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Effects of standardized ileal digestible tryptophan:lysine ratio in diets containing 30% dried distiller grains with solubles on the growth performance and carcass characteristics of finishing pigs in a commercial environment

Abstract

Two experiments were performed to determine the effects of increasing standardized ileal digestible (SID) tryptophan to lysine (trp:lys) ratio in growing-finishing pig diets containing 30% dried distillers grains with solubles (DDGS). In both experiments, soybean meal replaced crystalline lysine and threonine to alter the dietary SID trp:lys concentrations while maintaining minimum ratios of other amino acids. In Exp. 1, a total of 638 pigs (PIC 1050 x 337, initially 80.0 lb) were used in a 105-d trial with 26 to 27 pigs per pen and 6 pens per treatment. Pens of pigs were randomly allotted to 1 of 4 dietary treatments with standardized ileal digestible trp:lys ratios of 14.0, 15.0, 16.5, and 18.0%. All diets were fed in meal form and treatments were fed in 4 phases. For the overall trial, ADG and ADFI increased (linear; $P < 0.001$) as trp:lys increased through 18%; however, the response tended to be quadratic from d 0 to 42, with optimal ADG and ADFI at 16.5% SID trp:lys. Feed efficiency was not influenced by SID trp:lys ratio. Although feed cost per pig increased (linear; $P < 0.001$) as SID trp:lys ratio increased, so did (linear; $P < 0.04$) final live weight, HCW, income per pig, and income over feed cost (IOFC). The results of this experiment indicated the optimal SID trp:lys ratio was 16.5% from 80 to 160 lb, but at least 18% from 160 to 265 lb. In Exp. 2, a total of 1,214 pigs (PIC 1050 x 337, initially 146.2 lb) were used in a 73-d finishing trial with 25 to 28 pigs per pen and 9 pens per treatment. Pens of pigs were randomly allotted to 1 of 5 treatment groups. Pigs were fed common diets before the start of the experiment. Dietary treatments included corn-soybean meal-based diets with SID trp:lys ratios of 15.0, 16.5, 18.0, and 19.5, and the 15.0% diet with L-tryptophan added to achieve 18.0% SID trp:lys ratio. Overall (d 0 to 73), ADG, ADFI, F/G, final weight, and HCW improved (linear; $P < 0.03$) as dietary SID trp:lys increased through 19.5%. Increasing SID trp:lys increased (linear; $P < 0.001$) feed cost per pig, but also increased ($P < 0.01$) total income per pig. While there were no differences on an IOFC basis, pigs fed the highest level of SID trp:lys had numerically the greatest IOFC. Overall, there were no significant differences between the diet with 18.0% SID trp:lys and the diet with 15.0% SID trp:lys with added L-tryptophan to 18.0%. These experiments demonstrate there is opportunity to improve growth performance in late-finishing pigs with increased SID trp:lys ratios in diets containing high amounts of DDGS.; Swine Day, Manhattan, KS, November 18, 2010

Keywords

Swine Day, 2010; Kansas Agricultural Experiment Station contribution; no. 11-016-S; Report of progress (Kansas State University. Agricultural Experiment Station and Cooperative Extension Service); 1038; Swine; Amino acid ratio; Dried distillers grains with solubles; Lysine; Tryptophan

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Effects of Standardized Ileal Digestible Tryptophan:Lysine Ratio in Diets Containing 30% Dried Distiller Grains with Solubles on the Growth Performance and Carcass Characteristics of Finishing Pigs in a Commercial Environment¹

