THE OPTIMAL TRUE-ILEAL-DIGESTIBLE LYSINE AND THREONINE REQUIREMENTS FOR GROWING-FINISHING PIGS FROM 80 TO 130 AND 170 TO 230 POUNDS

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Summary

A total of 4388 pigs (PIC 337 × C22; Exp. 1: 1070 gilts, initially 79 lb BW; Exp. 2: 3318 pigs, initially 170 lb BW) were used in 28-d growth assays to examine both the true-ileal-digestible (TID) lysine and threonine requirements, and then determine the appropriate TID threonine-to-lysine ratio in growing-finishing pigs from 80 to 130 lb and 170 to 230 lb. In Exp. 1, four TID lysine (0.71. 0.81, 0.91, and 1.01%) and five TID threonine (0.50, 0.56, 0.62, 0.68 and 0.74%) concentrations were evaluated. In Exp. 2, four TID lysine (0.56, 0.64, 0.72, and 0.80%), and five TID threonine (0.43, 0.48, 0.53, 0.58 and 0.63%) concentrations were evaluated. The diet with the highest concentration of lysine and second-highest concentration of threonine served as a positive control in both studies, and this diet was combined as one treatment to give a total of nine treatments in each study. Other amino acids were formulated to meet, or exceed, requirement estimates to ensure that lysine and threonine were the only limiting amino acids. In Exp. 1, increasing TID lysine tended to increase ADG (quadratic, $P<0.06$), with the greatest response occurring from 0.71 to 0.81%. Increasing TID lysine also quadratically increased ADFI ($P<0.03$) up to 0.81% TID lysine, and linearly improved feed efficiency (F/G; $P<0.01$), up to 1.01% TID lysine. Increasing TID threonine did not affect ADG ($P>0.69$) or ADFI ($P>0.29$), but improved F/G (linear, $P<0.05$), with the maximum response occurring at 0.68% TID threonine. Values of 1.01% TID lysine and 0.68% TID threonine in Exp. 1 suggest an optimal TID threonine-to-lysine ratio of 67% for F/G. In Exp. 2, a treatment × gender interaction was observed for F/G ($P<0.02$). This was because gilts had a greater response to increasing TID lysine, whereas barrows had a greater response to increasing TID threonine. In Exp. 2, increasing TID lysine improved ADG (linear, $P<0.05$) in gilts and barrows ($P<0.07$), and improved F/G (linear, $P<0.01$) in gilts, as the TID lysine concentration increased to 0.72%. Increasing TID threonine improved ADG and F/G (linear, $P<0.04$) in barrows and increased ADG and ADFI (linear, $P<0.06$) in gilts as the threonine concentration increased to 0.48%. Values of 0.72% TID lysine and 0.48% TID threonine in Exp. 2 suggest an optimum TID threonine-to-lysine ratio of 67%. The practical TID threonine-to-lysine ratio suggested by this study for pigs from 80 to 130 lb and from 170 to 230 lb is 67%. Further research is needed to verify these results and evaluate the economics of feeding higher threonine concentrations.

(Key Words: Growing Pigs, Lysine, Pigs, Threonine.)

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Introduction

The National Research Council (NRC) suggests a dietary TID threonine concentration of 0.43% for a 80- to 130-lb pig and 0.34% for a 170- to 230-lb pig. The NRC also estimates dietary TID lysine concentrations of 0.66% and 0.52% for 80- to 130-lb and 170- to 230-lb pigs, respectively. This calculates to TID threonine-to-lysine ratios of 65% and 67% over the respective weight ranges. Lysine is considered the first-limiting amino acid, with threonine or methionine being second-limiting in corn-soybean meal diets. As increasing inclusion rates of crystalline amino acids become more cost effective, it is essential to understand the proper ratios, relative to lysine, required to promote optimal growth performance during different growing periods. When adding more than 0.15% L-lysine HCl to the diet, supplementation of both methionine and threonine also will be needed. The objective of this experiment was to determine the optimal ratio of threonine to lysine in diets to maximize growth performance of pigs in the late-growing and early-finishing phases. To achieve our objective, two trials were run simultaneously within each experiment, to determine a lysine and threonine requirement, and then to determine a TID threonine-to-lysine ratio from each experiment.

