Effects of Standardized Ileal Digestible Lysine:Crude Protein Ratio in Diets with or without Distillers Dried Grains with Solubles on Growth Performance of 25 to 45 lb Pigs

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Summary

A total of 5,059 pigs (PIC 800 × Camborough and DNA 600 × 241; initially 24.3 ± 1.99 lb) were used in an 18-d trial to evaluate SID Lys:CP ratios for 25 to 45 lb pigs in diets with and without DDGS, resulting in diets that contained high or low levels of SBM on growth performance. Pigs were weaned at approximately 21 d of age and housed in mixed-sex pens with approximately 35 pigs per pen. A pelleted early nursery diet was fed to all pigs from weaning until the beginning of the experiment. When pigs reached approximately 24 lb, pens were assigned to one of 12 treatments in a completely randomized design with pen serving as the experimental unit. A total of 143 pens were used, resulting in 11 or 12 replications per dietary treatment. Experimental treatments were arranged in a 2 × 6 factorial with main effects of DDGS (0 or 15%) and SID Lys:CP ratio (6.01, 6.22, 6.45, 6.70, 6.97, or 7.26). Pigs were weighed at the beginning and at the end of the study on d 18. Overall (d 0 to 18), a SID Lys:CP × DDGS interaction was observed (linear, $P < 0.001$) for feed efficiency where increasing SID Lys:CP ratio in diets without DDGS improved ($P < 0.001$) F/G quadratically, with the poorest F/G on the lowest and highest SID Lys:CP ratios; whereas in the diets with DDGS, F/G worsened (quadratic, $P < 0.002$) as the SID Lys:CP ratio increased above 6.45. For the main effects, ADG increased quadratically ($P = 0.021$) as the SID Lys:CP ratio increased, with the greatest ADG with ratios of 6.45 to 6.97. Conversely, ADFI increased linearly ($P = 0.018$) as SID Lys:CP increased up to the highest level tested. A tendency was observed for pigs fed no DDGS resulting in increased ($P = 0.071$) ADG and improved ($P = 0.010$) F/G. In conclusion, formulating diets to the SID Lys:CP ratio of 6.70 without DDGS and 6.45 in diets with DDGS improves feed efficiency. Further increasing the ratio leads to a reduction in feed efficiency, possibly

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due to nitrogen becoming the limiting factor as crude protein is decreased. Additionally, feeding diets without DDGS can lead to an improvement in ADG and F/G.

Introduction

The NRC (2012)[4] suggests an SID Lys:crude protein (CP) ratio of 6.5 for pigs weighing between 25 to 55 lb. The validation of this ratio in swine diets will help improve F/G and nitrogen utilization because the optimal balance of feed-grade amino acids and intact protein sources will occur. A preliminary study (Smallfield et al., 2024)[5] examined the effects of increasing SID Lys:CP ratio (6.0, 6.5, and 6.9) by replacing SBM with feed-grade AAs. These results showed a decrease in growth performance when pigs were fed a diet low in SBM but high in synthetic AA (SID Lys:CP ratio of 6.9) compared to pigs fed a diet where the SID Lys:CP ratio of 6.5 was achieved through either increased SBM inclusion or the addition of another nitrogen source (glycine or diammonium phosphate). Distillers dried grains with solubles (DDGS) can be utilized as a protein and energy source in swine diets when it is economical, but it can have a negative impact on nursery pig performance at higher inclusion levels. Further research is warranted to determine the SID Lys:CP ratio required in diets containing different sources of CP such as DDGS. This will help further determine the optimal SID Lys:CP ratio for pigs weighing 25 to 45 lb in diets containing different levels of SBM. Therefore, the objective of this study was to determine the optimum SID Lys:CP ratios in diets containing 0 or 15% DDGS.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at a commercial research-nursery site in southwest Minnesota. The barns were mechanically ventilated with totally slatted floors. Each pen was equipped with a five-hole stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water. Daily feed additions to each pen were accomplished using a robotic feeding system (DryExact Pro; Big Dutchman North America, Holland, MI) to record feed deliveries for individual pens.