J. A. Barnes, M. D. Tokach, S. S. Dritz², J. M. DeRouchey, R. D. Goodband, and J. L. Nelssen

Summary

Two experiments were performed to determine the effects of increasing standardized ileal digestible (SID) tryptophan to lysine (trp:lys) ratio in growing-finishing pig diets containing 30% dried distillers grains with solubles (DDGS). In both experiments, soybean meal replaced crystalline lysine and threonine to alter the dietary SID trp:lys concentrations while maintaining minimum ratios of other amino acids. In Exp. 1, a total of 638 pigs (PIC 1050 × 337, initially 80.0 lb) were used in a 105-d trial with 26 to 27 pigs per pen and 6 pens per treatment. Pens of pigs were randomly allotted to 1 of 4 dietary treatments with standardized ileal digestible trp:lys ratios of 14.0, 15.0, 16.5, and 18.0%. All diets were fed in meal form and treatments were fed in 4 phases. For the overall trial, ADG and ADFI increased (linear; $P < 0.001$) as trp:lys increased through 18%; however, the response tended to be quadratic from d 0 to 42, with optimal ADG and ADFI at 16.5% SID trp:lys. Feed efficiency was not influenced by SID trp:lys ratio. Although feed cost per pig increased (linear; $P < 0.001$) as SID trp:lys ratio increased, so did (linear; $P < 0.04$) final live weight, HCW, income per pig, and income over feed cost (IOFC). The results of this experiment indicated the optimal SID trp:lys ratio was 16.5% from 80 to 160 lb, but at least 18% from 160 to 265 lb.

In Exp. 2, a total of 1,214 pigs (PIC 1050 × 337, initially 146.2 lb) were used in a 73-d finishing trial with 25 to 28 pigs per pen and 9 pens per treatment. Pens of pigs were randomly allotted to 1 of 5 treatment groups. Pigs were fed common diets before the start of the experiment. Dietary treatments included corn-soybean meal-based diets with SID trp:lys ratios of 15.0, 16.5, 18.0, and 19.5, and the 15.0% diet with L-tryptophan added to achieve 18.0% SID trp:lys ratio. Overall (d 0 to 73), ADG, ADFI, F/G, final weight, and HCW improved (linear; $P < 0.03$) as dietary SID trp:lys increased through 19.5%. Increasing SID trp:lys increased (linear; $P < 0.001$) feed cost per pig, but also increased ($P < 0.01$) total income per pig. While there were no differences on an IOFC basis, pigs fed the highest level of SID trp:lys had numerically the greatest IOFC. Overall, there were no significant differences between the diet with 18.0% SID trp:lys and the diet with 15.0% SID trp:lys with added L-tryptophan to 18.0%.

¹ Appreciation is expressed to New Horizon Farms for use of pigs and facilities and to Richard Brobjerg, Scott Heidebrink, and Marty Heintz for technical assistance.

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These experiments demonstrate there is opportunity to improve growth performance in late-finishing pigs with increased SID trp:lys ratios in diets containing high amounts of DDGS.

Key words: amino acid ratio, dried distillers grains with solubles, lysine, tryptophan,

Introduction

Tryptophan is one of 10 essential amino acids that is not synthesized by swine and must be supplied through diet. Today, feed alternatives to corn and soybean meal are often used by the swine industry. Determining the proper nutritional value and optimum utilization of these alternative feedstuffs, such as dried distillers grains with solubles (DDGS), is critical to reduce diet costs.

Dried distillers grains with solubles, a corn by-product from ethanol production, has approximately 3 times the crude fat, protein, and fiber as corn, with a similar energy value. Also, DDGS are known to have higher bioavailability of phosphorus than corn. Because DDGS is high in methionine and threonine, greater concentrations of crystalline lysine can be used in diets containing DDGS before other amino acids become limiting. Tryptophan is often the second limiting amino acid in diets containing high levels of DDGS.

Limited data are available on the effects of SID tryptophan level in growing-finishing pig diets containing DDGS. Also, due to the availability of synthetic tryptophan, its effects on performance also need further investigation. Therefore, the objectives of these experiments were to evaluate the SID trp:lys ratio to accurately and economically formulate growing-finishing pig diets with DDGS and crystalline amino acids.

Procedures

The Kansas State University (K-State) Institutional Animal Care and Use Committee approved the protocol used in this experiment. The experiment was conducted in a commercial research-finishing barn in southwestern Minnesota. The barns were naturally ventilated and double-curtain sided. Pens had completely slatted flooring and deep pits for manure storage. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a cup waterer for ad libitum access to feed and water. Daily feed additions to each pen were accomplished through a robotic feeding system (FeedPro; Feedlogic Corp., Willmar, MN) capable of providing and measuring feed amounts for individual pens. Pigs were fed a common corn-soybean meal-based grower diet before the start of the trial that contained DDGS.