Procedures

General

Procedures used in these experiments were approved by the Kansas State University Animal Care and Use Committee. Both trials were conducted at a commercial swine research facility in southwestern Minnesota. The facility is made up of four individual barns, each 41 × 250 ft, with 48, 10 × 18 ft, totally slatted concrete pens. Each pen was equipped with a four-hole dry self-feeder (Staco, Schaefferstown, PA) and a one-cup waterer to allow ad libitum access to feed and water. The finishing facilities were double curtain-sided, deep-pit barns that operated on manual ventilation during the summer and on automatic ventilation during the winter. Pigs and feeders were weighed on d 0, 14, and 28 to determine the response criteria of ADG, ADFI, and F/G. From previous lysine-titration studies conducted in these same facilities, we estimated the pigs' actual lysine requirement over their respective weight ranges and used this as the third-highest lysine concentration in both experiments.

Experiment 1

A total of 1070 gilts (PIC 337 × C22, initially 79 lb BW) were blocked by weight in a 28-d growth assay. They were randomly allotted to one of eight dietary treatments in a randomized complete-block design, with the diet containing the highest lysine and second-highest threonine concentrations combined as one treatment to give a total of nine treatments. Each pen contained approximately 27 ± 1 pigs per pen and five replicates (pens) per treatment, with the number of pigs balanced across treatments. Experimental diets were based on corn-soybean meal (Table 1) and were fed for 28 d in meal form. The positive-control diet was formulated with the highest lysine (1.01%) and second-highest threonine (0.68%) concentrations. In formulating the remaining diets, either L-lysine HCl or L-threonine replaced corn. L-lysine HCl was added to provide 0.71, 0.81, 0.91, or 1.01% TID lysine. The diets for the threonine trial were set at 1.01% TID lysine, and crystalline L-threonine was added to obtain 0.50, 0.56, 0.62, 0.68, or 0.74% TID threonine. The values used in diet formulation and TID values were based on those published by the NRC.

Experiment 2

A total of 3318 pigs (PIC 337 × C22, initially 170 lb BW) were blocked by weight and sex in a 28-d growth assay. They were randomly allotted to one of eight dietary treatments in a randomized incomplete-block design. Each pen contained approximately 24 ± 2 pigs per pen. Three barns were used, two with four complete replications (two barrow and two gilt), and two incomplete blocks. The 0.56%-TID-lysine treatment was deleted from the middle block of barrows in one barn, whereas the 0.64%-TID-lysine treatment was deleted from the middle block of barrows in the other barn because of a shortage of pigs. The 0.53%-TID-threonine treatment was deleted from the middle block of gilts in one barn, and the 0.64%-TID-lysine and 0.63%-TID-threonine treatments from the middle block of gilts in the other barn. The third barn contained five complete replications of gilts. Thus, there were 14 to 16 replications of each treatment. Diets were based on corn-soybean meal (Table 2) and were fed in meal form for 28 d. The positive-control diet was formulated with the highest TID lysine (0.80%) and second-highest TID threonine (0.58%) concentration. In formulating the remaining diets, either L-lysine HCl or L-threonine replaced corn. L-lysine HCl was added to provide 0.56, 0.64, 0.72, or 0.80% TID lysine. The diets for the threonine trial were set at 0.80% TID lysine, and crystalline L-threonine was added to obtain 0.44, 0.48, 0.53, 0.58, or 0.63% TID threonine. The values used in diet formulation were based on those published by the NRC.

Statistical Analysis

Data were analyzed as a randomized complete-block design by using the PROC MIXED procedure of SAS, with pen as the experimental unit, in Exp. 1, and as a randomized incomplete-block design in Exp. 2. Linear and quadratic polynomial contrasts were performed to determine the effects of increasing dietary lysine and threonine in both experiments.

Results and Discussion

Experiment 1

Increasing dietary TID lysine increased ADG (linear, $P<0.04$; quadratic, $P<0.06$; Table 2), with the greatest response occurring from 0.71 to 0.81% TID lysine. Increasing TID lysine increased ADFI (quadratic, $P<0.03$), with pigs fed 0.81% TID lysine having the greatest intake. Increasing TID lysine also improved F/G (linear, $P<0.01$), with the maximum response for F/G occurring at 1.01%.

Increasing dietary TID threonine did not affect ADG ($P>0.69$; Table 3) or ADFI ($P>0.29$), but did improve F/G (linear, $P<0.05$), with the best F/G occurring at 0.68% TID threonine. Using 1.01% TID lysine for F/G, this results in a TID threonine-to-lysine ratio of 67%.

Experiment 2

A treatment × gender interaction was observed for F/G ($P<0.02$; Table 4). This was because TID lysine improved F/G in gilts, whereas TID threonine improved F/G in barrows. No other interactions were observed ($P>0.10$).

