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This section 2: nursery pig nutrition and management is available in Kansas Agricultural Experiment Station Research Reports: https://newprairiepress.org/kaesrr/vol11/iss7/30

K-STATE Research and Extension

SWINE DAY 2025

Evaluation of Net Energy, Standardized Ileal Digestible Lysine, and Soybean Meal Content Interactions in Pigs from 25 to 50 lb Using a Factorial Arrangement[1]

Hilario M. Cordoba, Mike D. Tokach, Jason C. Woodworth, Katelyn N. Gaffield, Robert D. Goodband, Joel M. DeRouchey, Jordan T. Gebhardt,[2] Henrique S. Cemin,[3] and Jose A. Soto[4]

Summary

A total of 4,336 pigs (PIC 337 × 1050; initially 23.4 ± 0.70 lb) were used in a 21-d trial to investigate the interaction of NE, SID lysine, and soybean meal content on growth performance of nursery pigs. Pigs were housed in mixed-sex pens with 34 pigs per pen and assigned in a randomized complete block design to 16 dietary treatments arranged in a 2 × 2 × 4 factorial with eight replications per treatment. The treatment structure consisted of two levels of NE: 1,100 or 1,214 kcal/lb; two levels of SBM: 25.5 or 33.5%; and four levels of SID Lys: 1.08, 1.20, 1.31, or 1.43%. Eight diets were formulated to various levels of NE, SID Lys, and SBM and blended to create the 16 dietary treatments. Diets were corn-soybean meal-based, and soy hulls and soybean oil were added to modify the NE content of the diet. Feed-grade amino acids and SBM were used to adjust SID Lys and SBM content, respectively, and to maintain SID threonine, tryptophan, methionine, valine, and isoleucine ratios relative to SID Lys. There was a tendency for a three-way interaction ($P = 0.063$) in ADG between the NE, SBM, and SID Lys levels driven by the linear increase ($P < 0.001$) in ADG as SID Lys increased in diets containing 1,214 kcal NE/lb and 33.5% SBM, whereas the response to SID Lys at lower NE or SBM increased up to 1.20% with no improvement thereafter. For F/G, there was a three-way interaction (linear, $P = 0.023$) between the NE, SBM, and SID Lys levels driven by the improvement (linear, $P < 0.001$) in F/G at 1.08% SID Lys when NE was at 1,100 kcal/lb and SBM at 33.5% compared to the higher NE and lower SBM containing treatments. This response was likely caused by the greater Lys to calorie ratio and non-essential amino acids provided in this diet compared to the other diets containing 1.08% SID Lys. In conclusion, ADG and F/G improved as SID Lys increased in the diet; however, the magnitude of response was influenced by the Lys-to-CP and Lys-to-calorie ratios used within the different NE and SBM inclusions. Feed cost and feed cost per lb of gain increased as the levels of NE, SBM, and SID Lys increased in the diet.

[1] The authors appreciate the United Soybean Board for their financial support of this trial.

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[3] Hubbard Feeds, Mankato, MN.

[4] Alltech, Nicholasville, KY.

Introduction

In a previous study by Cordoba et al. (2024),[5] five levels of NE, SBM, and SID Lys were used to test pig growth performance using a central composite design (CCD). The results showed a quadratic increase in ADG and F/G with increasing SID Lys, with the response being greater when SBM also increased in the diet. However, increasing levels of NE in the diet linearly decreased ADG and F/G. This was likely a result of an unbalanced SID Lys-to-calorie ratio in the diet or merely that pigs do not respond to increasing energy at this weight range.

The CCD is a model that allows scientists to build second-order models without needing to use a complete three-level factorial design. In our previous study, the five levels of NE, SBM, and SID Lys would represent 125 treatments, whereas by using a CCD only 15 treatments were required. The model predicts the intermediate values that were not tested based on the observed response to create a response surface. To generate the response surface, the CCD uses extreme values not typically used in practical formulations. For example, in our previous study, energy ranged from 1,059 to 1,253 kcal NE/lb, making it more difficult to balance the other nutrients to energy. While these energy levels are what was required to complete the CCD, they are not practical and would not represent diets fed in commercial production. Therefore, the objective of this study was to evaluate two levels of NE within practical levels used in the U.S. swine industry. Additionally, two levels of SBM and four levels of SID Lys that were used as minimum and maximum levels in the previous CCD study were evaluated. These levels were evaluated using a factorial design to determine growth performance and economics of pigs between 25 to 50 lb.