In Exp. 1, a total of 638 pigs (PIC 1050 × 337, initially 80.0 lb) were used in a 105-d growing-finishing trial. At placement, pigs were sorted by gender (barrow or gilt) and placed in pens with 26 to 27 pigs per pen. Pens of pigs were randomly allotted to 1 of 4 treatment groups with average pig weight balanced across treatments and 6 pens per treatment (3 pens of gilts and 3 pens of barrows per treatment). Dietary treatments included corn-soybean meal-based diets containing 30% DDGS, with soybean meal replacing crystalline lysine and threonine to make SID trp:lys ratios of 14.0, 15.0, 16.5, and 18.0% (Tables 1 and 2). All diets were fed in meal form and treatments were fed in all 4 phases.

Pens of pigs were weighed and feed intake was recorded on d 0, 21, 42, 63, 76, 95, and 105. From these data, ADG, ADFI, and F/G were calculated. On d 76 of the experiment, the 3 heaviest pigs from each pen (determined visually) were weighed and sold in accordance with the farm's normal marketing procedure. At the end of the experiment, pigs were individually tattooed according to gender and pen number to allow for carcass data collection and data retrieval by pen. Pigs were transported to JBS Swift and Company (Worthington, MN) for processing and data collection. Hot carcass weights were measured immediately after evisceration, and standard carcass criteria of percent yield, HCW, percentage lean, backfat depth, loin depth, and fat-free lean index were collected.

In Exp. 2, a total of 1,214 pigs (PIC 1050 × 337, initially 146.2 lb) were used in a 73-d finishing trial. Pens were mixed gender with 25 to 28 pigs per pen, with barrows and gilts approximately equal in number within pens. Pens of pigs were randomly allotted to 1 of 5 treatment groups with average pig weight balanced across treatments, 9 pens per treatment. Pigs were fed common diets during the first two phases from approximately 80 to 146 lb. These diets were formulated to contain 18% SID trp:lys (Table 3). Dietary treatments included corn-soybean meal-based diets with SID trp:lys ratios of 15.0, 16.5, 18.0, 19.5% and the 15.0% diet with L-tryptophan added to achieve 18.0% SID trp:lys (Tables 3 and 4).

Pens of pigs were weighed and feed intake was recorded on d 0, 20, 33, 47, 62, and 73. From these data, ADG, ADFI, and F/G were calculated. On d 47 of the experiment, the 3 heaviest pigs from each pen (2 barrows and 1 gilt, determined visually) were weighed and sold in accordance with the farm's normal marketing procedure. At the end of the experiment, pigs were individually tattooed according to pen number to allow for carcass data collection and data retrieval by pen. Pigs were transported to JBS Swift and Company (Worthington, MN) for processing and data collection. Hot carcass weights were measured immediately after evisceration, and standard carcass criteria of percent yield, HCW, percentage lean, backfat depth, loin depth, and fat-free lean index were collected.

Statistical analysis was performed by analysis of variance using the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Data were analyzed as a completely randomized design with pen as the experimental unit. The main effects of the treatment were determined in both experiments. In Exp. 1, the effect of gender and gender by treatment interactions were also tested. Backfat depth, loin depth, percentage lean, and fat-free lean index were adjusted to a common carcass weight. Linear and quadratic contrasts were used to determine the effects of treatments with increasing trp:lys. In Exp. 1, contrast coefficients for trp:lys percents (18.0, 16.5, 15.0, 14.0) were determined for unequally spaced treatments by using the IML procedure of SAS. In Exp. 2, contrast coefficients for trp:lys ratios (19.5, 18.0, 16.5, 15.0) and contrasts to compare the 18.0 and 15.0% with L-trp to 18.0% were used.

Results and Discussion

In Exp. 1, gender differences in growth performance were as expected, with barrows having greater ($P < 0.001$) ADG and ADFI than gilts (Table 5). Both barrows and gilts had improved ADG as SID trp:lys increased; however, the magnitude of the response was slightly greater for gilts than barrows (gender × treatment interaction $P < 0.05$).

Gilt carcasses had lower ($P < 0.001$) backfat depth and greater ($P < 0.001$) percentage lean and fat-free lean index than barrow carcasses. Because of numerically improved F/G and lighter final weight, gilts had lower ($P < 0.001$) feed cost per pig; however, barrows had greater ($P < 0.02$) income per pig due to the heavier final weight, leading to similar income over feed cost.

