Supplemental Lysine for Sows Nursing Large Litters

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ABSTRACT: A cooperative experiment involving 501 litters was conducted at four stations to assess the effects of supplemental lysine on lactational performance of sows nursing large litters. Basal diets were formulated to contain .60% lysine from corn or sorghum and soybean meal. Lysine·HCl (78.8% lysine) was substituted for grain to achieve dietary lysine levels of .75 and .90%. First-parity sows nursed a minimum of nine pigs per litter and older sows a minimum of 10 pigs per litter by d 3 of lactation. Overall mean litter size at 21 d of age was 9.7 pigs. Sows remained on treatment for three successive parities unless culled for structural unsoundness or reproductive failure. Dietary lysine did not affect body weight or backfat loss during lactation, sow ADFI, interval from weaning to estrus, or litter size at birth or at 21 d of age. Mean pig weights at birth and at 21 d of age increased quadratically to increasing lysine, with improvements found at all stations from increasing lysine from .60 to .75%. Twenty-one-day pig weights did not increase at the highest lysine level at stations feeding corn, but did improve at the station feeding sorghum, which resulted in a treatment × station interaction ($P < .05$). The different responses to lysine on different grain sources indicates intake of one or more other amino acid may have limited lactation performance at the highest level of lysine. These data indicate that a 13% CP corn-soybean meal containing .60% lysine is inadequate for sows nursing large litters and that supplemental synthetic lysine beyond .15% additional lysine will not be beneficial due to a deficiency of one or more other amino acids.

Key Words: Sows, Lysine, Lactation, Reproductive Performance

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Introduction

The amino acid requirements of lactating sows are closely correlated with the production and composition of sow's milk. The ARC (1981) estimates the lysine requirement for sows during lactation to be 33 g/d or .63% of the diet assuming a feed intake of 5.25 kg/d. The NRC (1988) estimate of the requirement for this period is .60%. Current lysine requirements are basically in agreement with the results of Baker et al. (1970) and Speer (1990). These authors made their calculations assuming milk yields of only 6 and 5 kg/d and milk protein contents of 5.2 and 5.0% (wet basis), respectively.

Sow productivity has increased dramatically in recent years because of the use of specific crosses of Landrace, Yorkshire, and Large White breeds to produce sows for terminal crossbreeding programs (USDA, 1992). It is appropriate to question whether previous assumptions concerning levels of milk production and the resulting lysine requirement adequately reflect the demand placed on sows today. King (1991) estimated that a 200-kg sow nursing 10 pigs would produce 10 to 12 kg milk/d and require 61 g of lysine/d. Stahly et al. (1990), Johnston et al. (1993), and Monegue et al. (1993) reported that sows nursing large litters and fed corn-soybean meal diets responded to protein levels in excess of those suggested by the NRC (1988).

Only a few studies (Boomgaardt et al., 1972; Lewis and Speer, 1973; Chen et al., 1978; Sohail et al., 1978; Wilkinson et al., 1982) have used the approach of supplementing a lysine-deficient basal diet with crystalline lysine to estimate the requirement. Lysine requirements determined by these researchers ranged from 20 to 51 g/d. Differences in experimental procedures, number of pigs nursed per litter, and weaning age undoubtedly influenced the estimated requirements.

The purpose of this cooperative research was to determine whether sows nursing large litters and consuming practical diets require more lysine than the .60% estimated by the NRC (1988).

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Table 1. Number of litters and husbandry practices by station

Item	Station			
	Alabama	Florida	Georgia	Texas
No. litters	121	43	183	154
Breeds (boar × sow)[a]	DHY	DHY	D × HY	DH × YL
Crossbreeding system	Three breed rotation	Three breed rotation	Three breed rotation	Four breed rotation
Initial sow parity	1	1.84	2.79	1
Avg parity	1.87	2.55	3.67	1.74
Avg days to 21 d	20.8	21.0	21.0	20.3
Avg age at weaning, d	28.0	21.0	25.6	27.4
Housing				
Breeding	Grouped on soil	Grouped on concrete	Individual stalls	Individual stalls
Gestation	Grouped on soil	Grouped on concrete	Individual stalls	Individual stalls
Lactation	Individual stalls	Individual stalls	Individual stalls	Individual stalls
Grain source	Corn	Corn	Corn	Sorghum

[a]Breeds were as follows: D, Duroc; H, Hampshire; L, Landrace; Y, Yorkshire.