Increasing TID lysine increased ADG (linear, $P<0.01$; Table 4), tended to increase ADFI (linear, $P<0.07$), and improved F/G (linear, $P<0.04$). In gilts, increasing TID lysine increased ADG (linear, $P<0.05$; Table 4) and F/G (linear, $P<0.01$), but did not affect ADFI ($P>0.49$). In barrows, increasing TID lysine tended to increase ADG (linear, $P<0.07$; Table 4) and increased ADFI (linear, $P<0.01$), but had no affect on F/G ($P>0.80$). Although the response to lysine was linear, ADG was maximized and F/G was minimized at 0.72% TID lysine in barrows and at 0.80% in gilts.

Increasing TID threonine improved ADG (linear, $P<0.01$; Table 5) and F/G (linear, $P<0.01$), but did not affect ADFI ($P>0.20$). Increasing TID threonine increased ADG (linear, $P<0.05$; Table 5) for both barrows and gilts. Increasing TID threonine tended to increase ADFI (linear, $P<0.06$) in gilts, but did not affect ADFI in barrows ($P>0.84$). Increasing TID threonine improved F/G (linear, $P<0.01$; quadratic, $P<0.08$) in barrows, but did not affect F/G in gilts ($P>0.38$). Although the response to TID threonine was linear, the greatest response to threonine occurred by increasing TID threonine from 0.43 to 0.48%. If 0.48% TID threonine and 0.72% TID lysine are used as the requirements, a TID threonine-to-lysine ratio of 67% seems optimal according to results of Exp. 2.

To further verify our threonine-to-lysine ratios, as suggested by the performance data, the range of F/G values obtained in Exp. 1 and the ADG and F/G values obtained in Exp. 2 were used in regression analysis to predict the TID lysine and threonine requirements and, thus, a ratio for different rates of ADG and F/G. Because there was no ADG response to additional threonine in Exp. 1, ADG values could not be used in the regression analysis to determine a threonine-to-lysine ratio for ADG. Figures 1 and 2 show TID lysine and threonine concentrations plotted against F/G values for Exp. 1; Figures 3, 4, 5, and 6 show TID lysine and threonine concentrations plotted against ADG and F/G values for Exp. 2. A trendline was added to each graph, resulting in a regression equation. On the basis of regression equations, a threonine-to-lysine ratio necessary to achieve a given ADG or F/G can be determined. Feed efficiency was maximized at a threonine-to-lysine ratio of 74% in Exp. 1, but more than 96% of the maximal response can be achieved by using a threonine-to-lysine ratio of 60% (Table 6). In Exp. 2, ADG is maximized at 77%, whereas F/G is maximized at 72% (Table 7). In 170- to 230-lb pigs, 95% of the maximal response can be achieved by using a threonine-to-lysine ratio of 70%.

The greater TID lysine requirement found in Exp. 1 is probably due to increased protein-deposition rates of modern genetics and because only gilts were used in this study. The greater threonine requirement found in our studies provides some validity to the proposed greater maintenance requirement for threonine of grow-finish pigs compared with that for nursery pigs and, when expressed as a ratio relative to lysine, is similar to NRC recommendations. Our data suggest that barrows respond more favorably to higher threonine concentrations than gilts do. This is reasonable, considering that barrows decrease in lean deposition rates sooner than gilts and, thus, would have a greater maintenance requirement at a similar body weight. The practical TID threonine-to-lysine ratio suggested by this study for 80- to 130-lb and 170- to 230-lb pigs is 67%, even though a statistical response to higher concentrations of threonine was observed.

Table 1. Diet Composition (Exp. 1 and 2; As-fed Basis)[a]

Item	Exp. 1[bc]	Exp. 2[d]
Ingredient, %		
Corn	74.95	81.06
Soybean meal, 46.5% CP	20.64	14.68
Choice white grease	2.00	2.00
Monocalcium phosphate, 21% P	0.40	0.40
Limestone	0.80	0.80
Salt	0.35	0.35
Vitamin premix with phytase	0.08	0.08
Trace mineral premix	0.10	0.10
L-Lysine HCl	0.38	0.30
DL-Methionine	0.13	0.08
L-Threonine	0.18	0.15
Calculated Values		
Total Lysine %	1.12	0.89
True-ileal-digestible amino acids		
Lysine, %	1.01	0.81
Isoleucine:lysine ratio %	0.59	0.60
Leucine:lysine ratio %	1.34	1.52
Methionine:lysine ratio %	0.35	0.37
Met & Cys:lysine ratio %	0.61	0.65
Threonine:lysine ratio %	0.69	0.72
Tryptophan:lysine ratio %	0.16	0.16
Valine:lysine ratio %	0.68	0.71
ME, kcal/lb	1,565	1,565
CP %	15.97	13.70
Ca %	0.47	0.45
P %	0.44	0.41
Lysine:calorie ratio, g/mcal	3.25	2.58