From d 0 to 42, increasing SID trp:lys ratio increased ADG (linear; $P < 0.001$) and ADFI (linear; $P < 0.003$). These responses also tended to be quadratic ($P < 0.07$), with no improvement in ADG, ADFI, or weight on d 42 above a SID trp:lys ratio of 16.5%.

From d 42 to 105, increasing SID trp:lys ratio increased (linear; $P < 0.001$) ADG and ADFI. Unlike the data from d 0 to 42, the response was clearly linear through the highest SID trp:lys ratio of 18.0%. There was a tendency for a quadratic effect in F/G ($P < 0.08$) of increasing SID trp:lys ratio, with pigs fed 15.0 and 16.5% having numerically worse F/G than pigs fed either 14.0 or 18.0%.

Overall (d 0 to 105), increasing SID trp:lys increased (linear; $P < 0.001$) final BW, ADG, and ADFI. Because of the improvement in ADG, pigs fed increasing SID trp:lys had heavier (linear; $P < 0.002$) HCW.

Because of linear increases in ADFI and diet cost, increasing the SID trp:lys ratio increased (linear; $P < 0.02$) feed cost per pig and feed cost per gain. Because of the ADG response, increasing SID trp:lys ratio increased (linear; $P < 0.04$) income per pig and IOFC.

In Exp. 2, increasing the dietary SID trp:lys ratio increased final BW (linear; $P < 0.02$), overall ADG (linear; $P < 0.001$), and ADFI (linear; $P < 0.03$; Table 6)). Additionally, increasing the dietary SID trp:lys ratio improved (linear; $P < 0.01$) F/G. For carcass traits, increasing SID trp:lys resulted in increased HCW (linear; $P < 0.01$) and a tendency for a quadratic effect ($P < 0.09$) for backfat depth and percentage lean, with pigs fed diets containing 16.5 and 18.0% SID trp:lys having increased percentage lean and lower backfat depth compared to pigs fed 15.0 and 19.5% SID trp:lys. Additionally, there was also a tendency for pigs fed the crystalline tryptophan diet to have increased ($P < 0.09$) backfat depth and decreased FFLI ($P < 0.08$) compared to pigs fed the same SID trp:lys ratio without crystalline tryptophan.

Because of high feed intake, increasing SID trp:lys resulted in increased (linear; $P < 0.001$) feed cost per pig, but did not change feed cost per lb of gain. Increasing SID trp:lys increased ($P < 0.01$) total income per pig. While there were no statistical differences in IOFC, pigs fed the highest level of SID trp:lys had the numerically highest IOFC. Overall, there were no significant differences between pigs fed the diet with 18.0% SID trp:lys and pigs fed the diet with 15.0% SID trp:lys with added L-tryptophan to 18.0%.

In conclusion, these results suggest there is opportunity to improve growth performance in late-finishing pigs with increasing SID try:lys ratio. In both experiments, feeding a high-SID trp:lys ratio resulted in greater final BW, ADG, and ADFI, with a tendency for improved HCW. Finally, feeding L-tryptophan to finishing pigs resulted in similar growth performance to pigs fed a diet formulated to the same SID trp:lys ratio without L-tryptophan.

