile	-Val	+AA		
Treatment	+Fish	-Fish	(14)	(50)	(55)	(14, 55, 65)	SEM	Trt
D0 BW	22.95	23.22	23.31	23.29	22.86	22.84	0.37	0.87
D12 BW	33.81	34.44	34.38	35.15	33.38	34.25	0.48	0.20
ADG 0-12	0.91[BC]	0.93[AB]	0.92[ABC]	0.98[A]	0.86[C]	0.95[AB]	0.02	0.03
ADFI 0-12	1.35[B]	1.40[AB]	1.38[AB]	1.43[A]	1.34[B]	1.42[A]	0.02	0.04
G:F 0-12	0.675	0.663	0.664	0.686	0.642	0.670	0.013	0.29
F:G 0-12	1.49	1.51	1.51	1.46	1.56	1.49	0.03	0.31

Ratliff et al., 2005

Figure 1. Effect of L-Lysine inclusion w/ added DL-Meth and L-Thr on growth performance (25-50 lbs).

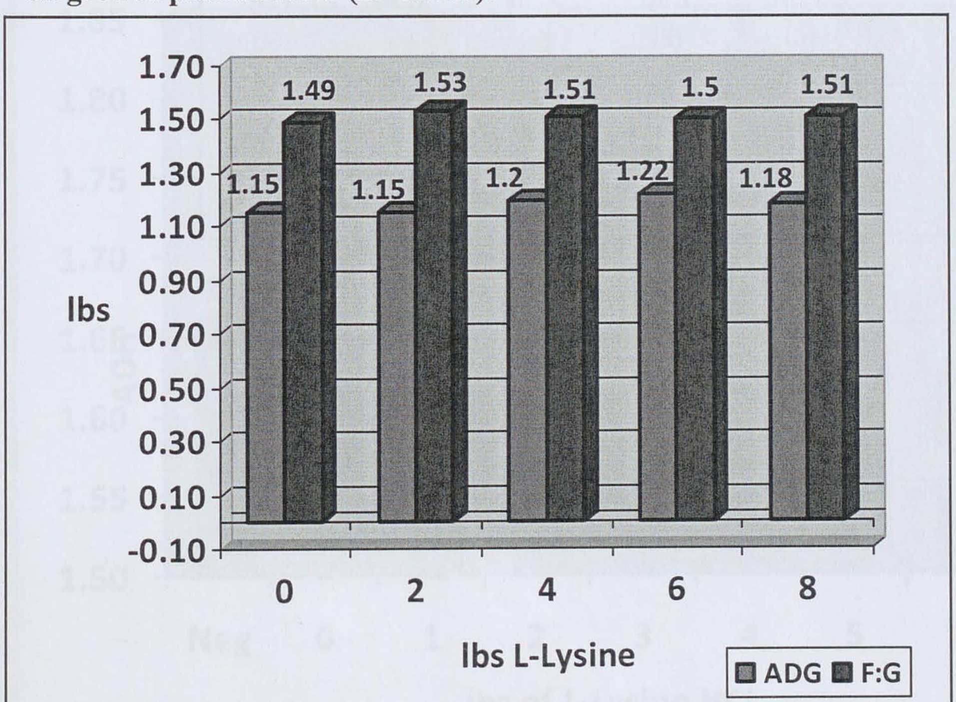


Table 4. Experimental diet composition (Ratliff et al., 2006b)					
L-Lysine, lbs	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**
Corn	1152	1209	1265	1320	1375
SBM 48%	696	634	572	510	448
Fat, CWG	60	60	60	60	60
Dical (18.5%)	36.6	37.1	37.5	38.0	38.4
Limestone	13.6	13.9	14.1	14.4	14.6
Salt	10	10	10	10	10
L-Lysine	6.0	8.0	10.0	12.0	14.0
DL-Methionine	3.3	3.9	4.5	5.1	5.7
L-Threonine	3.0	3.9	4.8	5.65	6.55
L-Tryptophan	---	---	0.35	0.70	1.05
L-Isoleucine	---	---	1.25	2.50	3.75
L-Valine	---	---	1.10	2.15	3.20
Other (VTM, Meds, etc)	19.5	20.2	19.4	19.5	19.75
Calculated Composition					
NRC ME (Mcal/lb)	1.55	1.55	1.55	1.55	1.55
Calcium	0.80	0.80	0.80	0.80	0.80
Available Phosphorous	0.40	0.40	0.40	0.40	0.40
TID Lysine	1.30	1.30	1.30	1.30	1.30
TID M+C:Lys	60	60	60	60	60
TID Thr:Lys	65	65	65	65	65
TID Trp:Lys	17.9	16.7	16.7	16.7	16.7
TID Ile:Lys	62.3	58.3	58.3	58.3	58.3
TID Val:Lys	68.5	64.5	64.5	64.5	64.5

