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Evaluation of SID Lys:CP Ratios for 14 to 25 lb Pigs Through the Use of Diammonium Phosphate as a Non-Protein Nitrogen Source

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Summary

A total of 360 barrows (DNA 200 × 400; initially 13.7 ± 0.09 lb) were used in a 32-d study to evaluate the effect of standardized ileal digestible lysine to crude protein (SID Lys:CP) ratios for 14 to 25 lb pigs in diets containing diammonium phosphate (DAP) as a non-protein nitrogen source. Pens of pigs were randomly allotted to one of six dietary treatments in a generalized randomized block design with BW as a blocking factor. There were four replications for each treatment within each BW block of light pigs (initially 12.3 ± 0.09 lb), medium pigs (initially 13.6 ± 0.09 lb), and heavy pigs (initially 15.2 ± 0.09 lb). There were five pigs per pen and 12 pens per treatment. Diets were corn-soybean meal-based with titrated amounts of diammonium phosphate (1.93, 1.51, 1.10, 0.72, 0.35, and 0%) resulting in SID Lys:CP ratios of 6.41, 6.57, 6.73, 6.89, 7.05, and 7.21%, respectively. Treatment diets were fed in one phase from d 0 to 18 (14 to 25 lb) followed by a common diet from d 18 to 32. On d 18, fecal samples were collected from three randomly selected pigs in each pen to determine fecal DM, and a blood sample was collected after a 12-h fasting period from one randomly selected pig in each pen to measure serum urea nitrogen. From d 0 to 18, decreasing the SID Lys:CP ratio through increased DAP decreased ADG, ADFI, and d 18 BW (linear, $P \leq 0.029$). Feed efficiency (F/G) tended to improve (linear, $P = 0.082$) as the SID Lys:CP ratio decreased. During the common period from d 18 to 32, no treatment differences were observed for ADG, ADFI, or F/G. However, decreasing SID Lys:CP ratio with increased addition of DAP tended to decrease d 32 BW (linear, $P = 0.053$). Overall, from d 0 to 32, decreasing SID Lys:CP ratio with increased DAP tended to decrease ADG (linear, $P = 0.056$) and decreased ADFI (linear, $P = 0.039$) but did not affect F/G. Decreasing SID Lys:CP ratio with DAP addition increased serum BUN (linear, $P < 0.001$) and decreased fecal DM (linear, $P = 0.028$). In conclusion, decreasing the SID Lys:CP ratio by increasing DAP as a non-protein nitrogen source decreased ADG and ADFI during the experimental period, which may have been caused by reduced diet palatability from the DAP addition. Additionally, fecal DM decreased as the SID Lys:CP ratio decreased, potentially due to the associated increase in dietary CP.

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Similarly, serum BUN increased with decreasing SID Lys:CP ratio, likely reflecting the higher CP concentration of the diets.

Introduction

Low-protein, amino acid-fortified diets are commonly used in swine production to reduce dietary crude protein, nitrogen excretion, and potentially diet cost. However, when crude protein is reduced too much, nitrogen may become limiting for the synthesis of non-essential amino acids, which can negatively affect growth performance. Therefore, the standardized ileal digestible lysine to crude protein (SID Lys:CP) ratio is a useful indicator of whether diets provide sufficient nitrogen relative to lysine. Based on calculations made from the NRC[2] requirement estimates for SID Lys and total N, an SID Lys:CP ratio of 6.59% is suggested for pigs weighing 15 to 25 lb.

Previous research has evaluated SID Lys:CP ratios in heavier pigs by titrating soybean meal inclusion. In those studies, reducing CP through lower soybean meal inclusion and greater use of feed-grade AA negatively affected growth performance when nitrogen became limiting. Similarly, Smallfield et al.[3] observed reduced growth performance in 25 to 55 lb pigs fed diets low in soybean meal and high in synthetic AA compared with pigs fed diets in which an SID Lys:CP ratio near 6.5% was achieved through increased soybean meal inclusion or the addition of another nitrogen source, either glycine or diammonium phosphate (DAP). This suggests that both the source and amount of nitrogen used to achieve a specific SID Lys:CP ratio may influence pig performance.

Although SID Lys:CP ratios have been evaluated in heavier pigs, this relationship has not been well defined in pigs weighing 15 to 25 lb. Additionally, no studies have evaluated SID Lys:CP ratios in this weight range using DAP as the titrated non-protein nitrogen source. Therefore, the objective of this study was to determine the effects of increasing SID Lys:CP ratio by decreasing DAP inclusion on growth performance, fecal dry matter, and serum blood urea nitrogen of pigs weighing 15 to 25 lb.