Table 1. (Exp. 1) Phase 1 and 2 diet composition (as-fed basis)¹

Item	Phase 1				Phase 2			
	Trp:Lys ratio, %				Trp:Lys ratio, %			
	14.0	15.0	16.5	18.0	14.0	15.0	16.5	18.0
Ingredient, %								
Corn	57.34	55.79	53.23	50.79	59.49	57.93	55.72	53.46
Soybean meal, 46.5% CP	10.30	11.96	14.69	17.26	8.19	9.85	12.22	14.60
DDGS ²	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Limestone	1.15	1.14	1.12	1.10	1.17	1.16	1.14	1.12
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
L-threonine	0.07	0.04	---	---	0.06	0.04	---	---
L-tryptophan	---	---	---	---	---	---	---	---
Liquid lysine	0.68	0.61	0.50	0.39	0.64	0.57	0.47	0.37
Phytase ³	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis								
Standardized ileal digestible (SID) amino acids, %								
Lysine	0.95	0.95	0.95	0.95	0.87	0.87	0.87	0.87
Isoleucine:lysine	60	63	67	72	61	64	69	73
Leucine:lysine	174	178	185	191	184	189	195	202
Methionine:lysine	30	31	32	34	32	33	34	35
Met & Cys:lysine	61	63	66	68	65	66	69	72
Threonine:lysine	62	62	62	65.62	64.08	64.45	63.68	67.46
Tryptophan:lysine	14.0	15.0	16.5	18.0	14.0	15.0	16.5	18.0
Valine:lysine	0.74	0.77	0.82	0.86	0.77	0.80	0.84	0.89
Total lysine, %	1.10	1.11	1.11	1.12	1.02	1.02	1.03	1.03
ME, kcal/lb	1,525	1,525	1,525	1,525	1,525	1,525	1,525	1,525
SID Lysine:ME ratio, g/Mcal	2.83	2.83	2.83	2.83	2.59	2.59	2.59	2.59
CP, %	17.87	18.49	19.52	20.50	17.07	17.69	18.58	19.49
Ca, %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
P, %	0.44	0.45	0.46	0.47	0.44	0.44	0.45	0.46
Available P, %	0.32	0.32	0.32	0.32	0.28	0.28	0.28	0.28

¹ Phase 1 diets were fed from approximately 80 to 120 lb; Phase 2 diets were fed from 120 to 160 lb.

² Dried distillers grains with solubles from Vera-Sun (Aurora, SD).

³ OptiPhos 2000 (Enzyvia LLC, Sheridan, IN).

Table 2. (Exp. 1) Phase 3 and 4 diet composition (as-fed basis)¹

Item	Phase 3				Phase 4			
	Trp:Lys ratio, %				Trp:Lys ratio, %			
	14.0	15.0	16.5	18.0	14.0	15.0	16.5	18.0
Ingredient, %								
Corn	61.99	60.64	58.53	56.51	64.43	63.20	61.43	59.51
Soybean meal, 46.5%	5.79	7.22	9.47	11.61	3.41	4.71	6.61	8.63
DDGS ²	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Limestone	1.14	1.14	1.12	1.10	1.15	1.14	1.12	1.11
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
L-threonine	0.05	0.03	---	---	0.05	0.03	---	---
L-tryptophan	---	---	---	---	---	---	---	---
Liquid lysine	0.59	0.53	0.43	0.34	0.54	0.48	0.40	0.32
Phytase ³	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.002
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis								
Standardized ileal digestible (SID) amino acids, %								
Lysine	0.78	0.78	0.78	0.78	0.69	0.69	0.69	0.69
Isoleucine:lysine	63	66	71	75	65	69	73	78
Methionine:lysine	34	35	36	38	37	38	39	40
Met & cys:lysine	69	71	74	76	75	77	79	82
Threonine:lysine	66	66	66	70	69	69	69	73
Tryptophan:lysine	14.0	15.0	16.5	18.0	14.0	15.0	16.5	18.0
Valine:lysine	80.48	83.54	88	93	85	88	93	98
Total lysine, %	0.92	0.92	0.93	0.94	0.83	0.83	0.83	0.84
ME, kcal/lb	1,526	1,526	1,526	1,526	1,526	1,526	1,526	1,526
SID Lysine:ME ratio, g/Mcal	2.32	2.32	2.32	2.32	2.05	2.05	2.05	2.05
CP, %	16.16	16.69	17.54	18.36	15.25	15.74	16.45	17.23
Ca, %	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
P, %	0.43	0.43	0.44	0.45	0.42	0.42	0.43	0.44
Available P, %	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23

¹ Phase 3 diets were fed from approximately 160 to 200 lb; Phase 4 diets were fed from 200 to 240 lb.

² Dried distillers grains with solubles from Vera-Sun (Aurora, SD).

³ OptiPhos 2000 (Enzyvia LLC, Sheridan, IN).