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 computerized feeding system (DryExact Pro; Big Dutchman North America, Holland, MI) to record feed deliveries for individual pens.

Animals and diets

A total of 4,336 pigs (PIC 337 × 1050; initially 23.4 ± 0.70 lb) were used in a 21-d trial to investigate the interaction of NE, SID Lys, and SBM content on growth performance of nursery pigs. Pigs were housed in mixed-sex pens with 34 pigs per pen and assigned in a randomized complete block design to 16 dietary treatments arranged in a 2 × 2 × 4 factorial with eight replications per treatment. The treatment structure consisted of two levels of NE: 1,100 or 1,214 kcal/lb; two levels of SBM: 25.5 or 33.5%; and four levels of SID Lys: 1.08, 1.20, 1.31, or 1.43%. Eight diets were formulated to various levels of NE, SID Lys, and SBM and blended to create the 16 dietary treatments. Diets were corn-soybean meal-based, and soy hulls and soybean oil were added to modify the NE content of the diet. Feed-grade amino acids and SBM were used to adjust SID Lys and SBM content, respectively, and to maintain SID Thr, Trp, Met, Val,

[5] Cordoba, H. M., M. D. Tokach, J. C. Woodworth, R. D. Goodband, J. M. DeRouchey, J. T. Gebhardt, H. S. Cemin, and J. A. Soto. 2024. J. Anim. Sci. 102(Suppl. 2):182-183. (Abstr.) doi:10.1093/jas/skae102.201.

and Ile ratios relative to SID Lys. In this trial, we assumed that SBM contained 90% of the NE of corn. All treatment diets were manufactured at the Hubbard Feeds Feed Mill in Mankato, MN, and except for SID Lys in some treatments, were formulated to meet or exceed NRC (2012)[6] requirement estimates for 25 to 50 lb pigs (Table 1).

Pens of pigs and feed disappearance were weighed at the beginning and at the end of the study to determine ADG, ADFI, and F/G.

Statistical analysis

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package in R (version 4.1.1 (2021-08-10), R Foundation for Statistical Computing, Vienna, Austria) with pen considered the experimental unit, treatment as the fixed effect, and initial weight as the blocking factor. Three-way interactions, two-way interactions, and main effects of NE, SBM, and SID Lys were evaluated, and the highest order model was reported when statistical significance was observed. If the three-way interaction was significant, then simple effects of two-way interaction within each level of the third factor were analyzed. Differences between treatments were considered significant at $P \leq 0.05$ and tendencies at $0.05 < P \leq 0.10$.

Results and Discussion

Relevant nutritional information from the 16 diets used is shown in Table 2. The chemical analysis of complete diets was consistent with the calculated values used in diet formulation.

From d 0 to 21, there was a tendency for a three-way interaction ($P = 0.063$) in ADG between the NE, SBM, and SID Lys levels (Figure 1) driven by the linear increase ($P < 0.001$) in ADG as SID Lys increased in diets containing 1,214 kcal NE/lb and 33.5% SBM, whereas the response to SID Lys appears quadratic for pigs fed the lower NE or SBM levels (Table 3). Pigs fed the diet formulated to 1.20% SID Lys at 33.5% SBM and 1,214 kcal/kg NE had decreased ADG compared to the other treatments formulated to the same SID Lys level. This can be explained by a reduced feed intake when 33.5% SBM was provided versus 25.5%, thus reducing total nutrient intake, and by a reduced Lys-to-calorie ratio in comparison to those with lower NE (Figure 1). For ADFI, there were significant ($P < 0.05$) main effects of NE and SBM, where increasing NE or SBM reduced feed intake. There also was a tendency (linear, $P = 0.085$) for increased ADFI as SID Lys increased. For F/G, there was a three-way interaction (linear, $P = 0.023$) observed between the NE, SBM, and SID Lys levels (Figure 2). Pigs fed the diet formulated to 1.08% SID Lys when NE was at 1,100 kcal/lb and SBM at 33.5% improved F/G compared to pigs fed the diets with the same SID Lys level, but with lower SBM and higher NE levels (Figure 2). This response was likely caused by the greater Lys-to-calorie ratio when comparing the response to those with higher NE and more non-essential amino acids provided by SBM in this diet compared to the diet containing 25.5% SBM.