Procedures

Animals and diets

The protocol used in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. This study was conducted at the Kansas State University Segregated Early Weaning facility in Manhattan, KS. The facility has two identical barns that are completely enclosed, environmentally controlled, and mechanically ventilated. Each pen contained a 4-hole, dry self-feeder and a cup waterer for ad libitum access to feed and water. Pens (4 4 ft) had metal tri-bar floors and allowed approximately 2.7 ft^2/pig.

A total of 360 barrows (DNA 200 × 400; initially 13.7 ± 0.09 lb) were used in a 32-d growth trial. Pigs were weaned at approximately 21 d of age and blocked by initial weight. Treatments were assigned in a generalized randomized block design. Pigs were

[2] Nutrient requirements of swine: Eleventh revised edition. 2012. National Academies Press, Washington, D.C. Available from: http://www.nap.edu/catalog/13298.

[3] Smallfield, J. L., M. D. Tokach, K. N. Gaffield, R. D. Goodband, J. C. Woodworth, J. M. DeRouchey, J. T. Gebhardt, K. D. Haydon, A. J. Warner, C. W. Hastad, D. J. Shawk, N. C. Gainey, H. S. Cemin, and J. A. Soto. 2026. Effects of standardized ileal digestible lysine:crude protein ratio and the use of non-protein nitrogen on growth performance of 11- to 25-kg pigs. J. Anim. Sci. 104:skag013. doi:10.1093/jas/skag013.

blocked into light (initially 12.3 ± 0.09 lb), medium (initially 13.6 ± 0.09 lb), and heavy (initially 15.2 ± 0.09 lb) groups. There were five pigs per pen, and within each block, there were four pens per treatment (two pens per weight group in each barn) for a total of 12 replications per treatment. Pens of pigs were randomly allotted to one of six dietary treatments. Diets were corn-soybean meal-based and formulated to the same SID Lys level at 1.26%, below the requirement estimate, so that performance responses reflect the availability of nitrogen. Treatments were formed by titrating diammonium phosphate (1.93, 1.51, 1.10, 0.72, 0.35, and 0%) resulting in SID Lys:CP ratios of 6.41, 6.57, 6.73, 6.89, 7.05, and 7.21%, respectively (Table 1). Diammonium phosphate was used to titrate the CP content of the treatments while keeping soybean meal constant and considering the P contained in the DAP. Additionally, sand was used to equalize NE of the diets due to treatment differences in added DAP, monocalcium phosphate, and calcium carbonate between treatment diets. Dietary additions of feed-grade AA were held constant in all diets, and they met or exceeded AA requirements in relation to Lys for Ile, Met and Cys, Thr, Trp, and Val. Diet samples were analyzed in duplicate at the University of Missouri Agricultural Experiment Station Chemical Laboratories (Columbia, MO) for AA profile and N content at the Kansas State University Swine Laboratory (Table 2). Pigs were fed a common pelleted starter diet for 4 d after weaning until they reached approximately 14 lb. Treatment diets were fed in one phase from d 0 to 18 followed by a common phase corn-soybean meal-based diet until d 32 of the trial. Treatment diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center in Manhattan, KS, and fed in meal form.

Measurements and sampling

Pig weights and feed disappearance were measured on d 0, 7, 14, 18, 25, and 32 to determine ADG, ADFI, and feed efficiency. Feces were collected on d 18 from the same three randomly selected pigs in each pen for fecal dry matter (DM) analysis. Fecal samples were dried at 131°F in a forced-air oven for 48 h, and the ratio of dried-to-wet fecal weight determined the fecal dry matter. Additionally, 10 mL of blood was collected via jugular venipuncture from one randomly selected pig per pen after a 12-h fasting period for serum urea nitrogen analysis. Serum urea nitrogen concentrations were determined using the Urea Nitrogen Colorimetric Detection Kit (Arbor Assays, Ann Arbor, MI).

Statistical analysis

Data were analyzed as a generalized randomized block design as a one-way ANOVA using the lmer function from the lme4 package in R Studio (Version 3.5.2, R Core Team, Vienna, Austria) with pen serving as the experimental unit, and dietary treatment and weight block (which incorporated barn) as fixed effects. Fecal DM data were analyzed in a similar manner with pen included as a random effect to account for subsampling. Blood urea nitrogen data were analyzed similarly with plate serving as a random effect to account for plate-to-plate variation. Linear, quadratic, and cubic contrasts were tested within increasing SID Lys:CP ratios. Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $0.05 < P$ 0.10.

Results and Discussion

Growth performance

From d 0 to 18, reducing the SID Lys:CP ratio through increased DAP reduced (linear, $P \leq 0.029$) ADG and ADFI (Table 3). Additionally, F/G tended to improve (linear, $P = 0.082$) as the SID Lys:CP ratio decreased. Furthermore, decreasing the SID Lys:CP ratio with DAP inclusion decreased d 18 BW (linear, $P = 0.029$).