Table 3. Phase 1, 2, and 3 diet composition (Exp. 2 as-fed basis)¹

Ingredient, %	Phase 1	Phase 2	Phase 3				
			Trp:Lys ratio, %				15.0 to 18.0 and L-trp
			15.0	16.5	18.0	19.5	
Corn	51.50	54.09	60.71	58.66	56.58	54.51	60.68
Soybean meal, 46.5%	16.42	13.84	7.05	9.26	11.46	13.67	7.05
DDGS ²	30.00	30.00	30.00	30.00	30.00	30.00	30.00
Limestone	1.12	1.14	1.14	1.12	1.10	1.08	1.14
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.10	0.10	0.09	0.09	0.09	0.09	0.09
L-threonine	---	---	0.03	---	---	---	0.03
L-tryptophan	---	---	---	---	---	---	0.02
Biolys ³	0.50	0.47	0.63	0.52	0.41	0.30	0.63
Phytase ⁴	0.01	0.01	0.003	0.003	0.003	0.003	0.003
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Standardized ileal digestible (SID) amino acids, %							
Lysine	0.95	0.87	0.78	0.78	0.78	0.78	0.78
Isoleucine:lysine	71	72	66	71	75	80	66
Methionine:lysine	33	35	35	36	37	39	35
Met & cys:lysine	68	71	71	74	77	79	71
Threonine:lysine	65	66	65	66	70	74	65
Tryptophan:lysine	18	18	15	16	18	19	18
Valine:lysine	85	88	84	88	93	98	84
Total lysine, %	1.12	1.03	0.92	0.93	0.94	0.94	0.92
ME, kcal/lb	1,526	1,526	1,528	1,527	1,527	1,526	1,528
SID Lysine:ME, g/Mcal	2.82	2.59	2.32	2.32	2.32	2.32	2.32
CP, %	20.55	19.55	17.09	17.84	18.61	19.38	17.11
Ca, %	0.51	0.51	0.48	0.48	0.48	0.48	0.48
P, %	0.47	0.46	0.43	0.44	0.45	0.46	0.43
Available P, %	0.33	0.27	0.24	0.24	0.25	0.25	0.24

¹ Phase 1 and 2 common diets were fed from 80 to 150 lb; Phase 3 diets were fed from 150 to 200 lb.

² Dried distillers grains with solubles from Vera-Sun (Aurora, SD).

³ Biolys contains 50.7% L-lys (Evonik Degussa GmbH, Hanau, Germany).

⁴ OptiPhos 2000 (Enzyvia LLC, Sheridan, IN).

Table 4. Phase 4 and 5 diet composition (Exp. 2 as-fed basis)¹

Ingredient, %	Phase 4					Phase 5				
	Trp:Lys ratio, %					Trp:Lys ratio, %				
	15.0	16.5	18.0	19.5	15.0 to 18.0 and L-trp	15.0	16.5	18.0	19.5	15.0 to 18.0 and L-trp
Corn	63.26	61.48	59.59	57.80	63.24	69.33	66.83	64.47	62.13	69.30
Soybean meal, 46.5%	4.58	6.48	8.49	10.39	4.58	13.13	15.79	18.35	20.85	13.14
DDGS	30.00	30.00	30.00	30.00	30.00	15.00	15.00	15.00	15.00	15.00
Limestone	1.13	1.12	1.10	1.08	1.13	1.10	1.12	1.10	1.08	1.10
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
DL-methionine	---	---	---	---	---	0.02	0.01	---	---	0.02
L-threonine	0.02	---	---	---	0.02	0.10	0.07	0.03	---	0.10
L-tryptophan	---	---	---	---	0.02	---	---	---	---	0.03
Biolys ²	0.58	0.48	0.38	0.29	0.58	0.65	0.52	0.39	0.27	0.65
Optiphos 2000 ³	0.002	0.002	0.002	0.002	0.002	0.01	0.01	0.01	0.01	0.01
Ractopamine HC, 9 g/lb ⁴	---	---	---	---	---	0.23	0.23	0.23	0.23	0.23
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Standardized ileal digestible (SID) amino acids, %										
Lysine	0.69	0.69	0.69	0.69	0.69	0.90	0.90	0.90	0.90	0.90
Isoleucine:lysine	68	73	78	83	68	60	65	69	74	60
Methionine:lysine	38	39	40	42	38	30	31	31	32	30
Met & cys:lysine	77	80	83	85	77	60	62	64	66	60
Threonine:lysine	68	69	73	77	68	66	66	65	66	66
Tryptophan:lysine	15	16	18	19	18	15	17	18	20	18
Valine:lysine	89	93	98	103	89	73	77	82	87	73
Total lysine, %	0.83	0.83	0.84	0.84	0.83	1.02	1.03	1.04	1.04	1.02
ME, kcal/lb	1,528	1,528	1,527	1,527	1,528	1,524	1,523	1,522	1,521	1,524
SID Lysine:ME, g/Mcal	2.05	2.05	2.05	2.05	2.05	2.68	2.68	2.68	2.68	2.68
CP, %	16.11	16.76	17.46	18.12	16.12	16.65	17.54	18.40	19.26	16.67
Ca, %	0.47	0.47	0.47	0.47	0.47	0.49	0.50	0.50	0.50	0.49
P, %	0.42	0.43	0.44	0.45	0.42	0.39	0.40	0.41	0.42	0.39
Available P, %	0.23	0.23	0.24	0.24	0.23	0.21	0.21	0.21	0.21	0.21