[a]Diets fed in meal form for 28 d.
[b]Corn replaced L-Lysine HCl to provide additional true-ileal-digestible (TID) lysine treatments (0.71, 0.81, 0.91, and 1.01%); L-threonine and corn were altered to provide additional TID threonine treatments (0.50, 0.56, 0.62, 0.68, and 0.74%).
[c]Analyzed values for diets with 0.71, 0.81, 0.91, and 1.01% TID lysine were 0.83, 0.90, 1.00, and 1.05% total lysine, respectively, and the diets containing 0.50, 0.56, 0.62, 0.68, and 0.74% TID threonine were 0.62, 0.66, 0.68, 0.73, and 0.77% total threonine, respectively.
[d]Corn replaced L-Lysine HCl, resulting in four true-ileal-digestible (TID) lysine treatments (0.56, 0.64, 0.72, and 0.80%), whereas L-threonine and corn were altered to provide the additional TID threonine treatments (0.43, 0.48, 0.53, 0.58, 0.63%).

Table 2. Effects of Increasing True-ileal-digestible (TID) Lysine in 80- to 130-lb Gilts (Exp. 1)[a]

	TID Lysine %					P-value	
Item	0.71	0.81	0.91	1.01[b]	SE	Linear	Quadratic
ADG, lb	1.58	1.76	1.72	1.73	0.060	0.04	0.06
ADFI, lb	3.91	4.12	4.05	3.91	0.105	0.78	0.03
F/G	2.49	2.34	2.36	2.26	0.049	0.01	0.47

[a]Each value is the mean of five replications with 27 ± 1 pigs (PIC 337 × C22, initially 79 lb BW) per pen.
[b]The 1.01% TID lysine treatment is also shown as the 0.68% TID threonine treatment in Table 3.

Table 3. Effects of Increasing True-ileal-digestible (TID) Threonine in 80- to 130-lb Gilts (Exp. 1)[a]

	TID Threonine %						P-value	
Item	0.50	0.56	0.62	0.68	0.74	SE	Linear	Quadratic
ADG, lb	1.69	1.65	1.67	1.73	1.68	0.060	0.69	0.85
ADFI, lb	3.97	3.84	3.84	3.91	3.81	0.105	0.29	0.61
F/G	2.35	2.33	2.30	2.26	2.27	0.049	0.05	0.77

[a]Each value is the mean of five replications with 27 ± 1 pigs (PIC 337 × C22, initially 79 lb BW) per pen.

Table 4. Effects of Increasing True-ileal-digestible (TID) Lysine in 170- to 230-lb Pigs (Exp. 2)[ab]

	TID Lysine %					P-value			
Item	0.56	0.64	0.72	0.80	SE	Linear	Quadratic	Treatment	Treatment*Sex
ADG, lb	1.89	1.90	1.99	1.97	0.038	0.01	0.52	0.01	0.14
Barrows	1.96	1.95	2.11	2.03	0.063	0.07	0.47		
Gilts	1.82	1.86	1.87	1.91	0.044	0.05	0.94		
ADFI, lb	5.74	5.76	5.86	5.86	0.081	0.60	0.10	0.07	0.83
Barrows	5.93	6.01	6.27	6.21	0.134	0.01	0.44		
Gilts	5.54	5.51	5.45	5.51	0.094	0.62	0.49		
F/G	3.06	3.03	2.96	2.98	0.040	0.01	0.02	0.02	0.42
Barrows	3.04	3.08	2.99	3.07	0.066	0.95	0.72		
Gilts	3.07	2.97	2.94	2.90	0.046	0.01	0.38		

[a]Each value is the mean of 14 to 16 replications with 24 ± 2 pigs (PIC 337 × C22, initially 170 lb BW) per pen.
[b]Each barrow or gilt value is the mean of 5 to 11 replications.