Table 5. Effect of L-Lysine inclusion on growth performance (25-50 lbs).									
	L-lysine HCl, lbs						P-Values		
Item	**6.0**	**8.0**	**10.0**	**12.0**	**14.0**	**SEM**	**Treatment**	**Linear**	**Quadratic**
Crude protein, %	21.8	20.7	19.6	18.5	17.5	---	---	---	---
TID lysine, %	1.30	1.30	1.30	1.30	1.30	---	---	---	---
BW, d 0	28.6	28.6	28.6	28.6	28.5	0.44	1.00	0.95	0.93
BW, d 14	45.9	46.4	46.4	45.6	44.8	0.58	0.40	0.12	0.14
ADG	1.25	1.28	1.27	1.21	1.16	0.03	0.14	0.04	0.12
ADFI	1.82	1.85	1.85	1.79	1.81	0.04	0.87	0.63	0.64
F:G	1.46[a]	1.44[a]	1.45[a]	1.48[a]	1.56[b]	0.02	< 0.01	< 0.01	0.02

Ratliff et al., 2006b

Figure 2. Effect of L-Lysine inclusion in growing finishing pigs from 65 to 265 lbs (De la Llata et al., 2002).

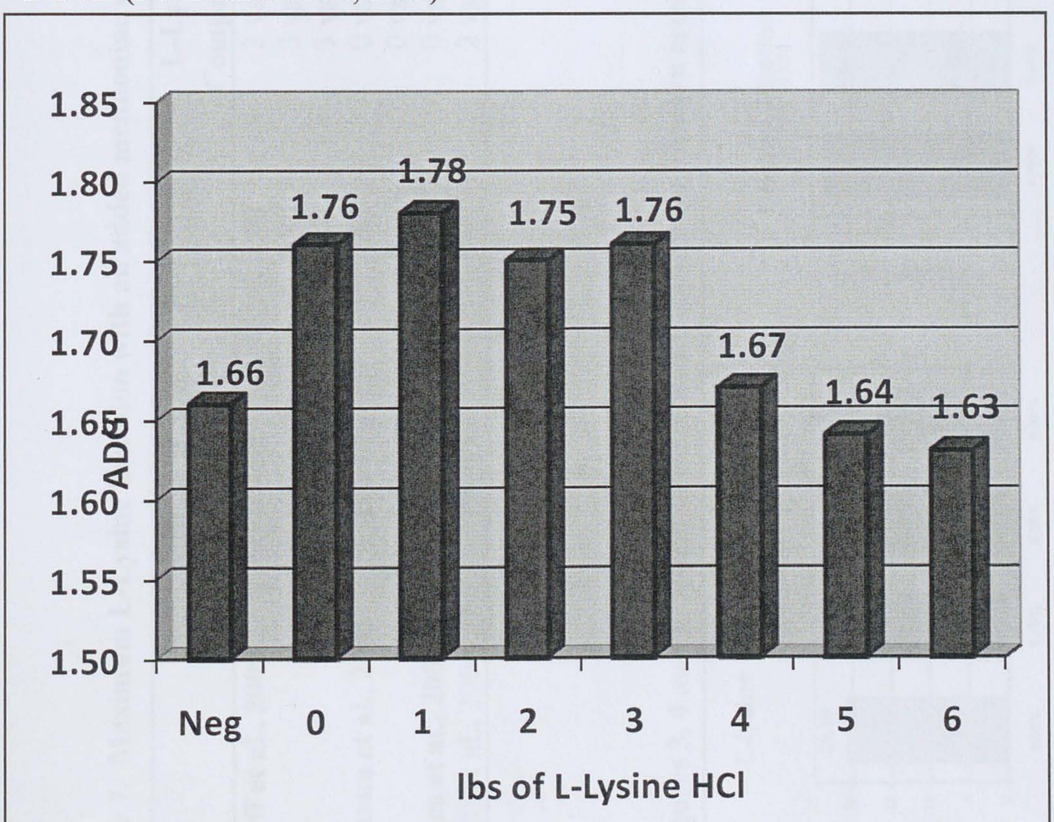


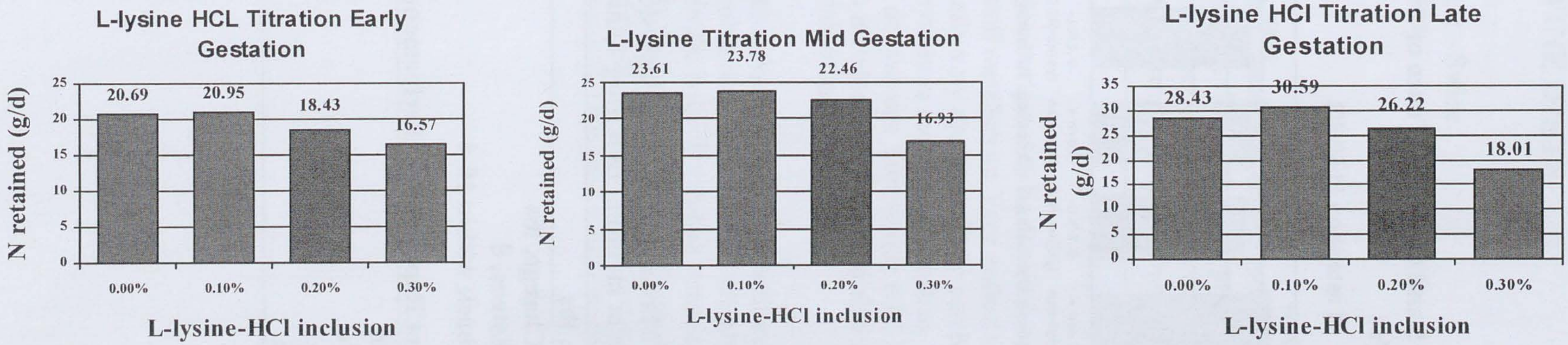
Table 6. Calculated standardized ileal digestible amino acid ratios relative to lysine in diets containing 0.15% L-Lysine (De la Llata et al., 2002).

Weight Range	65-100	100-155	155-200	200-265
Threonine	59	60	62	66
Methionine + Cystine	50	52	56	66
Tryptophan	19	19	19	16
Isoleucine	66	66	65	65

Table 7. Maximum L-Lysine inclusion with an added methionine source and L-Threonine in growing-finishing diets