In conclusion, ADG and F/G improved with increasing SID Lys. However, the magnitude of the ADG response was influenced to a greater extent by the Lys-to-calorie ratio when diets contained 33.5% SBM compared to 25.5% in diets containing 1,214 kcal/lb. In contrast, the F/G response was influenced to a greater extent by the Lys-to-CP ratio

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

when feeding 33.5% SBM compared to 25.5% in diets containing 1,100 kcal/lb NE. Results of this study demonstrate the complex relationship between SID Lys, SBM, and NE levels in diet formulation on pig growth performance.

Acknowledgments

The authors would like to thank the United Soybean Board; Hubbard Feeds, Mankato, MN; and Schwartz Farms, Sleepy Eye, MN for providing financial and technical support for these studies.

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

Item	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
Ingredients, %								
Corn	60.43	57.77	55.02	52.83	65.16	63.34	57.48	56.03
Soybean meal, 46.5% CP[2]	25.49	25.52	33.53	33.56	25.50	25.48	33.57	33.55
Soybean hulls	9.80	11.00	7.80	8.75	2.30	2.90	2.00	2.40
Soybean oil	1.00	1.05	0.85	0.90	3.60	3.45	4.05	3.90
Calcium carbonate	0.70	0.68	0.77	0.75	0.81	0.79	0.85	0.84
Monocalcium P, 21% P	1.03	1.03	1.00	1.00	1.03	1.03	1.00	1.00
Salt	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
L-Lys HCl	0.33	0.77	0.08	0.52	0.35	0.80	0.10	0.55
DL-Met	0.15	0.36	0.07	0.29	0.15	0.36	0.08	0.30
L-Trp	0.04	0.11	---	0.07	0.05	0.11	---	0.07
L-Thr	0.15	0.38	0.04	0.27	0.15	0.39	0.04	0.28
L-Val	0.05	0.30	---	0.16	0.06	0.31	---	0.17
L-Ile	---	0.22	---	0.08	0.01	0.23	---	0.09
Vitamin and mineral premix[3]	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Phytase[4]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	100	100	100	100	100	100	100	100
Calculated analysis								
Standardized ileal digestible (SID) amino acids, %								
Lys	1.08	1.43	1.08	1.43	1.08	1.43	1.08	1.43
Ile:Lys	60	60	73	60	60	60	72	60
Leu:Lys	127	95	145	106	127	95	145	108
Met:Lys	37	42	33	40	37	42	33	40
Met and Cys:Lys	60	60	60	60	60	60	60	60
Thr:Lys	65	65	65	65	65	65	65	65
Trp:Lys	21	21	21	21	21	21	21	21
Val:Lys	71	70	78	70	70	70	78	70
His:Lys	40	30	47	35	40	30	47	35
Total Lys, %	1.23	1.58	1.25	1.59	1.21	1.56	1.23	1.58
NE, kcal/lb	1,100	1,100	1,100	1,100	1,214	1,214	1,214	1,214
SID Lys:NE, g/Mcal	4.45	5.88	4.45	5.89	4.03	5.34	4.03	5.34
CP, %	18.7	19.7	21.5	22.3	18.4	19.4	21.1	22.0
Ca, %	0.62	0.61	0.65	0.65	0.62	0.61	0.65	0.65
Available P, %	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46

[1] Fed from approximately 23 to 50 lb.
[2] Crude protein.
[3] Vitamin and trace mineral premix with added Alltech Sel-Plex 600 (Alltech, Nicholasville, KY).
[4] Quantum Blue 5G (AB Vista, Marlborough, UK) was included at 680 FTU/kg providing an estimated release of 0.16% available P.