¹ Phase 4 diets were fed from 200 to 240 lb; Phase 5 diets were fed from 240 to 280 lb.

² Biolys contains 50.7% L-lys (Evonik Degussa GmbH, Hanau, Germany).

³ OptiPhos 2000 (Enzyvia LLC, Sheridan, IN).

⁴ Ractopamine HCl (Paylean, Elanco Animal Health, Greenfield, IN) at 9.0 g/ton was added.

Table 5. Effects of increasing tryptophan:lysine ratio on growth performance of growing-finishing pigs (Exp. 1)^{1,2}

Item	Trp:Lys ratio, %				TRT SEM	Gender		Gender SEM	Probability, <i>P</i> <		
	14.0	15.0	16.5	18.0		Barrows	Gilts		Gender	Linear	Quadratic
Initial wt, lb	79.8	80.1	80.2	80.0	1.95	79.7	80.4	1.13	0.69	0.96	0.89
d 42 wt, lb	152.2	157.4	161.7	161.6	2.67	157.3	157.0	1.54	0.90	0.01	0.23
Final wt, lb	258.5	265.5	275.6	286.0	2.97	276.1	266.7	2.10	0.006	<0.001	0.99
d 0 to 42											
ADG, lb	1.72	1.84	1.94	1.93	0.038	1.88	1.84	0.027	0.26	0.001	0.06
ADFI, lb	3.96	4.43	4.50	4.56	0.114	4.42	4.30	0.081	0.28	0.003	0.07
F/G	2.30	2.41	2.32	2.36	0.053	2.35	2.34	0.04	0.86	0.80	0.67
d 42 to 105											
ADG, lb	1.76	1.80	1.88	2.01	0.023	1.93	1.80	0.016	<0.001	<0.001	0.18
ADFI, lb	5.71	6.07	6.38	6.65	0.110	6.51	5.90	0.078	<0.001	<0.001	0.40
F/G	3.24	3.37	3.39	3.31	0.063	3.38	3.28	0.045	0.12	0.55	0.10
d 0 to 105											
ADG, lb	1.75	1.82	1.91	1.98	0.016	1.91	1.81	0.012	<0.001	<0.001	0.43
ADFI, lb	4.98	5.39	5.60	5.77	0.106	5.64	5.23	0.075	0.002	<0.001	0.16
F/G	2.85	2.97	2.94	2.92	0.050	2.96	2.88	0.035	0.16	0.53	0.21
Carcass characteristics											
Carcass yield, %	73.9	73.6	73.8	73.8	0.29	73.5	74.1	0.25	0.10	0.93	0.72
HCW, lb	191.7	195.6	206.0	209.6	3.75	204.4	197.0	2.29	0.03	0.002	0.60
Backfat depth, in ³	0.67	0.67	0.59	0.58	0.04	0.71	0.56	0.01	<0.001	0.63	0.86
Loin depth, in ³	2.45	2.43	2.43	2.43	0.03	2.4	2.4	0.03	0.41	0.11	0.79
Lean, % ³	55.9	55.9	57.2	57.3	0.68	55.0	57.7	0.19	<0.001	0.77	0.89
Fat-free lean index ³	50.3	50.4	51.3	51.4	0.51	49.6	51.7	0.14	<0.001	0.71	0.63
Economics ⁴											
Feed cost/pig, \$	43.04	46.70	51.13	51.18	1.041	50.37	45.66	0.637	<0.001	<0.001	0.01
Feed cost/lb gain, \$	0.221	0.231	0.238	0.233	0.005	0.24	0.23	0.003	0.02	0.02	0.04
Income/pig, \$ ⁵	123.44	125.95	132.64	134.97	2.413	131.65	126.85	1.418	0.02	<0.001	0.60
IOFC ⁶	80.40	79.25	81.51	83.79	2.630	81.33	81.20	1.117	0.95	0.04	0.38