Animals and diets

Weaned pigs (approximately 21 d of age) originating from two sow farms were placed into two rooms at the research facility. Pigs were housed in mixed-sex pens with approximately 35 pigs per pen. When pigs reached approximately 24 lb, pens of pigs were weighed and allotted to one of 12 dietary treatments in a completely randomized design. A total of 5,059 pigs (PIC 800 × Camborough and DNA 600 × 241; initially 24.3 ± 1.99 lb) were used in an 18-d trial to evaluate SID Lys:CP ratios for 25 to 45 lb pigs in diets containing different levels of DDGS resulting in diets that contain high or low levels of SBM on growth performance.

Prior to application of the treatment diets, a common early nursery diet was fed from weaning to the beginning of the study. Experimental treatments were arranged in a 2 × 6 factorial with main effects of DDGS (0 or 15%) and SID Lys:CP ratio (6.01, 6.22,

[4] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. https://doi.org/10.17226/13298.

[5] Smallfield, J. L.; Tokach, M. D.; Woodworth, J. C.; Goodband, R. D.; DeRouchey, J. M.; Gaffield, K. N.; Gebhardt, J. T.; Haydon, K. D.; Warner, A. J.; and Hastad, C. W. (2024) "Is Nitrogen the Limiting Factor to Maintain Feed Efficiency when Feeding Low Protein, Amino Acid Fortified Diets?" Kansas Agricultural Experiment Station Research Reports 2024.

6.45, 6.70, 6.97, or 7.26). There were 12 replications per treatment except for treatment 5 (SID Lys:CP of 6.97 with no DDGS) which had 11 replications. Prior to diet formulation, corn, SBM, and DDGS samples were analyzed for proximate analysis and complete AA profile (Table 1; University of Missouri Agricultural Experiment Station Chemical Laboratory). Diets were corn-soybean meal-based with dietary additions of feed-grade AA adjusted to meet or exceed AA NRC requirement estimates in relation to Lys for Met and Cys, Thr, Trp, Val, Ile, and His for 25 to 55 lb pigs. All treatment diets were manufactured at the Hubbard Feeds Feed Mill in Mankato, MN. Both the low and high SID Lys:CP ratio diets, 6.01 and 7.26, respectively, with and without DDGS, were manufactured in mash form (Table 2) and blended at the farm to make the other dietary treatments. Complete diet samples were collected from feeders at the research facility and subsampled to be analyzed for proximate analysis and complete AA profile (Table 3). Feed additions to each individual feeder were made and recorded by an electronic feeding system (Dry Extract; Big Dutchman, Inc., Holland, MI). Pens of pigs and feeders were weighed at the beginning and at the end of the study to determine ADG, ADFI, and feed efficiency.

Statistical analysis

Data were analyzed as a completely randomized design for one-way ANOVA using the lmer function from the lme4 package in R Studio (Version 3.5.2, R Core Team. Vienna, Austria). Pen was considered the experimental unit. Treatment was included in the model as a fixed effect and nursery entry date and room were included as random effects to account for differences in genetics and fill date. Contrast statements were used to evaluate the interactive effect of SID Lys:CP × DDGS, as well as the main effects of DDGS and SID Lys:CP ratio. Results were considered significant with $P \le 0.05$ and were considered marginally significant with $P \le 0.10$.

Results and Discussion

Growth performance

Overall (d 0 to 18), a SID Lys:CP × DDGS interaction was observed (linear, $P < 0.001$) where feed efficiency showed a quadratic response ($P < 0.001$) in the diets without DDGS, with the poorest F/G on the lowest and highest Lys:CP ratios. Whereas in the diets with DDGS, feed efficiency worsened (quadratic, $P < 0.002$) as the SID Lys:CP ratio increased above 6.45 (Table 4). For the main effects, ADG increased quadratically ($P = 0.021$) as the SID Lys:CP ratio increased, with the greatest improvement in ADG with ratios of 6.45 to 6.97 (Table 5). Conversely, ADFI linearly increased ($P = 0.018$) as SID Lys:CP increased up to the highest level tested. A tendency was observed for pigs fed no DDGS having increased ($P = 0.071$) ADG and improved F/G (Table 6).