Table 2. Main nutrient composition of the 16 dietary treatments (as-fed-basis)

	Diet															
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Calculated																
NE, kcal/lb	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,214	1,214	1,214	1,214	1,214	1,214	1,214	1,214
SBM, %	25.5	25.5	25.5	25.5	33.5	33.5	33.5	33.5	25.5	25.5	25.5	25.5	33.5	33.5	33.5	33.5
SID AA, %																
Lys	1.08	1.20	1.31	1.43	1.08	1.20	1.31	1.43	1.08	1.20	1.31	1.43	1.08	1.20	1.31	1.43
Ile:Lys	60	60	60	60	73	68	64	60	60	60	60	60	72	67	64	60
Leu:Lys	127	114	104	95	145	131	119	109	127	114	104	95	145	130	118	108
Met & Cys:Lys	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Thr:Lys	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Trp:Lys	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Val:Lys	71	70	70	70	78	75	72	70	70	70	70	70	78	74	72	70
His:Lys	40	36	33	30	47	42	39	35	40	36	32	30	47	42	38	35
Arg:Lys	99	89	82	75	121	109	99	91	97	88	80	73	119	107	98	90
Phe:Lys	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
CP, %	18.7	19.1	19.4	19.7	21.5	21.8	22.1	22.3	18.4	18.7	19.0	19.4	21.1	21.4	21.7	22.0
SID Lys:NE, g/Mcal	4.45	4.93	5.40	5.88	4.45	4.93	5.41	5.89	4.03	4.47	4.90	5.34	4.03	4.47	4.90	5.34
SID Lys:CP, %	5.76	6.27	6.76	7.23	5.03	5.49	5.95	6.39	5.87	6.38	6.89	7.37	5.11	5.58	6.04	6.49
Analyzed[1]																
CP, %	17.4	18.3	18.4	19.2	20.9	20.7	20.8	21.1	17.6	18.3	18.1	18.6	19.5	20.3	20.2	21.3
Ether extract, %	2.5	2.7	2.7	2.9	2.2	2.4	2.5	2.5	5.4	5.8	5.7	6.2	4.0	3.5	3.7	4.3
CF, %	5.1	5.1	6.1	5.9	4.3	4.9	5.3	5.1	2.7	2.8	2.6	2.5	2.7	2.8	2.7	2.9
Total Lys, %	1.30	1.44	1.53	1.60	1.31	1.48	1.60	1.68	1.33	1.44	1.43	1.65	1.23	1.48	1.48	1.64

[1] Chemical analysis of experimental diets (as-fed-basis). Values represent means from four composite samples. For each treatment, samples were collected from multiple feeders, blended, subsampled, ground, and analyzed (University of Missouri Agricultural Experiment Station Chemical Laboratory, Columbia, MO).

Table 3. Interactive and main effects of feeding pigs two levels of net energy (NE) and soybean meal (SBM) with four levels of SID lysine (Lys) on growth performance[1]

	Nutrient level			Growth performance response			
Diet	NE[2]	SBM, %	SID Lys, %	BW	ADG	ADFI	F/G
1	1,100	25.5	1.08	47.0	1.11	1.69	1.52
2	1,100	25.5	1.20	48.6	1.20	1.73	1.44
3	1,100	25.5	1.31	48.7	1.21	1.70	1.41
4	1,100	25.5	1.43	49.9	1.25	1.73	1.38
5	1,100	33.5	1.08	47.5	1.15	1.65	1.44
6	1,100	33.5	1.20	49.1	1.22	1.69	1.39
7	1,100	33.5	1.31	49.1	1.22	1.67	1.37
8	1,100	33.5	1.43	49.9	1.26	1.70	1.36
9	1,214	25.5	1.08	47.1	1.13	1.67	1.48
10	1,214	25.5	1.20	48.9	1.22	1.71	1.40
11	1,214	25.5	1.31	48.8	1.21	1.66	1.37
12	1,214	25.5	1.43	49.6	1.25	1.67	1.34
13	1,214	33.5	1.08	46.5	1.10	1.62	1.47
14	1,214	33.5	1.20	48.3	1.16	1.63	1.41
15	1,214	33.5	1.31	49.6	1.24	1.69	1.37
16	1,214	33.5	1.43	50.2	1.27	1.67	1.31
SEM				1.14	0.028	0.042	0.013
P = [3]							
Three-way interactions[4]							
Linear SID Lys × SBM × NE				NS	0.063	NS	0.023
Two-way interactions[4]							
NE × SBM				0.604	0.230	0.645	< 0.001
Linear SID Lys × NE				0.495	0.360	0.717	0.015
Linear SID Lys × SBM				0.529	0.419	0.250	0.485
Main effects							
NE				NS	0.650	0.018	0.002
SBM				NS	0.584	0.043	< 0.001
SID Lys, linear				< 0.001	< 0.001	0.085	< 0.001
SID Lys, quadratic				NS	0.068	0.407	0.005