¹ A total of 638 pigs (PIC 1050 × 337, initially 80.0 lb) were used in a 105-d growing-finishing trial with 26 to 27 pigs per pen and 6 pens per treatment.

² Includes pigs that died, were culled, topped, and were pulled off test during the experiment.

³ Carcass characteristics other than yield percentage were adjusted by using hot carcass weight as a covariate.

⁴ Diet cost was based on corn at \$3.50/bu; 46.5% soybean meal at \$300/ton; DDGS at \$120/ton; Biolys at \$0.50/lb; and L-tryptophan at \$15.00/lb.

⁵ Value was determined by using a base carcass price of \$64.40/cwt.

⁶ Income over feed cost = value of pig - feed costs during trial period.

Table 6. Effects of increasing tryptophan:lysine ratio on growth performance and carcass characteristics of finishing pigs (Exp. 2)^{1,2}

	Trp:Lys, %					SEM	Probability, <i>P</i> <		
	15.0	16.5	18.0	19.5	L-trp to 18.0		Linear	Quadratic	18.0 vs. L-trp to 18.0
Initial wt, lb	146.2	146.4	146.0	146.1	146.3	3.26	0.96	0.99	0.96
D 0 to 73									
ADG, lb	1.62	1.67	1.73	1.79	1.71	0.024	<0.001	0.86	0.54
ADFI, lb	5.33	5.35	5.53	5.57	5.39	0.088	0.03	0.91	0.26
F/G	3.30	3.21	3.20	3.11	3.15	0.042	0.01	0.98	0.39
Final wt, lb	260.6	264.5	270.5	272.9	267.3	3.88	0.02	0.86	0.57
Carcass characteristics									
Farm yield, %	74.8	74.9	73.8	75.3	74.1	0.40	0.76	0.08	0.59
Carcass yield, %	75.3	75.5	75.1	75.0	75.0	0.42	0.52	0.67	0.86
HCW, lb	194.9	198.0	199.6	205.4	198.1	2.77	0.01	0.62	0.71
Backfat depth, in ³	0.62	0.60	0.59	0.63	0.63	0.02	0.96	0.09	0.09
Loin depth, in ³	2.31	2.38	2.31	2.32	2.34	0.03	0.80	0.29	0.39
Lean, % ³	56.1	57.0	56.4	56.3	56.4	0.29	0.96	0.08	0.86
Fat-free lean index ³	50.9	51.1	51.3	51.1	50.8	0.19	0.98	0.07	0.08
Economics ⁴									
Feed cost/pig,\$	32.16	33.15	35.14	36.61	34.68	0.562	<0.001	0.67	0.57
Feed cost/lb gain,\$	0.275	0.277	0.280	0.282	0.282	0.004	0.22	1.00	0.90
Income/pig, \$ ⁵	142.07	144.27	145.67	149.41	144.42	2.032	0.01	0.71	0.66
IOFC ⁶	109.91	111.12	110.53	112.80	109.74	1.706	0.30	0.76	0.75

¹ A total of 1,214 pigs (PIC 1050 × 337, initially 146.2 lb) were used in a 73-d finishing trial, with 25 to 28 pigs per pen and 9 pens per treatment.

² Includes pigs that died, were culled, and were pulled off test during the experiment.

³ Carcass characteristics other than yield percentage were adjusted by using hot carcass weight as a covariate.

⁴ Diet cost was based on corn at \$3.50/bu; 46.5% soybean meal at \$300/ton; DDGS at \$120/ton; Biolys at \$0.50/lb; and L-tryptophan at \$15.00/lb.

⁵ Value was determined by using a base carcass price of \$72.90/cwt.

⁶ Income over feed cost = value of pig - feed costs during trial period.