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Effects of Increasing Histidine:Lysine Ratio During Lactation on Sow and Litter Performance[1]

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Summary

A total of 88 sows (Line 241, DNA) and their offspring were used to evaluate the effect of increasing SID His:Lys ratio in lactating sow diets on sow and litter performance. Sows were blocked by parity and body weight (BW) on approximately d 110 of gestation and allotted to one of three dietary treatments of increasing SID His:Lys ratios (40, 50, or 60% of Lys). Sows were fed approximately 6 lb/d of their treatment diet from d 110 of gestation until farrowing, after which they were allowed ad libitum access to their treatment diet. Litters were cross fostered within 48 h after farrowing to equalize litter size. Increasing SID His:Lys ratio did not affect ($P > 0.10$) sow BW, backfat, caliper score, or loin depth on d 110 of gestation or at weaning and did not alter the change in those measurements over the lactation period. Total born did not statistically differ ($P < 0.10$) based on sow lactation diet, however, there were numerical differences between treatments. Increasing SID His:Lys ratio tended to increase and then decrease (quadratic, $P \leq 0.062$) d 7 and weaning litter weight with sows fed a SID His:Lys ratio of 50% having the greatest litter weight. Increasing SID His:Lys ratio tended to increase d 7 to wean piglet ADG (linear, $P = 0.100$) but did not impact litter ADG or pre-weaning mortality ($P > 0.10$). Increasing SID His:Lys ratio increased and then decreased (quadratic, $P = 0.027$) total milk yield from d 2 of lactation until weaning and tended to increase and then decrease average daily milk yield (quadratic, $P = 0.078$) with sows fed a SID His:Lys ratio of 50% having the greatest total and average daily milk yield. Increasing SID His:Lys ratio ($P > 0.10$) did not affect milk composition. These results suggest that increasing the SID His:Lys ratio to 50% tended to increase litter weight on d 7 and at weaning and average daily milk yield.

Introduction

Histidine is an essential amino acid, which means it cannot be synthesized by swine at an adequate rate to meet their maintenance, growth, and reproductive needs. However, to the best of our knowledge, there is no existing research to elucidate the histidine

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requirement of lactating sows. Currently, the NRC (2012)[4] requirement estimate for SID His is 19.5 and 20.8 g/day for lactating gilts and sows, respectively. These estimates are associated with a SID His:Lys ratio of approximately 40%. Standard corn-soybean meal lactation diets have an SID His:Lys ratio that matches that recommendation of approximately 40%.

A meta-analysis of lactation studies in dairy cattle that investigated the effects of increased His in dairy lactation diets found that increased His leads to increased milk yield and milk protein content.[5] With the recent increase in availability of feed-grade histidine, it is more economical than it has been in the past. Therefore, the objective of this study was to determine if increased SID His:Lys above current recommendations will improve sow lactation performance.

Materials and Methods

The protocol for this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted at the Kansas State University Swine Teaching and Research Center. All diets were manufactured at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS.

Animals and diets

A total of 88 sows (Line 241, DNA, Columbus, NE) were used across three batch-farrowing groups from September to December 2023. On approximately d 110 of gestation, sows were moved into the farrowing house, weighed, blocked by body weight and parity and assigned to one of three dietary treatments. Two corn-soybean meal-based experimental diets were formulated to achieve SID His:Lys levels of 40% or 60% of Lys with increasing levels of L-Histidine. An electronic feeding system (Gestal Solo Feeders, Jyga Technologies, Quebec City, Quebec, Canada) was used to blend the two diets to a 50:50 blend (SID His:Lys of 50%) to form an intermediate treatment. Thus, the three treatments were SID His:Lys ratios of 40, 50, and 60% of Lys. Sows were fed approximately 6 lb/day of their treatment diet from d 110 of gestation until farrowing. After farrowing, sows had ad libitum access to their treatment diet. Lactation diets were formulated to meet or exceed NRC (2012)[4] requirement estimates (Table 1).

Sow BW was measured on d 110 of gestation, after farrowing, and at weaning. Sow backfat depth and loin depth were measured on d 110 of gestation and at weaning at the last rib, two inches from the midline using real-time ultrasound. Sow caliper score was measured on d 110 of gestation and at weaning at the last rib. Piglets were cross fostered within 48 h of birth within sow treatment to equalize litter size. Litters were weighed at birth, on d 2 and 7, and at weaning. All instances of piglet mortalities were recorded to determine pre-weaning mortality.

