Effects of Increasing Dietary Lysine on Performance of Lactating Sows in Commercial Conditions[1]

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Summary

A total of 710 mixed parity sows (Line 241; DNA, Columbus, NE) were used in a 21-d study to determine the effect of standardized ileal digestible (SID) lysine (Lys) intake during lactation on sow and litter performance and subsequent reproductive performance of primiparous and multiparous sows housed in a commercial production system. On d 112 of gestation, females were weighed and blocked by BW within expected farrowing date and parity (1 to 7) and randomly assigned to 1 of 4 dietary treatments within blocks. Dietary treatments were corn-soybean meal-based and consisted of increasing SID Lys (0.75, 0.90, 1.05, and 1.20%). Treatments were formulated by increasing both crystalline Lys and soybean meal to maintain a similar soybean meal to crystalline Lys ratio. Other feed-grade amino acids (AA) were added as needed to maintain a similar ratio to Lys across treatments. All other nutrients met or exceeded the NRC[4] requirement estimates. Dietary metabolizable energy was the same across all dietary treatments. Sow BW at weaning increased (quadratic, $P = 0.046$), and sow BW loss from post-farrow to weaning or d 112 to weaning decreased (quadratic, $P \leq 0.01$) as SID Lys increased. Sow backfat loss increased (linear, $P = 0.028$) as SID Lys increased. Conversely, longissimus muscle depth loss decreased (linear, $P = 0.002$) as SID Lys increased. Percentage of females bred by d 7 after weaning increased (linear, $P = 0.047$) as SID Lys increased in parity 1 sows, with no difference in parity 2 or 3+ sows. Litter weight at d 17 and litter gain from d 2 to 17 increased (quadratic, $P = 0.01$) as SID Lys was increased up to 1.05%, with no improvement thereafter. For subsequent litter characteristics, there were no differences in total born, percentage born alive, stillborn, or mummies. In conclusion, our results suggest that increasing dietary SID Lys can reduce sow protein loss in lactation. The optimal level of dietary SID Lys required by the sow may vary based on response criteria and parity.

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[2] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[3] Pillen Family Farms, Columbus, NE.

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

Introduction

During the past two decades, genetic improvements have increased the efficiency and productivity of the sow herd. As genetics continue to evolve, requirement estimates need to be reevaluated to ensure all nutrients are met for optimum performance. In lactation, nutrients need to be supplied to support both sow maintenance and litter growth.[5] With milk production representing about 75% of total nutrient requirements in lactation,[6] it becomes increasingly important to meet the sow's requirements through diet formulation as litter size increases.

Lysine is the first limiting amino acid in corn and soybean meal-based swine diets. Because primiparous sows consume less feed than multiparous sows, maternal growth accounts for a larger percentage of daily nutrient intake. Early literature has shown decreased BW loss but no difference in litter performance when Lys increased from 0.67 to 1.00% in the diet of lactating gilts,[7,8] with varying results in sows depending on response criteria.[9] However, with modern genetics and greater productivity levels, requirements to reduce mobilization of body protein reserves, maximize litter growth, and maintain reproductive function in high producing multiparous sows need to be reevaluated.

In a previous study, we evaluated the effect of different concentrations of SID Lys in lactating primiparous sows.[10] There was an increase then decrease for d 30 conception rate as conception rate increased up to 0.95% SID Lys, but then was lowest in sows fed 1.25% SID Lys.

Sow backfat loss decreased as dietary SID Lys increased from 0.80 to 1.25%, with no other differences in sow or litter performance observed. However, this research was conducted with a smaller sample size due to limitations of sows available and did not include multiparous sows. Thus, the objective of the current study was to evaluate the effect of increasing SID Lys in lactating primiparous and multiparous sows under commercial conditions.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocols used in this experiment. The experiment was conducted on a commercial

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[5] Dourmad, J. Y., M. Etienne, A. Valancogne, S. Dubois, J. v. Milgen, and J. Noblet. 2008. InraPorc: A model and decision support tool for the nutrition of sows. Anim. Feed Sci. Technol. 143:372-386. doi:10.1016/j.anifeedsci.2007.05.019.