In conclusion, formulating diets to the SID Lys:CP ratio of 6.70 without DDGS and 6.45 in diets with DDGS improved the feed efficiency. Increasing the ratio further led to a reduction in feed efficiency, possibly due to nitrogen becoming the limiting factor as crude protein decreased. Additionally, feeding diets without DDGS can improve ADG and F/G.

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Table 1. Analyzed composition of corn, soybean meal (SBM), and dried distillers grains with solubles (DDGS; as-fed basis)[1]

Nutrient, %	Corn	SBM	DDGS
CP	6.76	45.64	28.50
Dry matter	85.66	89.76	88.89
Crude fat	2.62	1.98	8.30
Crude fiber	1.61	4.08	7.53
Ash	1.10	6.51	4.96
Essential AAs			
Arg	0.34	3.30	1.28
His	0.20	1.22	0.81
Ile	0.25	2.27	1.07
Leu	0.77	3.59	3.05
Lys	0.27	3.02	0.96
Met	0.15	0.67	0.49
Phe	0.33	2.43	1.31
Thr	0.25	1.80	1.07
Trp	0.05	0.63	0.21
Val	0.34	2.36	1.42
Non-essential AAs			
Ala	0.50	2.04	1.80
Asp	0.49	5.33	1.77
Cys	0.16	0.71	0.54
Glu	1.25	8.65	3.73
Gly	0.29	1.99	1.09
Pro	0.62	2.39	2.04
Ser	0.30	1.98	1.18
Tyr	0.23	1.76	1.03

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

Table 2. Diet composition (as-fed basis)[1]

	No DDGS		15% DDGS	
SID Lys:CP:	**6.01**	**7.26**	**6.01**	**7.26**
Ingredient, %				
Corn	59.03	69.18	52.99	63.18
Soybean meal	37.79	26.48	28.70	17.24
Corn DDGS (8.3% oil)	---	---	15.00	15.00
Calcium carbonate	0.95	0.92	1.04	1.00
Monocalcium P (21.5% P)	0.85	1.05	0.65	0.83
Salt	0.60	0.61	0.54	0.55
L-Lys	0.21	0.57	0.43	0.79
DL-Met	0.15	0.27	0.16	0.27
L-Thr	0.15	0.31	0.19	0.35
L-Trp	0.01	0.07	0.04	0.10
L-Val	---	0.18	0.01	0.23
L-Ile	---	0.06	---	0.14
L-His	---	0.05	---	0.08
Trace mineral premix	0.08	0.08	0.08	0.08
Vitamin premix	0.05	0.05	0.05	0.05
Copper sulfate	0.07	0.07	0.07	0.07
Selenium	0.05	0.05	0.05	0.05
Phytase[2]	0.02	0.02	0.02	0.02
Total	100	100	100	100

continued

Table 2. Diet composition (as-fed basis)[1]

	No DDGS		15% DDGS	
SID Lys:CP:	**6.01**	**7.26**	**6.01**	**7.26**
Calculated analysis				
SID AA, %				
Lys, %	1.30	1.30	1.30	1.30
Ile:Lys	68	56	62	56
Leu:Lys	122	100	127	104
Met:Lys	35	39	35	39
Met and Cys:Lys	58	58	58	58
Thr:Lys	65	65	65	65
Trp:Lys	19	19	19	19
Val:Lys	72	70	70	70
His:Lys	39	34	38	34
Total Lys, %	1.47	1.44	1.49	1.46
SID EAA:NEAA	0.88	0.99	0.92	1.07
NE, kcal/lb	1,136	1,151	1,129	1,146
SID Lys:NE, g/Mcal	5.19	5.12	5.22	5.15
CP, %	21.6	17.9	21.6	17.9
Ca, %	0.67	0.65	0.65	0.63
STTD P, %	0.45	0.46	0.45	0.45
Ca:P	1.10	1.10	1.10	1.10

[1] Diets were fed from d 0 (24 lb) to d 18 (45 lb).

