JOURNAL OF ANIMAL SCIENCE
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J Anim Sci 2007.85:1453-1458.
doi: 10.2527/jas.2006-402 originally published online Feb 12, 2007;

Evaluation of sex and lysine during the nursery period

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ABSTRACT: Split-sex feeding in the grow-finish period of swine production was an innovative technology of the last decade because of the different growth rates, feed efficiencies, and perhaps different nutrient needs between gilts and barrows. However, due to various weaning strategies, split-sex feeding has not been adequately evaluated in the nursery. The objectives of our research were to determine 1) if gilts and barrows responded similarly to increased protein (Lys) after weaning, and 2) if the current NRC estimated requirements for Lys are adequate. Six experiment stations (KS, KY, MI, MN, OH, and SD) utilized 748 pigs (6.7 kg of BW; 19.4 ± 1.1 d of age). The pigs were allotted to 4 treatments in 32 replications (5 to 7 pigs/pen) in a randomized complete block design. Barrows and gilts were penned separately, and complex nursery diets were fed in 3 phases (d 1 to 7, 8 to 21, and 22 to 35). Lysine was provided at the NRC estimated requirements or at 0.20% greater (1.35 vs. 1.55%, 1.25 vs. 1.45%, and 1.15 vs. 1.35% for the 3 phases, respectively). Pigs and feed were weighed initially and at the end of each phase. The results demonstrated that sex did not affect ADG, ADFI, or G:F in any phase or during the 35-d study (453 vs. 452 g/d, 674 vs. 675 g/d, and 0.673 vs. 0.671 for barrows and gilts, respectively). The greater Lys concentration improved ADG in phase 3 (628 vs. 589 g; $P < 0.001$) and overall (465 vs. 441 g; $P < 0.001$) compared with pigs fed the NRC-estimated Lys requirements. Increased Lys in the diet increased ADFI in phase 2 ($P < 0.05$), but not in the other phases or for the overall 35-d study. Gain:feed was improved by feeding greater Lys concentrations in phase 2 (0.785 vs. 0.704; $P < 0.001$) and in the overall 35-d experiment (0.695 vs. 0.649; $P < 0.001$). There was no evidence of a sex × Lys interaction ($P = 0.33$) for any of the response variables during any of the phases or overall. Our results demonstrate that increasing Lys concentrations in nursery diets results in improved pig performance of both sexes, and there appears to be no benefit to split-sex feeding when mixed genotypes are fed in the nursery.

Key words: sex, lysine, nursery pig, pig

J. Anim. Sci. 2007. 85:1453–1458
doi:10.2527/jas.2006-402

INTRODUCTION

Split-sex feeding has been an innovative technology for the past decade in grow-finish pig production. The NCR-42 Committee on Swine Nutrition reported that gilts had a greater Lys need from 35 to 105 kg compared with barrows, who maximized their gain at a lower protein concentration (Cromwell et al., 1993). With producers often weaning intact litters to minimize stress, this technology has not been applied in the nursery phase. Utilizing wean-to-finish facilities, Wolter et al. (2000; 2001) studied group size and floor space allowance for this production system, but they did not consider sex. Hence, it is important to determine if there is a different nutrient need for sex during the nursery phase of production.

Kornegay et al. (1994) reported that gilts grew faster and ate more feed than barrows when weaned at 25 d of age, regardless of the CP concentration (16 vs. 22%) of the diet, but barrows and gilts fed 22% CP-diets gained faster compared with those fed 16%. In those studies, equal numbers of barrows and gilts were fed in each pen. Cromwell et al. (1996) utilized posthoc analysis of data from pigs fed in mixed-sex pens and reported that gilts gained faster than barrows. How-

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Received June 23, 2006.

Accepted January 25, 2007.