[6] Noblet, J., J. Y. Dourmad, and M. Etienne. 1990. Energy utilization in pregnant and lactating sows: modeling of energy requirements. J. Anim. Sci. 68:562-572. doi:10.2527/1990.682562x.

[7] Boomgaardt, J., D. H. Baker, A. H. Jensen, and B. G. Harmon. 1972. Effect of dietary lysine levels on 21-day lactation performance of first litter sows. J. Anim. Sci. 34:408-409. doi:10.2527/jas1972.343408x.

[8] Dourmad, J., J. Noblet, and M. Etienne. 1998. Effect of protein and lysine supply on performance, nitrogen balance, and body composition changes of sows during lactation. J. Anim. Sci. 76:542-550. doi:10.2527/1998.762542x.

[9] Boyd, R. D., K. J. Touchette. G. C. Castro, M. E. Johnston, K. U. Lee, and In K. Han. 2000. Recent advances in amino acid and energy nutrition of prolific sows-review. Asian. Aus. J. Anim. Sci. 13:1638-1652. doi:10.5713/ajas.2000.1638.

[10] Gourley, K. M., J. C. Woodworth, J. M. DeRouchey, M. D. Tokach, S. S. Dritz, and R. D. Goodband. 2016. Effects of lysine on performance of lactating primiparous sows. Kansas Agricultural Experiment Station Research Reports. 2:8. doi: 10.4148/2378-5977.1286.

sow farm in central Nebraska from mid-June until mid-August, 2016. Females were individually housed from d 0 to 113 of gestation and were fed a common diet with 0.70% standardized ileal digestible (SID) Lys according to body condition (thin, ideal, and fat females were offered 5.5, 4.0, and 3.0 lb, respectively). All females had ad libitum access to water.

A total of 710 primiparous and multiparous females (Line 241, DNA Genetics, Columbus, NE) were used. At d 112 of gestation, females were weighed, and on a subsample of females (n = 369), backfat and longissimus muscle depth were collected via ultrasound (Aloka SSD 500V, Hitachi Aloka Medical Ltd., Wallingford, CT; between the 10th and 11th ribs, 2.5 in. from the midline). Females were blocked by BW within expected farrowing date and parity (1 to 7) and were then randomly assigned to 1 of 4 dietary treatments within blocks. Dietary treatments were corn-soybean meal-based and consisted of increasing SID Lys (0.75, 0.90, 1.05, and 1.20%). Treatments were formulated by increasing both crystalline Lys and soybean meal to maintain a similar soybean meal to crystalline Lys ratio. Other feed-grade AA were added as needed to maintain a similar ratio to Lys across treatments. All other nutrients met or exceeded the NRC[4] requirement estimates. Dietary energy (ME, kcal/lb) was the same across all dietary treatments (Table 1).

On d 113 of gestation, females were moved to the farrowing house and fed treatment diets. Sows received 6 lb/d of feed until farrowing. Cross fostering occurred irrespective of dietary treatment until 48 h postpartum in an attempt to equalize litter size (minimum of 10 pigs per litter). Piglets did not have to be cross fostered within their respective dietary treatments. Litters were weighed on d 2 (after equalization) and d 17 post-farrowing.

At weaning (21.3 d [range 19 to 24] after farrowing), sows were returned to the gestation barn where sow body weight was determined and back fat and longissimus muscle depth were again measured via ultrasound (Aloka SSD 500V, Hitachi Aloka Medical Ltd., Wallingford, CT; between 10th and 11th ribs, 2.5 in. from the midline). Each sow was housed individually and checked daily for signs of estrus using a boar. The wean-to-estrus interval (WEI) was determined as the number of days between weaning and when sows were first observed to show a positive response to the back-pressure test. Conception rate was determined based on pregnancy confirmation using ultrasound at approximately d 30 after first insemination.

Due to the commercial setting, sow BW 24 h after farrowing was not measured. Thus, a post-farrowing weight was calculated for each sow by subtracting the weight of conceptus from the d 112 BW. Final weight of conceptus was calculated using the original equation listed in the NRC[4] and corrected by Thomas et al.[11] using the variables of parity, length of gestation, and total born.