[2] Quantum Blue 5G (AB Vista, Marlborough, Wiltshire, UK) included at 751 FTU/kg provided an estimated release of 0.12% STTD P.

Table 3. Analyzed diet composition (as-fed basis)[1]

	No DDGS						DDGS					
SID Lys:CP:	**6.01**	**6.22**	**6.45**	**6.70**	**6.97**	**7.26**	**6.01**	**6.22**	**6.45**	**6.70**	**6.97**	**7.26**
Nutrient, %												
CP	22.70	20.94	19.95	19.69	19.44	18.55	21.81	21.08	19.94	19.86	18.73	18.73
Dry matter	87.73	87.84	87.83	87.66	87.57	87.88	88.63	88.48	88.63	88.45	88.25	88.36
Crude fat	1.90	2.04	2.17	1.75	1.53	1.69	2.52	2.70	2.88	2.69	3.02	3.01
Crude fiber	2.36	2.40	2.40	1.89	1.70	1.72	2.77	2.74	2.69	3.07	2.80	2.93
Ash	5.33	4.93	5.02	5.81	5.03	4.50	5.68	5.35	5.30	5.43	5.22	5.32
Essential AA												
Arg	1.48	1.36	1.30	1.23	1.21	1.12	1.31	1.26	1.21	1.15	1.05	1.05
His	0.63	0.59	0.59	0.57	0.56	0.53	0.61	0.60	0.60	0.59	0.57	0.60
Ile	1.01	0.94	0.91	0.90	0.87	0.81	0.95	0.91	0.92	0.88	0.85	0.86
Leu	1.84	1.75	1.68	1.63	1.59	1.53	1.96	1.90	1.86	1.78	1.71	1.73
Lys	1.50	1.44	1.44	1.51	1.52	1.42	1.53	1.49	1.51	1.46	1.46	1.51
Met	0.41	0.45	0.39	0.44	0.46	0.42	0.49	0.47	0.46	0.44	0.43	0.46
Phe	1.14	1.06	1.01	0.98	0.96	0.89	1.10	1.06	1.02	0.97	0.91	0.91
Thr	1.00	0.92	0.94	0.96	0.97	0.93	0.99	0.99	0.97	0.94	0.90	0.95
Trp	0.26	0.25	0.27	0.27	0.25	0.25	0.25	0.26	0.27	0.26	0.27	0.26
Val	1.10	1.08	1.04	1.05	1.06	1.01	1.07	1.08	1.09	1.05	1.05	1.06
Non-essential AA												
Ala	1.07	1.02	0.98	0.94	0.92	0.89	1.15	1.13	1.10	1.05	1.01	1.03
Asp	2.32	2.12	2.03	1.94	1.91	1.74	2.05	1.96	1.87	1.75	1.63	1.62
Cys	0.37	0.35	0.33	0.32	0.31	0.30	0.38	0.38	0.36	0.35	0.33	0.35
Glu	4.10	3.82	3.66	3.53	3.46	3.24	3.88	3.75	3.66	3.43	3.25	3.26
Gly	0.93	0.86	0.82	0.78	0.77	0.73	0.88	0.86	0.83	0.78	0.73	0.74
Pro	1.24	1.19	1.14	1.10	1.08	1.05	1.35	1.32	1.28	1.23	1.19	1.21
Ser	0.97	0.90	0.87	0.82	0.80	0.77	0.93	0.92	0.86	0.80	0.78	0.79
Tyr	0.79	0.74	0.72	0.69	0.67	0.63	0.78	0.76	0.73	0.70	0.66	0.67