Milk was collected from 10 sows per treatment on approximately d 7 after farrowing and the day before weaning. Milk was collected from the third, fourth, and fifth teats

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

[5] Räisänen, S. E., H. Lapierre, W. J. Price, and A. N. Hristov. 2023. Lactational performance effects of supplemental histidine in dairy cows: A meta-analysis. J. Dairy Sci. 106:6216–6231. doi:10.3168/jds.2022-22966.

on either side of the underline. To determine which sows were selected to collect milk samples, blocks of three sows (one sow from each treatment) were selected in order to create a representative population of the overall trial population. From each litter that milk was collected, the medium-weight barrow was selected, and blood was drawn on d 7 after farrowing and the day before weaning in order to determine plasma free amino acid concentration. All samples were frozen and stored at -20°F until analysis.

Milk yield was estimated utilizing the model developed by Hansen et al. (2012).[6] This model utilized litter weaning size and litter ADG to estimate daily milk yield from d 2 until weaning. Total milk yield was calculated by the summation of daily milk yield from d 2 of lactation until weaning. Total milk yield was then divided by the difference of weaning age from d 2 to determine average milk yield per day.

Statistical analysis

Performance data for the sow portion of the trial were analyzed using the lme4 package of R (Version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria) as a randomized complete block design. Blocking structure accounted for parity and BW. Sow served as the experimental unit. Treatment was included as a fixed effect and block was included as a random effect. Count data were analyzed using a Poisson distribution using a log link function. Proportion data, including litter born alive, stillborn, born mummified, and pre-weaning mortality were analyzed using a binomial distribution using a logit link function. Differences were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Sow BW at entry and weaning, as well as sow lactation BW loss did not differ (P > 0.10; Table 2) based on lactation diet SID His:Lys ratio. There were no linear or quadratic effects ($P > 0.10$) on sow backfat, caliper score, or loin depth upon entry into the farrowing house or at weaning, nor entry-to-wean change with increasing SID His:Lys ratio. Increasing SID His:Lys ratio did not affect ($P > 0.10$) sow ADFI prior to farrowing and from farrowing until weaning. Average SID His g/d intake increased (linear, $P < 0.001$) with increasing SID His:Lys ratio as expected. It should be noted that the NRC (2012) requirement estimates for gilts and sows (19.5 and 20.8 g/day, respectively) were exceeded in all three treatments (29.0, 38.0. and 44.9 g/day, respectively) due to the high lactation feed intake in this trial. This could contribute to the limited responses observed in this trial. Wean-to-estrus interval (WEI) was unaffected ($P > 0.10$) by increasing His:Lys ratio.

There were no differences ($P > 0.10$; Table 3) in the number of total pigs born per litter with increasing SID His:Lys ratio. However, numerical differences in the number of total pigs born per litter were observed with the 50% SID His:Lys and 60% SID His:Lys treatments having 0.8 and 0.6 more total pigs per litter on average when compared to the 40% SID His:Lys treatment. This may have influenced the tendency for a decrease (linear, $P = 0.085$) in percentage born alive observed with increasing SID His:Lys ratio. This decrease in percentage born alive was due to an increased percentage

[6] Hansen, A. V., A. B. Strathe, E. Kebreab, J. France, and P. K. Theil. 2012. Predicting milk yield and composition in lactating sows: A Bayesian approach1. Journal of Animal Science. 90:2285–2298. doi:10.2527/jas.2011-4788.

of stillbirths (linear, $P = 0.049$) with increasing SID His:Lys ratio. Percentage of mummified fetuses did not differ ($P > 0.10$) based on sow lactation diet.

Litter size did not differ ($P > 0.10$; Table 3) on d 0, 2, 7, or at weaning with increased SID His:Lys ratio. There were no linear or quadratic effects ($P > 0.10$) on litter weight on d 2 of lactation with increased SID His:Lys ratio. However, on d 7 and weaning, litter weight tended to increase then decrease (quadratic, $P \leq 0.062$) with increasing SID His:Lys ratio. Sows fed the diet with the 50% SID His:Lys ratio had numerically the highest litter weight on d 7 and at weaning. There was no effect ($P > 0.10$) of increasing SID His:Lys ratio on mean piglet BW on d 0, 2, 7, or at weaning. There was a tendency for a linear increase ($P = 0.10$) on piglet ADG from d 7 to wean. However, there were no linear or quadratic effects ($P > 0.10$) with increased SID His:Lys ratio on litter ADG from d 2 to d 7, d 7 to weaning, or from d 2 to weaning. Increasing SID His:Lys ratio increased then decreased (quadratic, $P = 0.027$) total milk yield where sows fed a diet with the 50% SID His:Lys ratio had numerically the highest total milk yield. When lactation length was accounted for, there was a tendency an increase then decrease (quadratic, $P = 0.078$) on average milk yield where sows fed a diet with the 50% SID His:Lys ratio had numerically the highest average milk yield. Preweaning mortality from birth until d 2 and from d 2 until weaning did not differ ($P > 0.10$) based on SID His:Lys ratio.