No dietary treatments were applied after weaning and all females were fed a blend of 4 lb of a 0.70% SID Lys gestation diet and 3 lb of a 1.05% SID Lys lactation diet until

[11] Thomas, L. L. 2017. Effects of parity and stage of gestation on whole body and maternal growth and feed efficiency of sows. Master's thesis. Kansas State University, Manhattan, KS. http://hdl.handle.net/2097/35461.

breeding. After breeding, each sow was fed the gestation diet according to their body condition for the remainder of gestation (thin, ideal, and fat females were fed 5.5, 4.0, and 3.0 lb, respectively). Subsequent performance (total born, number born alive, mummies, and stillborn) were collected from sows remaining in the herd on their subsequent parity.

Experimental diets were manufactured at the Pillen Family Farms Feed Mill in Albion, NE. Feed was continuously delivered in bulk throughout the study period, and feed delivery amounts by treatment were recorded to determine total feed consumed in lactation. Average daily feed intake by treatment was calculated by dividing the total feed delivered during the trial period by number of sows on each treatment diet for each day of the trial period.

Chemical Analysis

Diet samples were taken three times per week at the lactation feeder. Samples were pooled by week to make a single composite sample. Six composite samples per dietary treatment were analyzed at a commercial laboratory (Ward Laboratories, Kearney, NE) for DM, CP, calcium (Ca), and phosphorus (P). Similarly, 6 composite samples per dietary treatment were analyzed for complete diet amino acid concentration (University of Missouri Experimental Station Chemical Laboratories, Columbia, MO; Table 2).

Data Analysis

Data were analyzed using generalized linear mixed models where dietary treatment and parity category (P1, P2, and P3+), and dietary treatment within parity category were evaluated as fixed effects, with a random effect of block. The response variables of sow BW (d 112, post farrow, and weaning), BW loss, backfat change, longissimus muscle depth change, litter weight (d 2 and d 17), litter gain, and lactation length were fitted assuming a normal distribution. Total born was used as a covariate for post farrow sow BW. Longissimus muscle depth on d 112 was used as a covariate for the depth at weaning and change over lactation period. Litter weight on d 2 was used as a covariate to improve the fit of the model for d 17 litter weight and litter gain response variables. Litter weight on d 2 and lactation length were used as covariates for sow weaning BW, sow BW change from d 112 to weaning, and sow BW change after farrow to weaning.

Day 2 litter size, d 17 litter size, and subsequent total born were fitted using a negative binomial distribution. Females bred by d 7, d 30 conception rate, and farrowing rate were fitted using a binary distribution. Subsequent born alive, stillborn, and mummies were modeled using a binomial distribution.

Results were considered significant at $P \leq 0.05$. Use of covariates were included in the model if they improved the Bayesian information criterion (BIC) by greater than 2 units. For normally distributed data, the residual assumptions were found to be reasonably met using evaluation of the studentized residuals. Statistical models were fit using PROC GLIMMIX of SAS (Version 9.4, SAS Institute Inc., Cary, NC).

Results and Discussion

Chemical analysis of DM, CP, Ca, P, and AA were similar to the formulated values (Table 2). There were no differences (*P* > 0.05) among dietary treatments in initial sow BW, backfat, or longissimus muscle depth at d 112 of gestation, which validates the randomization of sows to treatments (Table 3). There were also no differences (*P* = 0.940) in lactation length across dietary treatments.

Increasing SID Lys to 1.20% reduced BW loss within parity 2 (linear, *P* = 0.028) and parity 3+ (quadratic, *P* < 0.007) sow categories (Figure 1). Sow BW loss in lactation is common due to greater nutrient demands than voluntary feed intake can support. Previous studies have found a decrease in BW loss as dietary Lys increased.[6,12] The results for the multiparous sows do not agree with the results for primiparous sows, where no differences (*P* = 0.361) were observed in BW loss regardless of dietary Lys concentration. Additionally, previous data[11,13] did not show any differences in BW loss as Lys increased in first parity sows. The summary of research and present data would suggest that BW loss can be reduced when increasing SID Lys in multiparous sows, with minor or no benefit in primiparous sows.