Materials and Methods

A cooperative regional study involving 501 litters was conducted at four research stations. Participating stations were in Alabama, Florida, Georgia, and Texas. Number of litters provided by each station and procedural variables for each station are given in Table 1.

Sows and gilts were allotted at the beginning of their first lactation of the experiment to the three dietary treatments based on parity, 110-d gestation weight, and boar to which sows were bred. They remained on the same treatment for three consecutive parities unless culled for structural unsoundness, failure to show estrus within 30 d after weaning, or failure to farrow after the first service after weaning.

The basal diets were formulated to contain .60% lysine from corn plus soybean meal or from sorghum plus soybean meal (Table 2). Lysine·HCl (78.8% lysine) was substituted for grain in the basal diets to achieve dietary levels of either .75 or .90% lysine. Calcium and P contents exceeded NRC (1988) estimates, and all stations used the same vitamin and trace mineral premixes.

During the gestation period before assignment to treatment and during the interval from weaning to farrowing, sows were fed 1.8 kg/d of the basal diet. During the winter months of December, January, and February, intake was increased to 2.3 kg/d. Beginning on the day of farrowing, sows had ad libitum access to diet and water throughout lactation.

Sows were weighed within 24 h after farrowing, at 21 d of lactation and at weaning. Backfat measurements at the last rib about 4 to 5 cm off of the midline were obtained within 24 h after farrowing and at 21 d of lactation. All stations used ultrasound devices for measuring backfat. Days from weaning to estrus were recorded. Some sows culled for structural unsoundness were sold after weaning, and days to estrus were not determined. Sows not expressing estrus within 30 d were assigned a value of 30 d and then culled.

Pigs per litter and average pig weights were obtained for total and live pigs at birth, after crossfostering, and at 21 d of lactation. Pigs were crossfostered among litters, irrespective of dietary treatment, to have at least nine pigs per litter for first parity sows and at least 10 pigs per litter for multiparous sows by d 3 of lactation.

Table 2. Composition of basal diets[a]

	Grain[b]	
	Corn	Sorghum
Ground grain	82.89	82.31
Soybean meal (44% CP)[c]	13.69	14.30
Dicalcium phosphate	1.51	1.50
Limestone	1.16	1.14
Salt	.50	.50
Vitamin-trace mineral premix[d]	.25	.25
Calculated analyses[e]		
CP, %	13.1	13.6
Lysine, %	.60	.60
Methionine + cystine	.49	.49
Isoleucine, %	.56	.65
Threonine, %	.53	.47
Tryptophan, %	.13	.17
Valine, %	.67	.72
DE, Mcal/kg	3.40	3.31

[a]As-fed basis. Lysine·HCl (78.8% lysine) was substituted for .19 and .38% grain to obtain dietary lysine contents of .75 and .90%, respectively. All diets were formulated to contain .80% Ca and .70% P.

[b]Sorghum was used at Texas A&M University. All others used corn.

[c]When 48% CP soybean meal was used, soybean meal was decreased and grain increased by 1.15% or 1.20% when corn or sorghum, respectively, were used.

[d]Provided the following (per kilogram of the completed diet): vitamin A, 11,000 IU; vitamin D_3, 550 IU; vitamin E, 44 IU; menadione sodium bisulfite complex, 9.1 mg; vitamin B_{12}, 33 μg; riboflavin, 6.6 mg; *d*-pantothenic acid, 22 mg; niacin, 28 mg; choline, 660 mg; *d*-biotin, .220 mg; zinc, 125 mg; iron, 125 mg; manganese, 40 mg; copper, 10 mg; iodine, .125 mg; selenium, .3 mg.