On d 7 and the day before weaning, milk samples were collected from 10 females per treatment and analyzed for milk fat, protein, lactose, total solids, and somatic cell count. There were no differences ($P > 0.10$; Table 4) in milk composition due to increased SID His:Lys ratio, day of lactation, or an interaction between the two.

In conclusion, increased SID His:Lys ratio in sow lactation diets increased stillbirths and tended to decrease percentage of pigs born alive. Worth noting is the numerical differences in number of total pigs born per litter between the 40% SID His:Lys treatment and the higher SID His:Lys treatments which likely contributed to differences in stillbirths. Increasing SID His:Lys ratio increased (quadratic, $P \leq 0.062$) d 7 and weaning litter weight where sows fed the diet with 50% SID His:Lys ratio had numerically the heaviest litters. Sows fed the diet containing 50% SID His:Lys ratio also had numerically the highest milk yield. These results suggest that increasing the SID His:Lys ratio to 50% tended to increase litter weight on d 7 and at weaning and average daily milk yield.

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

Ingredient, %	Control	High Histidine
Corn	69.60	69.35
Soybean meal, 46.5% CP	24.40	24.45
Soybean oil	2.00	2.00
Calcium carbonate	1.13	1.13
Monocalcium P, 21.5% P	1.20	1.20
Sodium chloride	0.50	0.50
L-Lys-HCl	0.35	0.35
L-Met	0.08	0.08
L-Thr	0.18	0.18
L-Trp	0.03	0.03
L-Val	0.05	0.05
L-His	---	0.22
Trace mineral premix	0.25	0.25
Vitamin premix	0.25	0.25
Total	100.00	100.00
Calculated analysis		
SID AA, %		
Lys	1.05	1.05
Ile:Lys	60	60
Leu:Lys	129	129
Met:Lys	31	31
Met and Cys:Lys	55	55
Thr:Lys	65	65
Trp:Lys	20	20
Val:Lys	70	70
His:Lys	40	60
Total Lys, %	1.18	1.18
ME, kcal/lb	1,526	1,522
NE, kcal/lb	1,152	1,149
SID Lys:NE, g/Mcal	4.13	4.14
CP, %	17.9	17.9
Ca, %	0.80	0.80
P, %	0.61	0.61
STTD P, %	0.50	0.50

[1]Diets were fed from approximately d 110 of gestation until weaning. Control and high-His diets were blended at a 50:50 ratio to form the intermediate treatment.

Table 2. Effects of increasing Histidine in lactation diets on sow lactation performance[1]

	SID His:Lys ratio, %[2]				P =	
	40	50	60	SEM	Linear	Quadratic
Count, n	30	30	28	---	---	---
Parity	2.2	2.2	2.2	0.32	0.989	0.896
Lactation length, d	17.8	18.1	17.7	0.22	0.973	0.136
Sow BW, lb						
Entry	539.1	538.9	540.6	12.64	0.725	0.794
Wean	498.7	499.1	499.1	14.67	0.957	0.977
Lactation change (entry to wean)	-36.6	-40.8	-41.5	5.66	0.489	0.775
Sow backfat, mm						
Entry	13.5	13.3	13.5	0.39	0.956	0.604
Wean	12.4	11.9	11.8	0.41	0.163	0.561
Lactation change (entry to wean)	-1.0	-1.4	-1.7	0.33	0.109	0.960
Sow caliper score						
Entry	16.4	16.0	15.9	0.30	0.243	0.553
Wean	15.0	14.7	14.4	0.43	0.278	0.960
Lactation change (entry to wean)	-1.4	-1.3	-1.5	0.31	0.821	0.641
Sow loin depth, mm						
Entry	57.1	57.6	56.3	0.78	0.337	0.233
Wean	54.4	54.9	54.2	0.72	0.813	0.504
Lactation change (entry to wean)	-2.6	-2.8	-2.1	0.80	0.551	0.580
Sow ADFI, lb						
Pre-farrow	5.6	5.6	5.5	0.07	0.139	0.786
Farrow to wean	15.2	16.0	15.7	0.44	0.296	0.225
Average SID His intake, g/d	29.0[c]	38.0[b]	44.9[a]	1.07	< 0.001	0.295
Wean to estrus interval, d	5.0	5.0	5.2	0.17	0.336	0.932

[1]A total of 88 mixed-parity sows (Line 241, DNA, Columbus NE) and litters were used from day 110 of gestation until weaning. Litters were cross fostered within treatment group to equalize litter size up to 48-h post farrowing.
[2]Sow treatment consisted of providing a control diet (40% SID His:Lys ratio), a high-histidine diet, accomplished by adding feed-grade histidine (60% SID His:Lys ratio), or a 50:50 blend of the two diets (50% SID His:Lys ratio) from d 110 of gestation until weaning.