Sow backfat loss in lactation increased (linear, *P* = 0.028) from -1.4 to -2.8 mm as SID Lys increased in the diet. Conversely, longissimus muscle depth loss decreased (linear, *P* = 0.002) from -1.9 to 0.5 mm as SID Lys increased, resulting in increased (linear, *P* = 0.002) depth at weaning as SID Lys level increased from 0.75 to 1.20%. Percentage of females bred by d 7 after weaning increased (linear, *P* = 0.047) as SID Lys increased in P1 sows, with no difference in P2 or P3+ sows (Figure 2), which is similar to previous studies.[11,12] No differences were observed in d 30 conception rate or farrowing rate.

For litter performance, there were no differences observed in litter size at d 2 after equalization or d 17 (Table 4). Litter weight at d 2 increased from 47.3 to 48.8 lb (quadratic, *P* = 0.016) as SID Lys level increased up to 1.05% SID Lys. This was unexpected due to cross fostering to equalize litter size. Litter weight at d 17 and litter gain from d 2 to 17 increased (quadratic, *P* = 0.001) in sows fed up to 1.05% SID Lys. There was a decrease in litter growth in sows fed 1.20% SID Lys; however, there was also a decrease in ADFI in females fed this diet. Another study[14] observed that energy had to be increased along with Lys in order to obtain benefits in milk output, which could suggest why we saw a decrease in litter growth on the highest Lys treatment with reduced feed intake. When estimating the SID Lys recommended on a g/kg of litter growth basis,[4] our sows should have required 43 to 47 g SID Lys/d. However, the estimated SID Lys consumption based on ADFI was 48 to 70 g/d of SID Lys. This would mean the sows were consuming more SID Lys than what was needed for litter growth and may have

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[12] Xue, L., X. Piao, D. Li, P. Li, R. Zhang, S. W. Kim, and B. Dong. 2012. The effect of the ratio of standardized ileal digestible lysine to metabolizable energy on growth performance, blood metabolites and hormones of lactating sows. J. Anim. Sci. Biotech. 3:11. doi:10.1186/2049-1891-3-11.

[13] Yang, H., J. E. Pettigrew, L. J. Johnston, G. C. Shurson, J. E. Wheaton, M. E. White, Y. Koketsu, A. F. Sower, and J. A. Rathmacher. 2000. Effects of dietary lysine intake during lactation on blood metabolites, hormones, and reproductive performance in primiparous sows. J. Anim. Sci. 78:1001-1009. doi:/2000.7841001x.

[14] Tokach, M. D., J. E. Pettigrew, B. A. Crooker, G. D. Dial, and A. F. Sower. 1992. Quantitative influence of lysine and energy intake on yield of milk components in the primiparous sow. J. Anim. Sci. 70:1864-1872. doi:10.2527/1992.7061864x.

been depositing excess SID Lys and AA's as body protein, which is supported by increased loin eye depth at weaning with increasing SID Lys. For subsequent reproductive performance, there were no differences in total born pigs per sow farrowed, number of pigs born alive, percentage of mummies, or stillborn ($P > 0.05$).

In conclusion, our results demonstrate that the sow will mobilize body fat reserves to satisfy litter growth requirements if nutrients are not met by dietary intake. However, increasing the levels of AA's can support the reduction of protein loss in lactation. While the optimal level of dietary SID Lys required by the sow may vary based on response criteria and parity, it is evident that reducing protein mobilization is beneficial to reproductive performance.

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

	Standardized ileal digestible Lys, %			
Ingredient	0.75	0.90	1.05	1.20
Corn	73.40	68.36	63.28	58.51
Soybean meal, 46.5% CP	19.28	24.23	29.18	33.96
Corn oil	3.00	3.00	3.00	3.00
Limestone	1.41	1.39	1.36	1.34
Monocalcium P, 21%	1.33	1.30	1.27	1.24
Salt	0.50	0.50	0.50	0.50
L-Lys-HCL	0.15	0.19	0.23	0.28
L-Thr	0.04	0.07	0.11	0.15
L-Trp	0.01	0.01	0.02	0.02
DL-Met	---	0.003	0.05	0.09
L-Val	0.06	0.12	0.18	0.24
Sal Curb[2]	0.33	0.33	0.33	0.33
Sow vitamin premix	0.20	0.20	0.20	0.20
Choline chloride	0.13	0.13	0.13	0.13
AxtraPhy 2500[3]	0.02	0.02	0.02	0.02
Dye[4]	0.16	0.16	0.16	---
Total	100	100	100	100
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.75	0.90	1.05	1.20
IIe:Lys	71	68	66	64
Met:Lys	30	30	30	31
Met and Cys:Lys	61	56	56	56
Thr:Lys	67	67	67	67
Trp:Lys	20	20	20	20
Val:Lys	90	90	90	90
Total Lys, %	0.87	1.04	1.20	1.37
ME, kcal/lb	1,553	1,553	1,553	1,553
CP, %	15.5	17.5	19.6	21.6
Ca, %	0.85	0.85	0.85	0.85
P, %	0.62	0.63	0.65	0.66
Available P, %	0.45	0.45	0.45	0.45