Table 5. Effects of Increasing True-ileal-digestible (TID) Threonine in 170- to 230-lb Pigs (Exp. 2)[ab]

	TID Threonine %						P-value	
Item	0.43	0.48	0.53	0.58	0.63	SE	Linear	Quadratic
ADG, lb	1.89	1.95	1.96	1.97	2.00	0.036	0.01	0.49
Barrows	1.92	2.07	2.06	2.03	2.08	0.057	0.04	0.16
Gilts	1.86	1.83	1.87	1.91	1.92	0.044	0.05	0.47
ADFI, lb	5.78	5.76	5.78	5.86	5.85	0.077	0.20	0.75
Barrows	6.15	6.18	6.15	6.21	6.16	0.121	0.87	0.84
Gilts	5.41	5.35	5.41	5.51	5.53	0.094	0.06	0.43
F/G	3.07	2.97	2.95	2.98	2.94	0.038	0.01	0.10
Barrows	3.20	3.00	3.00	3.07	2.98	0.060	0.01	0.08
Gilts	2.93	2.93	2.91	2.90	2.91	0.046	0.38	0.98

[a]Each value is the mean of 15 or 16 replications with 24 ± 2 pigs (PIC 337 × C22, initially 170 lb BW) per pen.
[b]Each barrow or gilt value is the mean of 5 to 11 replications.

Table 6. Estimation of True-ileal-digestible (TID) Lysine and Threonine Requirements, and a Threonine-to-Lysine Ratio, Based on Regression Analysis for Different Levels of Pig Performance (Exp. 1)[a]

Feed Efficiency[b]	Lysine	Threonine	Threonine-to-lysine	% of max
2.26	0.986	0.729	73.9	100
2.30	0.949	0.658	69.4	98.7
2.33	0.912	0.588	64.4	97.4
2.35	0.863	0.494	59.1	96.2

[a]The range of feed-efficiency values were plotted against TID lysine and threonine concentrations in the experiment to determine TID lysine and threonine concentrations necessary to achieve a given feed efficiency, and to calculate a TID threonine-to-lysine ratio (Exp. 1).
[b]Regression equations of $y = -1.228230891x + 3.761695692$ and $y = -2.34693878x + 6.03265306$ were used to determine lysine and threonine requirements, respectively, for the range of feed-efficiency values from Figures 1 and 2.

Table 7. Estimation of True-ileal-digestible (TID) Lysine and Threonine Requirements, and a Threonine-to-Lysine Ratio, Based on Regression Analysis for Different Levels of Pig Performance (Exp. 2)[a]

Item	Lysine	Threonine	Threonine-to-lysine	% of max
ADG, lb[b]				
1.99	0.773	0.596	77	100.0
1.95	0.702	0.523	74	98.0
1.90	0.614	0.431	70	95.5
Feed Efficiency[c]				
2.96	0.774	0.556	72	100.0
3.00	0.696	0.509	73	98.7
3.03	0.637	0.474	74	97.7
3.06	0.578	0.439	76	96.7

[a]The range of ADG and feed-efficiency values as observed in Exp. 2 were plotted against TID lysine and threonine concentrations used in the experiment to determine TID lysine and threonine concentrations necessary to achieve a given ADG or feed efficiency, and to calculate a TID threonine-to-lysine ratio (Exp. 2).
[b]Regression equations of $y = 4.078431373x - 2.898823529$ and $y = 4.16666667x - 3.16166667$ were used to determine lysine and threonine requirements, respectively, for the range of ADG values from Figures 3 and 4.
[c]Regression equations of $y = 1.765886288x - 2.741404682$ and $y = 1.84049080x - 3.06631902$ were used to determine lysine and threonine requirements, respectively, for the range of feed-efficiency values from Figures 5 and 6.