[e]Calculated contents based on NRC (1988) nutrient contents for feedstuffs.

Table 3. Effect of station on reproductive performance of sows

Item	Station[a] AL	FL	GA	TX	SEM
No. litters	121	43	183	154	
Sow traits					
Postfarrowing wt, kg[b]	185.2	218.9	195.5	180.6	2.20
21 d lactation wt change, kg	–1.2	–5.6	–1.2	–6.4	.77
Postfarrowing backfat, mm[b]	14.3	21.9	14.6	18.0	.42
21 d lactation backfat change, mm	.9	–1.3	–.6	–1.3	.23
ADFI to d 21, kg	7.50	5.23	5.17	4.82	.06
Weaning to estrus, d[c]	6.1	5.6	5.5	6.6	.26
Avg. litter size					
Total born[b]	11.3	12.6	11.1	9.4	.31
Live born[b]	10.7	12.1	10.4	9.2	.30
After crossfostering	11.0	11.5	10.7	10.7	.10
21 d of age	10.2	10.5	9.4	9.3	.11
Avg. pig weight					
Total born[b]	1.52	1.43	1.42	1.55	.03
Live born[b]	1.54	1.45	1.44	1.55	.03
After crossfostering	1.52	1.50	1.41	1.54	.02
21 d of age	5.02	4.98	5.51	5.05	.04

[a]Stations were AL (Auburn University), FL (University of Florida), GA (University of Georgia, Coastal Plains Experiment Station), and TX (Texas A&M University).
[b]Means do not include data for first farrowings because dietary treatments had been imposed only 3 to 5 d before data were collected. Numbers of observations are 72, 18, 92, and 80 for AL, FL, GA, and TX, respectively, when data for first farrowings are not included.
[c]Numbers of observations are 120, 25, 173, and 149 for AL, FL, GA, and TX, respectively.

Standard litter management procedures, including injection of iron, clipping needle teeth, tail docking, and ear notching, were performed. Pigs were weaned at 21 d of age (Florida) or 28 d of age (Alabama, Georgia, Texas). Creep feed was not offered before 21 d of age.

The independent variables in the statistical model were the main effects of treatment, station, and sow parity and the interactions of the main effects. A parity value of three was assigned to observations with parities of four or more. Treatment sums of squares were partitioned into linear and quadratic effects of dietary lysine. All treatment means were adjusted for sow parity by covariant analyses. Means for average weights of all pigs born, live pigs born, and pigs after crossfostering were adjusted using total pigs per litter, live pigs per litter, and pigs per litter after crossfostering as covariates, respectively. Average pig weight at 21 d was adjusted using number of pigs per litter at 21 d, age at 21 d and average weight of pigs born alive as covariates. Adjusted means are reported. Statistical calculations were conducted using the GLM procedure of SAS (1985). Mean squares based on type III sums of squares were tested using the residual error term.

Results

Station effects ($P < .05$, Table 3) were found for all measured traits, with the exception of average weight of total and live pigs born and days from weaning to estrus. Station effects are common to cooperative research studies and are expected due to differences in environment and genetic potential of sows and pigs among stations. Litter size after crossfostering and at 21 d of age ranged from 10.7 to 11.5 and from 9.3 to 10.5, among stations, respectively, suggesting that nursing stimulus should have been adequate to cause a high lactation demand.

Increasing dietary lysine in a 13% CP diet did not affect the weaning to estrus interval, or average litter size at birth (total or live), after crossfostering or at 21 d of age (Table 4). Increasing lysine did result in a quadratic improvement ($P < .05$) in average weights of total and live pigs born. A treatment × station interaction occurred for average 21-d pig weight. Increasing dietary lysine from .60 to .75% increased 21-d pig weights at all stations, but the increase to .90% lysine improved pig weights only at the Texas station (Figure 1). The highest level of lysine at stations other than Texas seemed to reduce average pig weight at 21 d.