[1] Diets were fed from d 114 of gestation to weaning.
[2] Kemin Industries (Des Moines, IA).
[3] Dupont (St. Louis, MO).
[4] Different colored dyes were added to distinguish among diets at the farm.

Table 2. Chemical analysis of the diets (as-fed basis)[1]

	Standardized ileal digestible Lys, %			
Item, %	0.75	0.90	1.05	1.20
DM	88.02	88.24	88.54	88.88
CP	14.78	16.87	18.25	20.08
Ca	0.97	0.94	1.04	0.99
P	0.62	0.66	0.62	0.63
Total AA, %				
Lys	0.89	1.03	1.19	1.31
Ile	0.64	0.71	0.82	0.88
Leu	1.36	1.48	1.61	1.69
Met	0.22	0.24	0.32	0.38
Met and Cys	0.46	0.50	0.62	0.68
Thr	0.58	0.68	0.79	0.89
Trp	0.12	0.15	0.16	0.18
Val	0.82	0.94	1.12	1.25
His	0.38	0.42	0.48	0.51
Phe	0.75	0.84	0.94	1.00
Free Lys	0.12	0.14	0.18	0.21

[1] Diets were collected twice per week and pooled to make a composite sample. Six composite samples per dietary treatment were used for analysis. Total AA analyses were conducted by University of Missouri Experimental Station Chemical Laboratories (Columbia, MO). Dry matter, CP, Ca and P analyses were conducted by Ward Laboratories (Kearney, NE).

Table 3. Effects of increasing dietary lysine on sow performance in lactation of gilts and sows under commercial conditions[1]

	Standardized ileal digestible (SID) Lys, %					Probability, $P <$	
	0.75	0.90	1.05	1.20	SEM[9]	Linear	Quadratic
Count, n	187	185	194	144	---	---	---
Parity	3.1	3.2	3.2	3.2	0.15	0.576	0.928
Sow BW, lb							
d 112[2]	460	460	460	458	4.0	0.478	0.932
Post-farrow [2,3]	429	427	427	424	4.0	0.487	0.958
Wean[2]	381	387	396	389	4.4	0.017	0.046
Sow BW change, lb							
Post-farrow[3] to wean[2]	-46.9	-40.0	-32.1	-37.2	3.19	0.001	0.018
d 112 to wean[2]	-78.5	-70.2	-62.7	-69.5	3.30	0.003	0.004
Sow back fat,[4] mm							
d 112[2]	20.0	21.2	20.3	20.1	0.65	0.676	0.184
Wean[2]	18.6	18.4	17.6	18.0	0.45	0.121	0.395
Change (d 112 to wean)[2]	-1.4	-2.6	-2.8	-2.6	0.44	0.028	0.061
Loin eye depth, mm							
d 112[2]	52.9	52.4	52.3	52.6	0.77	0.722	0.575
Wean[2]	50.2	51.2	52.0	52.6	0.64	0.002	0.784
Change (d 112 to wean)[2]	-1.9	-1.0	-0.1	0.5	0.61	0.002	0.784
Lactation length, d	21.3	21.4	21.4	21.4	0.11	0.485	0.435
Females bred by d 7 after weaning,[2] %	88.9	92.6	94.8	92.4	2.60	0.227	0.199
d 30 conception rate,[5] %	94.7	89.7	95.8	90.8	2.86	0.928	0.700
Farrowing rate,[6] %	92.3	85.6	93.8	88.6	3.39	0.957	0.951
ADFI from feed delivery records,[7] lb	14.19	13.99	14.70	12.98	---	---	---
SID Lys intake,[8] g/d	48.4	57.2	70.2	70.6	---	---	---