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

Table 4. Interactive effects of SID Lys:CP and DDGS on growth performance[1]

	No DDGS						15% DDGS							SID Lys:CP × DDGS, *P* =	
SID Lys:CP:	**6.01**	**6.22**	**6.45**	**6.70**	**6.97**	**7.26**	**6.01**	**6.22**	**6.45**	**6.70**	**6.97**	**7.26**	**SEM**	**Linear**	**Quadratic**
BW, lb															
d 0	24.1	24.3	24.4	24.4	24.1	24.7	24.4	24.4	24.4	24.1	24.5	24.0	1.99	0.511	0.745
d 18	44.3	45.1	44.9	45.5	45.4	45.5	44.3	44.4	45.5	44.9	45.0	43.9	2.83	0.267	0.464
Overall (d 0 to 18)															
ADG, lb	1.12	1.15	1.13	1.17	1.18	1.15	1.10	1.11	1.17	1.14	1.13	1.10	0.050	0.282	0.358
ADFI, lb	1.64	1.65	1.62	1.64	1.68	1.68	1.59	1.59	1.66	1.65	1.67	1.66	0.100	0.540	0.219
G:F[2]	0.68	0.70	0.70	0.71	0.70	0.69	0.70	0.70	0.71	0.69	0.68	0.67	0.014	< 0.001	0.437
F/G[3]	1.47	1.43	1.42	1.40	1.43	1.45	1.44	1.43	1.41	1.44	1.47	1.50	0.028	---	---

[1] A total of 5,059 pigs (initially 24.3 ± 1.99 lb) were used in an 18-d growth study with approximately 35 pigs per pen and 11 or 12 replications per treatment.
[2] Quadratic effect of SID Lys:CP in no DDGS, *P* < 0.001. Linear effect of SID Lys:CP, *P* < 0.001; and quadratic effect of SID Lys:CP in DDGS, *P* = 0.002.
[3] F/G was calculated by taking the inverse of G:F. *P*-values are the same as reported for G:F.

Table 5. Main effects of SID Lys:CP ratio on growth performance[1]

	SID Lys:CP ratio							*P* =	
	6.01	**6.22**	**6.45**	**6.70**	**6.97**	**7.26**	**SEM**	**Linear**	**Quadratic**
BW, lb									
d 0	24.2	24.3	24.4	24.2	24.3	24.3	1.96	0.895	0.971
d 18	44.3	44.8	45.2	45.2	45.2	44.7	2.78	0.432	0.145
Overall (d 0 to 18)									
ADG, lb	1.11	1.13	1.15	1.15	1.15	1.13	0.047	0.211	0.021
ADFI, lb	1.61	1.62	1.64	1.65	1.67	1.67	0.097	0.018	0.714
G:F	0.69	0.70	0.71	0.70	0.69	0.68	0.013	0.007	< 0.001
F/G[2]	1.45	1.43	1.42	1.42	1.45	1.47	0.027	---	---

[1] A total of 5,059 pigs (initially 24.3 ± 1.99 lb) were used in an 18-d growth study with approximately 35 pigs per pen and 11 or 12 replications per treatment.
[2] F/G was calculated by taking the inverse of G:F. *P*-values are the same as reported for G:F.

Table 6. Main effects of DDGS on growth performance[1]

	No DDGS	**DDGS**	**SEM**	***P* =**
BW, lb				
d 0	24.3	24.3	1.94	0.980
d 18	45.1	44.7	2.74	0.287
Overall (d 0 to 18)				
ADG, lb	1.15	1.13	0.045	0.071
ADFI, lb	1.65	1.63	0.095	0.389
G:F	0.70	0.69	0.013	0.010
F/G[2]	1.43	1.45	0.026	-----

[1] A total of 5,059 pigs (initially 24.3 ± 1.99 lb) were used in an 18-d growth study with approximately 35 pigs per pen and 11 or 12 replications per treatment.
[2] F/G was calculated taking the inverse of G:F. *P*-values are the same as reported for G:F.