Treatment × station interactions also occurred for 21-d lactation weight change ($P < .01$) and sow ADFI ($P < .05$). Increasing lysine reduced lactation weight loss at two stations (Alabama, –4.2, –.9, and 1.8 kg for the .60, .75, and .90% lysine treatments, respectively; Florida, –6.7, –6.0, –4.5 kg) but tended to increase weight loss at the other stations (Georgia, 1.5, –2.5, –2.7 kg; Texas –5.7, –5.7, –8.1 kg). Sow feed intake

Table 4. Effect of dietary lysine on lactational performance

Item	Lysine, %			P[a]				
				Lysine				
	.60	.75	.90	Linear	Quadratic	Lys × Sta	Lys × Parity	SEM
No. litters	172	164	165					
Sow traits								
Postfarrowing wt, kg[b]	185.3	191.9	192.2	.67	.39	.28	.07	2.20
21 d lactation wt change, kg	–2.8	–3.6	–3.3	.78	.69	<.01	.17	.77
Postfarrowing backfat, mm[b]	15.4	16.1	16.6	.23	.72	.78	.02	.42
21 d lactation backfat change, mm	–.6	–.5	–.5	.66	.73	.33	<.01	.23
ADFI to d 21, kg	5.68	5.59	5.62	.26	.59	.04	.21	.06
Weaning to estrus, d[c]	6.1	6.1	6.0	.26	.44	.38	.24	.26
Avg litter size								
Total born[b]	10.7	10.7	10.8	.47	.78	.57	.50	.31
Live born[b]	10.2	10.2	10.3	.59	.94	.31	.38	.30
After crossfostering	10.8	10.9	10.9	.42	.59	.20	.14	.10
21 d of age	9.6	9.7	9.7	.55	.86	.21	.29	.11
Avg pig weight[de]								
Total born[b]	1.47	1.54	1.46	.26	.02	.85	.72	.03
Live born[b]	1.49	1.55	1.47	.36	.03	.92	.79	.03
After crossfostering	1.47	1.52	1.47	.09	.11	.19	.94	.02
21 d of age	5.01	5.24	5.20	.03	.07	.01	.07	.56

[a]Parity effect was significant ($P < .10$) for all traits. Station (Sta) effect was significant ($P < .05$) for all traits except average weight of total and live pigs born and weaning to estrus interval.
[b]Means do not include data from the first farrowings of sows and gilts. The numbers of observations are 91, 81, and 90 for the .60, .75, and .90% lysine treatments, respectively.
[c]Numbers of observations are 163, 147, and 157 for the .60, .75, and .90% lysine treatments, respectively.
[d]Average pig weights adjusted for litter size.
[e]Main effect P values for total born, live born, after crossfostering, and at 21 d of age are .03, .04, .06, and .02, respectively.

was increased by increasing lysine at Florida (4.85, 5.23, 5.50 kg/d) and Texas (4.65, 4.92, 4.90 kg/d) but not at Georgia (5.26, 5.23, 5.02 kg/d) or Alabama (7.59, 7.30, 7.56 kg/d). The main effect of dietary lysine on ADFI and lactation weight change was not significant ($P > .40$).

A treatment × parity interaction ($P < .10$) for 21-d pig weights resulted from a greater increase in pig weights for parity 3 and older sows than for parity 1 and 2 sows as lysine increased from .60 to .75% (Figure 1). Treatment × parity interactions occurred in 21-d lactation backfat change ($P < .01$). During parity 1, increasing lysine resulted in a reduction in backfat loss (–1.7, –1.2, and –.4 mm for the .60, .75, and .90% lysine diets, respectively), whereas in parity 2 (–1.5, .1, –1.1 mm) and parities of 3 and older (.3, –.5, –.2 mm) no clear response to lysine was found. The main effect of lysine on 21-d lactation backfat change was not significant ($P > .40$).