[1] A total of 710 sows (DNA 241) and litters were used in a lactation study from d 112 of gestation until weaning.
[2] Significant differences of treatment within parity category were observed.
[3] Post-farrow weight was calculated using d 112 BW and subtracting weight of conceptus (calculated using modified equation by Thomas et al., 2016).
[4] A subsample of sows (n = 369) were ultrasounded on d 112 for backfat and loin eye depth and subsequently used in the backfat and loin eye depth change calculation. All 710 sows were measured at weaning for backfat and loin eye depth.
[5] Number of sows confirmed pregnant on d 30 post mating divided by number of sows bred.
[6] Number of sows farrowed divided by number of sows bred by d 21 after weaning.
[7] Calculated using total feed deliveries by treatment and dividing by total number of sow lactation days per treatment.
[8] Calculated using ADFI multiplied by SID Lys in the experimental diet.
[9] SEM = standard error of the means.

Table 4. Effects of increasing dietary lysine in lactation on litter performance of gilts and sows under commercial conditions[1]

	Standardized ileal digestible Lys, %					Probability, *P* <	
	0.75	0.90	1.05	1.20	SEM[4]	Linear	Quadratic
Total born	15.9	15.4	15.4	16.4	0.38	0.497	0.255
Litter size,[2] n							
d 2	13.6	13.7	13.7	13.7	0.07	0.950	0.965
d 17	12.6	12.7	12.7	12.7	0.11	0.896	0.945
Litter weight, lb							
d 2	47.3	48.0	48.8	46.6	0.75	0.835	0.016
d 17	134.9	135.3	141.0	132.4	1.41	0.807	0.001
Litter gain d 2 to 17, lb	87.3	87.6	93.5	84.9	1.41	0.807	0.001
Litter ADG d 2 to 17, lb	5.93	5.95	6.35	5.76	0.095	0.807	0.001
Subsequent performance[3]							
Total born per sow farrowed, n	15.9	16.0	16.3	15.1	0.41	0.482	0.310
Born alive, %	92.0	93.0	92.0	92.4	0.78	0.863	0.666
Stillborns, %	4.3	3.3	4.2	5.1	0.63	0.150	0.065
Mummies, %	3.5	3.6	3.7	2.4	0.51	0.158	0.110

[1] A total of 710 sows (DNA 241) and litters were used in a lactation study from d 112 of gestation until weaning.

[2] Litters were cross-fostered to equalize litter size up to 48-h post-farrowing.

[3] Number of sows included in subsequent performance are 161, 149, 140, and 108 for dietary treatments of 0.75, 0.90, 1.05, and 1.20% standardized ileal digestible (SID) Lys, respectively.

[4] SEM = standard error of the mean.