	Weight Range	SID Lysine, %	L-Lysine Comparison	ADG (lbs) Low	ADG (lbs) High	Feed:Gain Low	Feed:Gain High	SID Ratios Thr	SID Ratios M+C	SID Ratios Trp
Ratliff et al., 2005	65-105	1.00	3 vs. 8	1.94	1.93	1.96	1.95	61	60	15.5
	105-150	0.90	3 vs. 7	1.93	1.86	2.39	2.38	62	60	15.5
	150-190	0.77	3 vs. 7	1.79	1.84	2.63	2.55	63	60	14.5
Srichana et al., 2005	115-170	0.87	0 vs. 6	2.42	2.39	2.43	2.45	66	60	16.2
	170-230	0.75	0 vs. 6	2.31	2.27	3.03	3.02	67	62	15.5
Gaines et al., 2004	Paylean	0.93	0 vs. 6	2.36	2.36	2.71	2.74	70	58	16.5
Ratliff et al., 2004	Paylean	0.93	2 vs. 8	2.24	2.30	2.84	2.84	70	65	15.0

Figures 3, 4 and 5. Effect of increased L-Lysine on nitrogen retention in gestating gilts (Srichana et al.,2007a)



Figures 5 and 6. Effect of once or twice a day feeding on nitrogen retention (Srichana et al., 2007a)

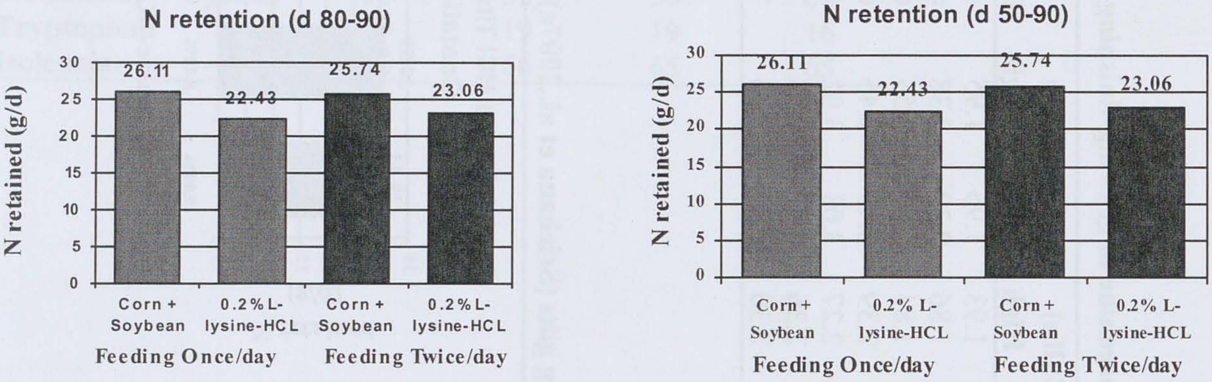


Table 8. Maximum L-Lysine inclusion with an added methionine source and L-Threonine in lactating first litter females (Srichana et al., 2007b).

L-Lysine, lbs	0.0	1.5	3.0	4.5	6.0
Sow BW Change, lbs	+1.4	+2.9	+0.0	+4.6	+4.4
Wean to Estrus, d	7.1	6.4	5.5	5.9	5.5
% Breed back within 10 d	89.8	94.4	97.7	96.4	98.3
Subsequent Reproductive Performance					
Total Born	11.75	12.52	12.45	12.05	12.48
Born Alive	10.95	11.47	11.41	11.42	11.62
Still Born	0.35	0.52	0.59	0.37	0.67
Mummies	0.45	0.52	0.45	0.26	0.19