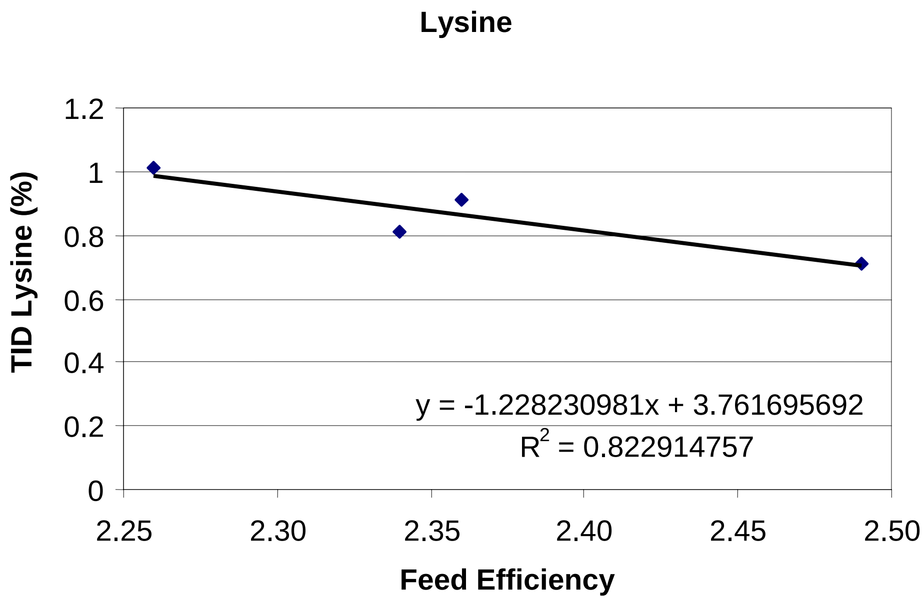

Figure 1. The Effect of Increasing True-ileal-digestible (TID) Lysine on Feed Efficiency (Exp. 1). A total of 1,070 pigs (PIC 337 × C22, initially 79 lb BW) with 27 ± 1 pigs per pen and five pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible lysine concentrations were 0.71, 0.81, 0.91, and 1.01%. The range of F/G values were plotted against TID lysine concentrations used in the experiment to determine the lysine concentration necessary to achieve a certain F/G.

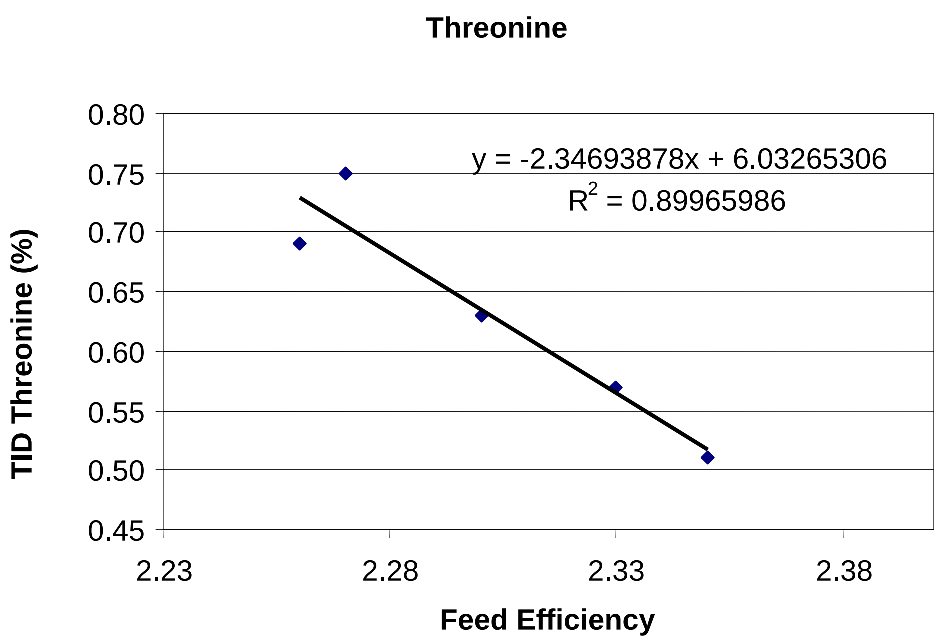

Figure 2. The Effect of Increasing True-ileal-digestible (TID) Threonine on Feed Efficiency (Exp. 1). A total of 1,070 pigs (PIC 337 × C22, initially 79 lb BW) with 27 ± 1 pigs per pen and 5 pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible threonine concentrations were 0.50, 0.56, 0.62, 0.68 and 0.74%. The range of F/G values were plotted against TID threonine concentrations used in the experiment to determine the threonine-to-lysine ratio necessary to achieve a certain F/G.