Discussion

The addition of lysine·HCl to a 13% CP diet did not affect (main effects) sow ADFI, lactation weight loss, lactation backfat loss, days to estrus postweaning, or litter size at birth or at 21 d of age. Recent studies in which dietary lysine was increased by increasing dietary CP support most of these findings. Sow ADFI, backfat loss, and litter size at weaning were not affected by increases in lysine from .42 to .92% (Stahly et al., 1990), .62 to 1.05% (Johnston et al., 1993), .60 to .90% (Monegue et al., 1993), .60 to .70% (Weeden et al., 1994), or .80 to 1.20% (Richert et al., 1994). Similarly, Stahly et al. (1990), Johnston et al. (1993), Monegue et al. (1993), and Weeden et al. (1994) reported that increased dietary protein did not affect days from weaning to estrus. However, Stahly et al. (1990), Johnston et al. (1993), Monegue et al. (1993), and Richert et al. (1994) found that increasing CP reduced lactation weight loss, which is in contrast to the present study, indicating that lysine alone will not spare body stores of nursing sows. The NCR-42 (1978), Greenhalgh et al. (1977; 1980), and Weeden et al. (1994) reported that increasing the percentage of CP in the lactation diet did not affect litter size at birth in the subsequent parity. Because inadequate protein intake in gestation affects subsequent lactational response to dietary protein (Mahan and Mangan, 1975), it is important to note that, in the present study and those cited above, sows were fed at least an 11% CP diet during gestation.

In the present study, sows fed the .60, .75, or the .90% lysine diet consumed, on average, 34, 42, and 51 g/d of lysine, respectively. The response in 21-d pig weights from increasing lysine intake from 34 to 42 g/d is consistent with reports evaluating dietary protein levels for sows nursing large litters. Maximal

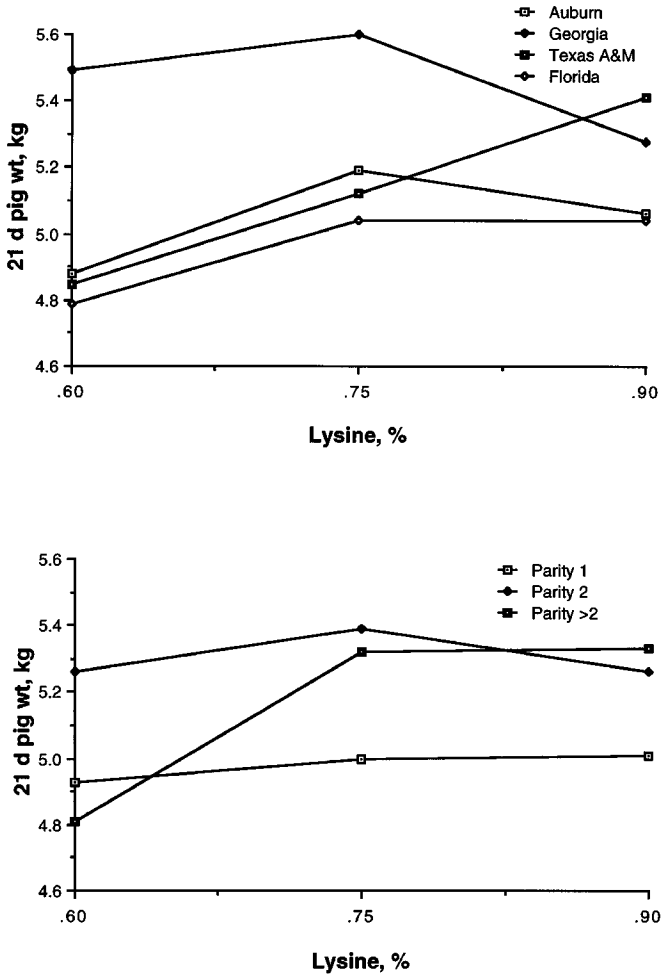

Figure 1. Interactions of dietary lysine with station and parity for average pig weight at 21 d. Pooled SEM was .56.