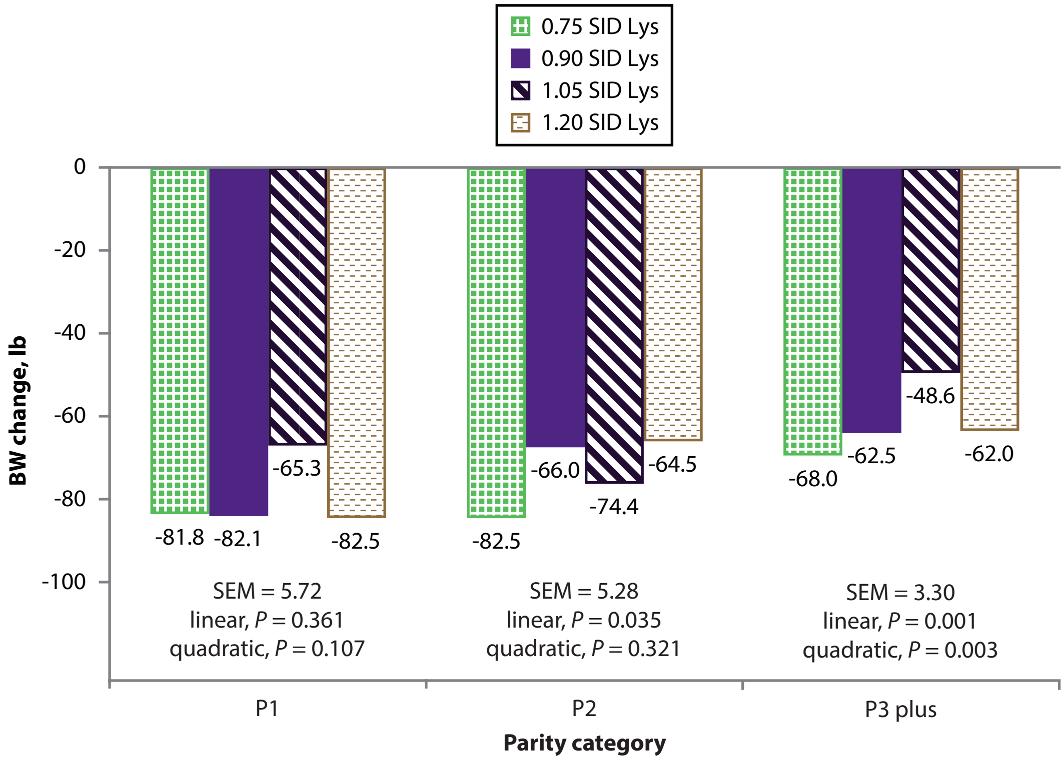

Figure 1. Estimated mean sow BW loss from d 112 of gestation until weaning within parity category for sows fed increasing standardized ileal digestible (SID) Lys in lactation. SEM = standard error of the mean.

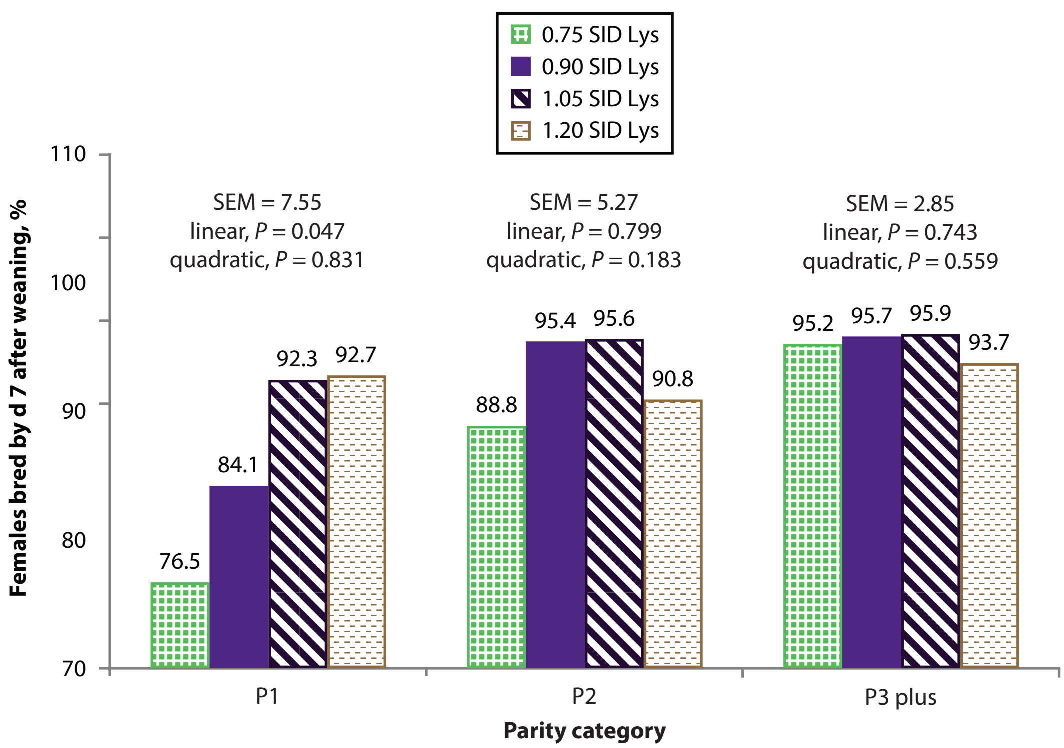

Figure 2. Estimated percentage females bred by d 7 after weaning within parity category for sows fed increasing standardized ileal digestible (SID) Lys in lactation. SEM = standard error of the mean.