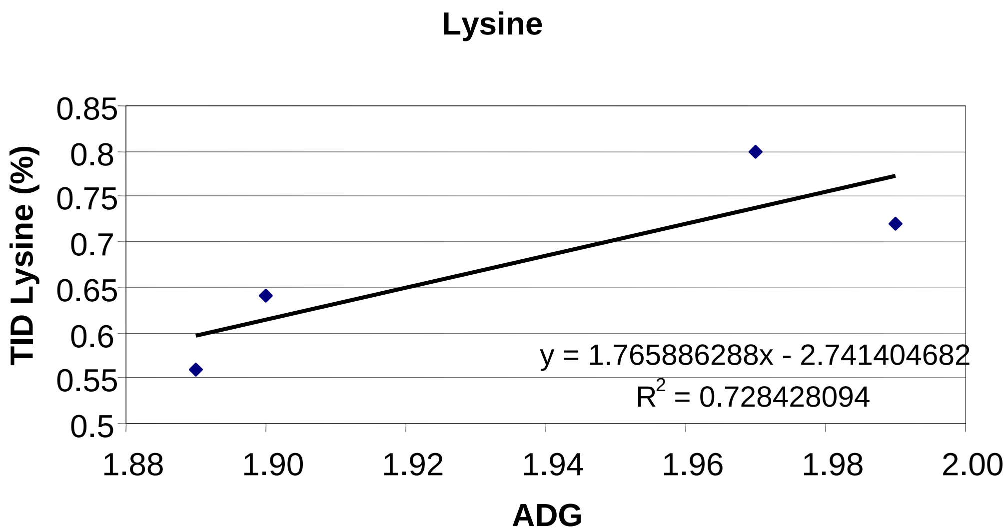

Figure 3. The Effect of Increasing True-ileal-digestible (TID) Lysine on ADG (Exp. 2). A total of 3,318 pigs (PIC 337 × C22, initially 170 lb BW) with 24 ± 2 pigs per pen and 14 to 16 pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible lysine concentrations were 0.56, 0.64, 0.72, and 0.80%. The range of ADG values were plotted against TID lysine concentrations used in the experiment to determine the lysine concentration necessary to achieve a certain ADG.

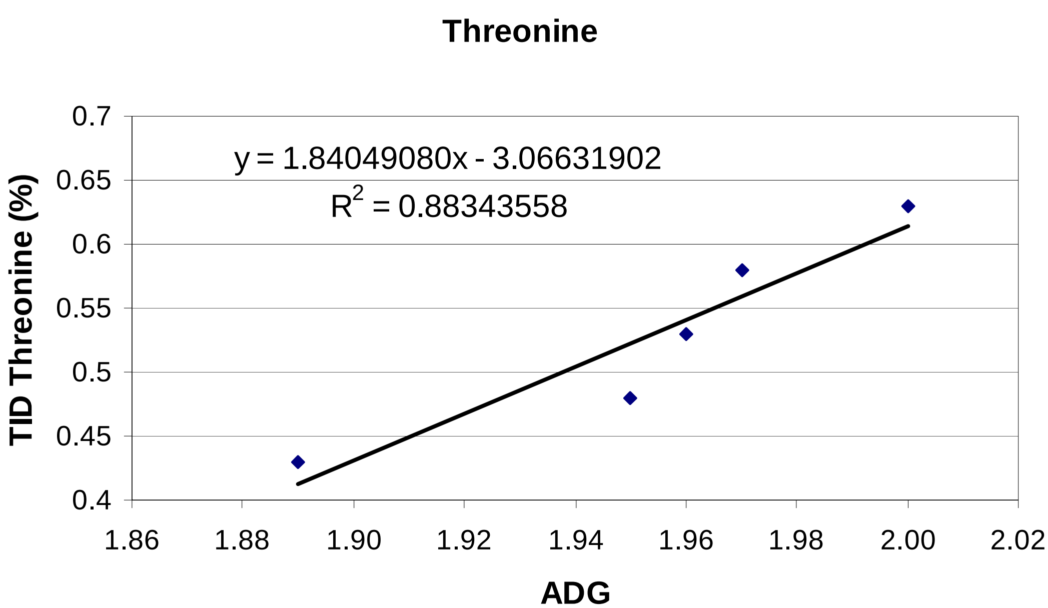

Figure 4. The Effect of Increasing True-ileal-digestible (TID) Threonine on ADG (Exp. 2). A total of 3,318 pigs (PIC 337 × C22, initially 170 lb BW) with 24 ± 2 pigs per pen and 15 or 16 pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible threonine concentrations were 0.43, 0.48, 0.53, 0.58 and 0.63%. The range of ADG values were plotted against TID threonine concentrations used in the experiment to determine the threonine-to-lysine ratio necessary to achieve a certain ADG.