[1] A total of 4,336 pigs (PIC 337 × 1050, initially 23.4 ± 0.70 lb) were used in a 21-d experiment. Approximately 34 pigs per pen were used and assigned to one of 16 treatments in a completely randomized block design.
[2] kcal/lb
[3] Results were considered significant at a *P* value ≤ 0.05 and marginally significant at 0.05 < *P* < 0.10.
NS = non-significant.
[4] Quadratic terms of SID Lys with the two other factors were not significant (*P* > 0.10).

Table 4. Interactive and main effects of feeding pigs two levels of net energy (NE) and soybean meal (SBM) with four levels of SID lysine (Lys) on economics[1]

	Nutrient level			Economics, $/pig placed			
Diet	NE[2]	SBM, %	SID Lys, %	Feed cost[3]	Feed cost/lb[4]	Revenue[5]	IOFC[6]
1	1,100	25.5	1.08	4.62	0.12	15.56	10.94
2	1,100	25.5	1.20	5.20	0.13	16.93	11.74
3	1,100	25.5	1.31	5.53	0.13	17.03	11.50
4	1,100	25.5	1.43	6.00	0.14	17.56	11.56
5	1,100	33.5	1.08	4.55	0.12	16.08	11.54
6	1,100	33.5	1.20	4.94	0.12	17.23	12.29
7	1,100	33.5	1.31	5.15	0.12	17.29	12.14
8	1,100	33.5	1.43	5.47	0.13	17.67	12.19
9	1,214	25.5	1.08	5.30	0.14	16.00	10.70
10	1,214	25.5	1.20	5.80	0.14	17.17	11.37
11	1,214	25.5	1.31	6.02	0.15	17.04	11.02
12	1,214	25.5	1.43	6.47	0.15	17.65	11.18
13	1,214	33.5	1.08	5.23	0.14	15.55	10.32
14	1,214	33.5	1.20	5.42	0.14	16.06	10.64
15	1,214	33.5	1.31	5.98	0.14	17.51	11.53
16	1,214	33.5	1.43	6.16	0.14	19.93	11.81
SEM				0.145	0.001	0.429	0.299
P = [7]							
Three-way interactions							
Linear SID Lys × SBM × NE[8]				NS	NS	0.069	0.063
Two-way interactions[8]							
NE × SBM				NS	< 0.001	NS	0.014
Linear SID Lys × NE				NS	< 0.001	NS	NS
Quadratic SID Lys × NE				NS	0.055	NS	NS
Linear SID Lys × SBM				0.015	< 0.001	NS	0.041
Quadratic SID Lys × SBM				NS	NS	NS	NS
Main effects							
NE				< 0.001	< 0.001	NS	< 0.001
SBM				< 0.001	< 0.001	NS	0.012
SID Lys, linear				< 0.001	< 0.001	< 0.001	< 0.001
SID Lys, quadratic				NS	0.064	0.077	0.041

[1] A total of 4,336 pigs (PIC 337 × 1050, initially 23.4 ± 0.70 lb) were used in a 21-d experiment. Approximately 34 pigs per pen were used and assigned to one of 16 treatments in a completely randomized block design.
[2] kcal/lb
[3] Feed cost = total feed intake per pig × diet cost per lb.
[4] Feed cost/lb gain = total feed cost per pig divided by total gain per pig.
[5] Revenue = (total gain × carcass yield) × carcass price.
[6] Income over feed cost = revenue – feed cost.
[7] Results were considered significant at a *P* value ≤ 0.05 and marginally significant at 0.05 < *P* < 0.10. NS = non-significant.
[8] Quadratic terms of SID Lys with the two other factors were not significant (*P* > 0.10).