response in pig weaning weights, or litter weaning weights, occurred at 47 g lysine/d (Stahly et al., 1990; sows consumed 20 to 47 g/d and weaned 10.5 pigs per litter), 55 g/d (Johnston et al., 1993; sows consumed 36 to 57 g/d and weaned 10.5 pigs per litter), 55 g/d (Monegue et al., 1993; sows consumed 35 to 55 g/d and weaned 11.1 pigs per litter), and 57 g/d (Richert et al., 1994; sows consumed 36 or 57 g/d and weaned 10.5 pigs per litter). Sows nursing smaller litters have failed to respond to lysine in excess of NRC (1988) requirements. A 14% CP corn-soybean meal diet was adequate for sows weaning 8.1 pigs per litter (Weeden et al., 1994). Similarly, sows nursing 10.5 pigs per litter responded to lysine in excess of .80%, whereas those nursing 8.5 pigs per litter did not (Richert et al., 1994). The data suggest that litter size and litter weight gain should be factored into the estimation of amino acid requirements of sows.

At the three stations feeding corn-based diets, 21-d pig weights were not increased by feeding the .90% lysine diet. Although the possibility exists that the .75% lysine diet met the sow's nutrient needs, another possibility is that a nutrient deficiency was limiting the sow's ability to respond to the higher lysine intake. Energy intake is known to affect milk yield (King and Williams, 1984; Tokach et al., 1992), but energy intake should not have been the limiting factor in the present study. On average, sows consumed about 19 Mcal of DE/d. King et al. (1993) fed sows nursing nine pigs 14.4 Mcal of DE/d and found increases in N retention up to 1.3% lysine (52 g/d) and increases in pig weaning weights up to 1.1% lysine (45 g/d).

The improvement in 21-d pig weights by feeding .90% lysine in the sorghum-based diet suggests that an amino acid other than lysine was limiting performance of sows fed the corn-based diet. A comparison of calculated amino acid contents of the corn- and sorghum based-diets indicates that tryptophan may have been the limiting amino acid in the corn-based diets. Tryptophan contents expressed as a percentage of lysine were 22, 17, and 14% for the corn-based diet and 28, 23, and 19% for the sorghum-based diet containing .60, .75, and .90% lysine, respectively. Speer (1990) estimated the proportion of tryptophan to lysine should be 16% for the lactating sow. The proportions of tryptophan to lysine in the lactation diet indicated by the ARC (1981), INRA (1984), CSIRO (1987), and NRC (1988) are 19, 20, 19, and 20%, respectively. The proportion of tryptophan to lysine in sow's milk has been reported to be 17% (Elliott et al., 1971). Isoleucine and valine contents of the sorghum-based diet were also higher than the contents of the corn-based diet. At .90% dietary lysine, the proportions of isoleucine and valine to lysine were estimated to be 62 and 74%, respectively, for the corn-based diet and 72 and 80% for the sorghum-based diet. Corresponding values reported for sow's milk were 51 and 63% for isoleucine and valine, respectively (Elliott et al., 1971). Therefore both amino acids were perhaps adequate in the corn-based diet. Regardless of which amino acid was limiting performance at the .90% lysine diet, the lack of response shows there are upper limits to which synthetic lysine can be used to meet the needs of the sow nursing in excess of 9.5 pigs and fed a 13% CP corn-based diet supplemented with only lysine.

Threonine contents of both corn and sorghum diets containing .90% lysine may have been inadequate for maximum lactational response. Calculated threonine: lysine ratios were .59 and .52 for the corn- and sorghum-based diets containing .90% lysine, respectively, and these values are below the .60 and .67 ratios suggested by ARC (1981) and NRC (1988), respectively. Similar calculations for the other essential amino acids show that their ratios to lysine exceed NRC (1988) and ARC (1981) suggestions, with the exception of the methionine + cystine:lysine ratio of .54, which is less than the .57 suggested by NRC (1988) but more than the .50 suggested by ARC (1981).

Implications

These data indicate that 13% crude protein grain-soybean meal diets containing .60% lysine will not support maximum lactational performance of sows nursing litters in excess of 9.5 pigs. The addition of .15% synthetic lysine to the 13% crude protein diets improved milk production in the sow, as indicated by increased 21-day pig weights. Further addition of lysine to corn-based diets failed to improve performance, indicating that one or more amino acids other than lysine was limiting performance.

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