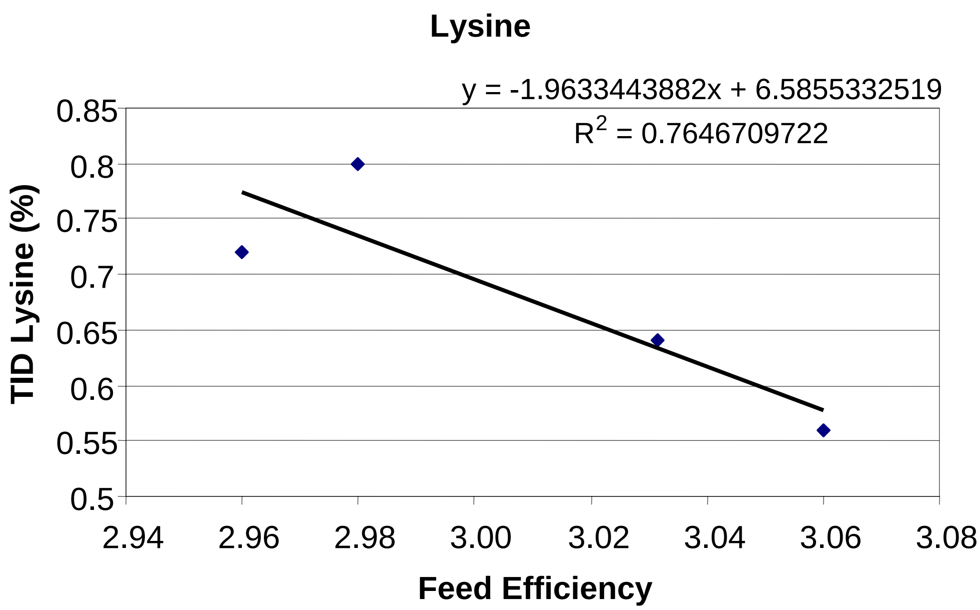

Figure 5. The Effect of Increasing True-ileal-digestible (TID) Lysine on F/G (Exp. 2). A total of 3,318 pigs (PIC 337 × C22, initially 170 lb BW) with 24 ± 2 pigs per pen and 14 to 16 pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible lysine concentrations were 0.56, 0.64, 0.72, and 0.80%. The range of F/G values were plotted against TID lysine concentrations used in the experiment to determine the lysine concentration necessary to achieve a certain F/G.

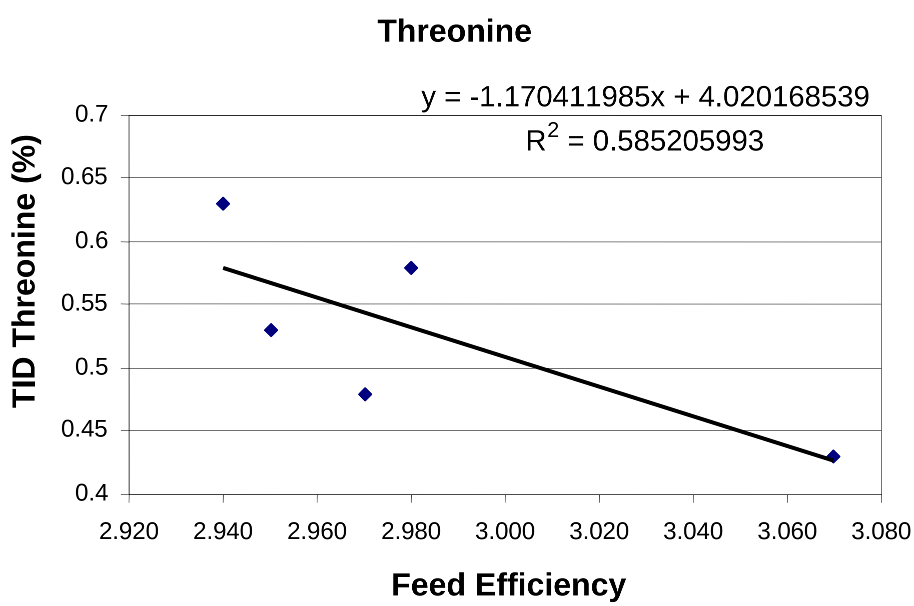

Figure 6. The Effect of Increasing True-ileal-digestible (TID) Threonine on F/G (Exp. 2). A total of 3,318 pigs (PIC 337 × C22, initially 170 lb BW) with 24 ± 2 pigs per pen and 15 or 16 pens per treatment. Experimental diets were fed for 28 d. True-ileal-digestible threonine concentrations were 0.43, 0.48, 0.53, 0.58 and 0.63%. The range of F/G values were plotted against TID threonine concentrations used in the experiment to determine the threonine-to-lysine ratio necessary to achieve a certain F/G.