Table 3. Effects of increasing Histidine in lactation diets on litter performance[1]

	SID His:Lys ratio, %[2]				*P* =	
	40	50	60	SEM	Linear	Quadratic
Litter characteristics						
Total born, n	15.9	16.7	16.5	0.81	0.569	0.542
Born alive, %	92.9	90.7	89.7	1.58	0.085	0.629
Stillborn, %	3.9	6.3	6.8	1.29	0.049	0.344
Mummy, %	2.5	2.4	2.8	0.88	0.764	0.732
Litter size, n						
d 0	14.8	14.6	14.8	0.73	0.989	0.823
d 2	14.2	14.3	14.1	0.71	0.925	0.863
d 7	13.9	14.2	13.8	0.70	0.909	0.731
Wean	13.9	14.0	13.6	0.70	0.768	0.767
Litter weight, lb						
d 2	51.9	53.3	53.3	1.53	0.449	0.640
d 7	87.5	92.4	87.2	2.38	0.926	0.062
Wean	164.2	174.1	167.9	3.83	0.441	0.053
Mean piglet BW, lb						
d 0	3.47	3.50	3.45	0.119	0.921	0.794
d 2	3.66	3.73	3.77	0.104	0.432	0.882
d 7	6.30	6.51	6.30	0.157	0.995	0.250
Wean	11.87	12.44	12.37	0.298	0.151	0.274
Litter ADG, lb/d						
d 2 to d 7	6.56	6.74	6.34	0.178	0.378	0.171
d 7 to wean	7.42	7.89	7.77	0.241	0.204	0.211
d 2 to wean	7.11	7.50	7.29	0.190	0.443	0.135
Piglet ADG, lb/d						
d 2 to d 7	0.47	0.48	0.46	0.013	0.411	0.484
d 7 to wean	0.54	0.56	0.57	0.019	0.100	0.676
d 2 to wean	0.51	0.54	0.54	0.015	0.218	0.497
Milk yield[3]						
Total yield (d 2-wean), lb	449.4	474.5	443.8	10.32	0.702	0.027
Average yield, lb/d	28.5	29.4	28.2	0.51	0.719	0.078
Preweaning mortality, %						
Birth to d 2	1.4	1.0	2.0	0.92	0.369	0.167
d 2 to wean	2.6	2.0	3.0	0.96	0.767	0.341

[1]A total of 88 mixed-parity sows (Line 241, DNA, Columbus NE) and litters were used from day 110 of gestation until weaning. Litters were cross-fostered within treatment group to equalize litter size up to 48-h post farrowing.
[2]Sow treatment consisted of providing a control diet (40% SID His:Lys ratio), a high-His diet, accomplished by adding feed-grade His (60% SID His:Lys ratio), or a 50:50 blend of the two diets (50% SID His:Lys ratio) from d 110 of gestation until weaning.
[3]Total milk yield was estimated utilizing the model developed by Hansen et al. (2012).
Average milk yield = Total milk yield / (Wean age – 2)

Table 4. Evaluation of increased SID Lys:His on sow milk composition[1]

	SID His:Lys ratio, %[2]				*P* =		
	40	50	60	SEM	Treatment × sample	Treatment	Sample
Fat, %							
d 7	6.9	7.5	6.7	0.39	0.243	0.229	0.480
Wean	6.6	6.4	6.7				
Protein, %							
d 7	4.5	4.5	4.4	0.10	0.827	0.838	0.624
Wean	4.4	4.4	4.3				
Lactose, %							
d 7	5.5	5.4	5.6	0.08	0.144	0.158	0.180
Wean	5.6	5.6	5.5				
Total solids, %							
d 7	11.2	11.1	11.2	0.12	0.136	0.656	0.561
Wean	11.3	11.3	11.0				
Somatic cell count							
d 7	719.9	1104.3	493.0	267.07	0.389	0.197	0.916
Wean	754.1	996.7	996.2				

[1]A total of 88 mixed-parity sows (Line 241, DNA, Columbus NE) and litters were used from day 110 of gestation until weaning. Litters were cross fostered within treatment group to equalize litter size up to 48-h post farrowing.
[2]Sow treatment consisted of providing a control diet (40% SID His:Lys ratio), a high-His diet, accomplished by adding feed-grade His (60% SID His:Lys ratio), or a 50:50 blend of the two diets (50% SID His:Lys ratio) from d 110 of gestation until weaning.