During the common period from d 18 to 32, no treatment differences were observed for ADG, ADFI, or F/G. However, decreasing SID Lys:CP ratio with increased DAP tended to decrease d 32 BW (linear, $P = 0.053$). Overall, from d 0 to 32, decreasing SID Lys:CP ratio with increased additions of DAP tended to decrease ADG (linear, $P = 0.056$) and decreased ADFI (linear, $P = 0.039$).

Fecal DM and BUN analyses

Decreased SID Lys:CP ratio from increasing DAP increased serum BUN (linear, $P < 0.001$) and decreased fecal DM (linear, $P = 0.028$) on d 18.

In conclusion, decreasing the SID Lys:CP ratio by increasing DAP as a non-protein nitrogen source decreased ADG and ADFI during the experimental period, which may have been caused by poorer diet palatability resulting from the increased DAP. The increase in fecal DM with increased SID Lys:CP may indicate improved fecal consistency as dietary CP and DAP inclusion decreased. Additionally, the increase in serum BUN likely reflects higher dietary CP and increased nitrogen intake as DAP was increased in the diet. Overall, these results suggest that DAP as a non-protein nitrogen source added to reduce the SID Lys:CP ratio may not be beneficial in early nursery diets, particularly when fed over 1.51% of the diet, because it may negatively affect feed intake and growth performance.

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Table 1. Diet composition (as-fed basis)[1]

	SID Lys:CP						
	6.41	6.57	6.73	6.89	7.05	7.21	Common
Ingredient, %:							
Corn	66.15	66.16	66.18	66.13	66.14	66.14	65.88
Soybean meal, 45.1% CP	17.65	17.65	17.65	17.65	17.65	17.65	29.76
Whey permeate	6.25	6.25	6.25	6.25	6.25	6.25	---
Microbially enhanced soybean meal[1]	3.75	3.75	3.75	3.75	3.75	3.75	---
Diammonium phosphate, 18% N	1.93	1.51	1.10	0.72	0.35	---	---
Calcium carbonate	1.39	1.22	1.05	0.87	0.73	0.55	0.75
Monocalcium phosphate, 21% P	---	0.37	0.74	1.10	1.45	1.78	0.90
Sand	---	0.20	0.40	0.65	0.80	1.00	---
Salt	0.60	0.60	0.59	0.59	0.59	0.59	0.60
Soybean oil	---	---	---	---	---	---	0.50
L-Lys-HCl	0.65	0.65	0.65	0.65	0.65	0.65	0.50
DL-Met	0.25	0.25	0.25	0.25	0.25	0.25	0.21
L-Thr	0.30	0.30	0.30	0.30	0.30	0.30	0.23
L-Trp	0.07	0.07	0.07	0.07	0.07	0.07	0.05
L-Val	0.21	0.21	0.21	0.21	0.21	0.21	0.16
L-Ile	0.07	0.07	0.07	0.07	0.07	0.07	---
L-His-HCl	0.03	0.03	0.03	0.03	0.03	0.03	---
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Phytase[2]	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Zinc oxide	0.26	0.26	0.26	0.26	0.26	0.26	---
Total	100	100	100	100	100	100	100
Calculated analysis							
SID Lys, %	1.26	1.26	1.26	1.26	1.26	1.26	1.30
SID AA:SID Lys							
Ile	54	54	54	54	54	54	55
Leu	103	103	103	103	103	103	115
Met	38	38	38	38	38	38	37
Met and Cys	57	57	57	57	57	57	58
Thr	64	64	64	64	64	64	65
Trp	19.1	19.1	19.1	19.1	19.1	19.1	20.0
Val	71	71	71	71	71	71	72
His	33	33	33	33	33	33	36
Arg	73	73	73	73	73	73	91
Phe	56	56	56	56	56	56	65
Phe and Tyr	86	86	86	86	86	86	108
NE, kcal/lb	1,115	1,115	1,115	1,115	1,115	1,115	1,116

SID Lys:NE, g/Mcal	5.13	5.13	5.12	5.13	5.13	5.13	5.28
CP, %	19.6	19.2	18.7	18.3	17.9	17.5	20.6
Ca, %	0.72	0.72	0.72	0.71	0.72	0.71	0.62
STTD P, %	0.49	0.49	0.49	0.49	0.49	0.49	0.33
Ca:P	1.00	1.01	1.01	1.00	1.01	1.00	1.08

[1] ACCESS Starter Protein (Houdek, Volga, SD).

[2] Ronozyme HiPhorius 2400 (Novonesis, Kongens Lyngby, Denmark) provided an estimated release of 0.14% STTD P with 681 FYT/lb.