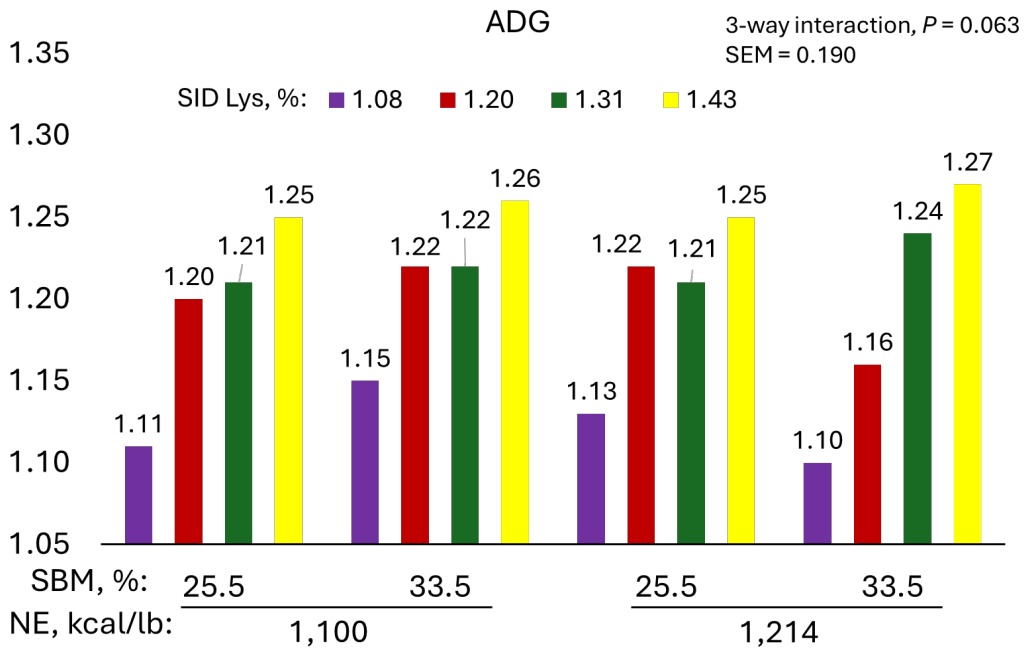

Figure 1. The influence of NE, SBM, and SID Lys on ADG from 23 to 50 lb.

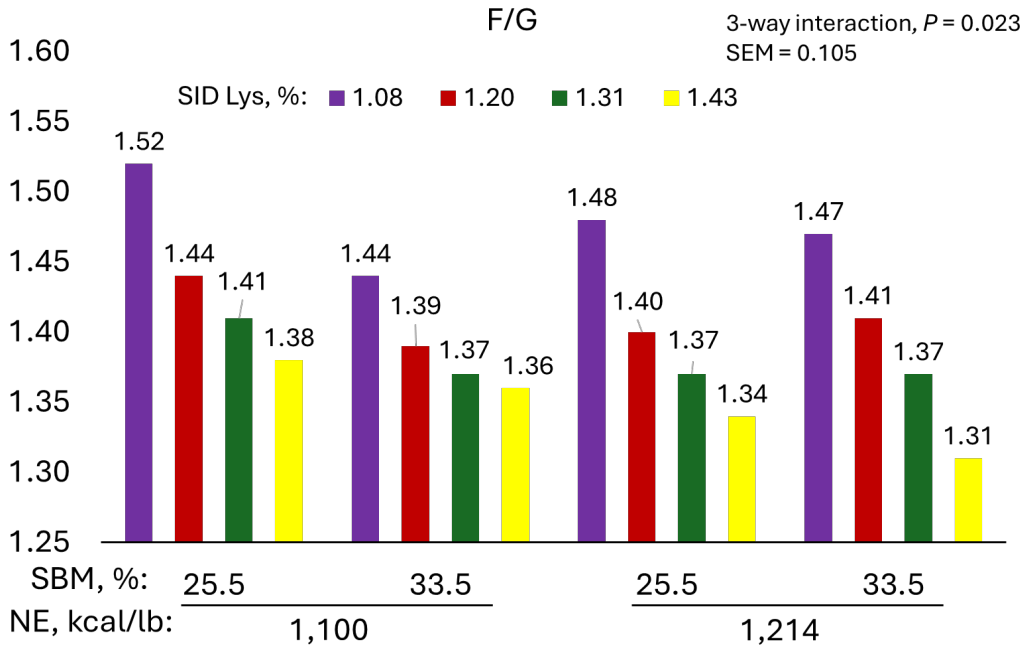

Figure 2. The influence of NE, SBM, and SID Lys on F/G from 23 to 50 lb.