Table 2. Analyzed composition of diets (as-fed basis)[1]

	SID Lys:CP					
	6.41	6.57	6.73	6.89	7.05	7.21
Nutrient, %						
CP[2]	19.7	18.7	18.6	18.0	18.3	17.2
Essential AAs						
Arg	0.98	0.95	1.00	0.97	0.92	0.94
His	0.45	0.45	0.44	0.44	0.43	0.43
Ile	0.79	0.76	0.77	0.77	0.74	0.75
Leu	1.46	1.42	1.47	1.45	1.40	1.40
Lys	1.26	1.30	1.35	1.31	1.25	1.36
Met	0.47	0.45	0.46	0.40	0.44	0.44
Phe	0.81	0.79	0.82	0.81	0.77	0.78
Thr	0.86	0.85	0.85	0.85	0.80	0.85
Trp	0.23	0.23	0.23	0.24	0.23	0.23
Val	0.94	0.95	0.94	0.98	0.91	0.93
Non-essential AAs						
Ala	0.85	0.84	0.86	0.85	0.82	0.82
Asp	1.52	1.47	1.53	1.50	1.42	1.45
Cys	0.28	0.28	0.28	0.27	0.26	0.27
Glu	2.98	2.88	3.00	2.95	2.82	2.85
Gly	0.65	0.63	0.65	0.64	0.62	0.62
Pro	1.01	0.99	1.02	1.00	0.96	0.97
Ser	0.69	0.67	0.70	0.69	0.64	0.66
Tyr	0.56	0.55	0.58	0.56	0.54	0.55

[1] Samples were analyzed for complete AA profile (University of Missouri Agricultural Experiment Station Chemical Laboratory).

[2] Analyzed in duplicate using Leco TruMac N with TruMac operating software (Leco Corporation, St. Joseph, MI) at Kansas State University Swine Laboratory.

Table 3. Effect of standardized ileal digestible lysine to crude protein (SID Lys:CP) ratio achieved by inclusion of diammonium phosphate (DAP) on growth performance, blood urea nitrogen (BUN), and fecal dry matter (DM) of nursery pigs[1]

SID Lys:CP:	6.41	6.57	6.73	6.89	7.05	7.21				
CP, %:	19.6	19.2	18.7	18.3	17.9	17.5			*P* =	
DAP, %:	1.93	1.51	1.10	0.72	0.35	---	SEM	Linear	Quadratic	Cubic
BW, lb										
d 0	13.7	13.7	13.7	13.7	13.7	13.7	0.09	0.823	0.941	0.916
d 18	24.8	25.3	25.6	25.6	25.5	26.0	0.35	0.029	0.605	0.341
d 32	42.2	43.4	43.8	43.6	43.7	44.1	0.64	0.053	0.409	0.343
Experimental period (d 0 to 18)										
ADG, lb	0.62	0.65	0.66	0.65	0.65	0.68	0.018	0.029	0.673	0.145
ADFI, lb	0.84	0.89	0.90	0.90	0.91	0.96	0.026	0.003	0.838	0.186
G:F	0.74	0.73	0.74	0.73	0.71	0.71	0.012	0.082	0.653	0.832
F/G	1.36	1.38	1.36	1.38	1.41	1.40	0.023	---	---	---
Common period (d 18 to 32)										
ADG, lb	1.24	1.29	1.29	1.29	1.30	1.30	0.029	0.238	0.388	0.496
ADFI, lb	1.75	1.85	1.82	1.81	1.82	1.83	0.040	0.351	0.433	0.245
G:F	0.71	0.70	0.71	0.71	0.71	0.71	0.008	0.672	0.814	0.372
F/G	1.41	1.44	1.41	1.41	1.41	1.42	0.017	---	---	---
Overall (d 0 to 32)										
ADG, lb	0.89	0.93	0.94	0.93	0.93	0.95	0.019	0.056	0.444	0.192
ADFI, lb	1.23	1.31	1.30	1.30	1.31	1.34	0.029	0.039	0.579	0.144
G:F	0.72	0.71	0.72	0.72	0.71	0.71	0.008	0.462	0.687	0.667
F/G	1.39	1.41	1.39	1.40	1.41	1.41	0.016	---	---	---
BUN, mg/dL[2]	7.89	6.94	6.04	6.12	5.47	3.94	0.759	< 0.001	0.769	0.300
Fecal DM, %[3]	27.4	27.1	26.8	27.9	28.5	29.1	0.74	0.028	0.212	0.564

[1] A total of 360 pigs were used with five pigs per pen and 12 pens per treatment.

[2] Blood urea nitrogen; blood samples were taken the evening of d 18 from one pig per pen to measure serum urea N after a 12-h fasting period.

[3] Fecal samples were taken the morning of d 18 from three pigs per pen.