Table 1. Summary of pigs used and station conditions in the experiment

	Station					
Item	A	B	C	D	E	F
No. of pigs	192	120	168	96	100	72
Pigs/pen	6 or 7	5	6	6	5	6
Pig genetics[1]	PIC 327 × L 42	(Y × L) × D or Y × D	(Y × L) × Duroc	GAP (Canada)	(Y × L) × PIC	AusGene International Inc.
Pen flooring type	Woven wire	Plastic coated woven wire	Flat bar steel	Plastic coated	Plastic coated	Plastic
Floor space/pig, m^2	0.25	0.28	0.37	0.31	0.30	0.25
No. of replications	7	6	7	4	5	3
Mean initial age, d	21	19	19	18	19	20
Initial BW, kg	6.2 ± 0.1	8.1 ± 0.2	6.3 ± 0.1	6.5 ± 0.2	7.1 ± 0.2	5.3 ± 0.2
Final BW, kg	22.1 ± 0.3	25.8 ± 0.4	20.3 ± 0.3	23.1 ± 0.5	23.0 ± 0.4	19.0 ± 0.5
ADG, g	451 ± 7	544 ± 7	399 ± 7	475 ± 9	455 ± 8	392 ± 10
ADFI, g	653 ± 10	820 ± 11	585 ± 10	701 ± 13	688 ± 12	599 ± 15

[1]PIC = PIC International; Y = Yorkshire; L = Landrace; D = Duroc; GAP = genetically advanced pigs; and AusGene = a genetic line of pigs originally developed in Australia.

ever, more recently, with over 2,000 lean-genotype nursery pigs in several studies, Yi et al. (2006) reported that sex did not affect any production variable. Martinez and Knabe (1990) studied the addition of 0.62 to 1.01% Lys to starter diets and reported that the digestible Lys requirement of pigs weaned at 28 d of age was 1.03%. More recent work from Kansas State University (Schneider et al., 2005) indicates that the true ileal, digestible Lys need for nursery pigs is 1.3%.

Therefore, the objectives of this research were to determine 1) if gilts and barrows from different stations and of differing management strategies and genetic backgrounds respond similarly to increased protein (Lys) after weaning, and 2) if the current NRC (1998) Lys estimated requirements are adequate to maximize growth performance.

MATERIALS AND METHODS

Pigs and Diets

Six experiment stations (KS, KY, MI, MN, OH, and SD) provided a total of 748 pigs (6.7 kg; 19.4 ± 1.1 d). Each station followed the approved experimental procedures for their respective animal care and use committees. Pigs from the different stations had varying genetics, as described in Table 1. The pigs were allotted to 4 treatments in 32 replications (5 to 7 pigs/pen) in a randomized complete block design (Table 1). Barrows and gilts were penned separately, and complex nursery diets were fed in 3 phases (d 1 to 7, 8 to 21, and 22 to 35). Total Lys was provided at the NRC (1998)-estimated requirements or at 0.20% greater (1.35 vs. 1.55%, 1.25 vs. 1.45%, and 1.15 vs. 1.35% for each of the 3 phases, respectively). The additional Lys was supplied by increasing levels of fish meal. Because these were nursery-age pigs, we chose to use an animal protein source (fish meal) to supply the additional Lys rather than utilizing soybean meal or crystalline Lys. In all diets, dispensable AA other than Lys were included at constant ratios relative to Lys (NRC, 1998). The experimental diets (Tables 2 and 3) were formulated to meet all known nutrient needs for pigs of this weight (NRC, 1998). Feed and water were available ad libitum throughout the study. Individual pig weights were recorded initially and at the end of each phase. Feed disappearance was recorded for each phase. At the conclusion of the experiment, the data were summarized, and the ADG, ADFI, and G:F were calculated for each phase and overall for the entire experiment.

Chemical Analysis

The diets from each experiment station were analyzed for DM (AOAC, 1998) and for CP (AOAC, 2000). Amino acids were analyzed in all diet samples with an amino acid analyzer (Beckman 6300, Beckman Instruments Corp., Palo Alto, CA) using ninhydrin for postcolumn derivatization and norleucine as the internal standard. Before analysis, the samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C (AOAC, 1998). Methionine and Cys were determined as Met sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis (AOAC, 1998). Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C (AOAC, 1995). All analyses were performed at South Dakota State University.

Statistical Analysis

The data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC). The model included the effects of station, replication within station, sex, Lys concentration, and the sex × Lys interaction. Pen was considered the experimental unit for ADG, ADFI, and G:F. A probability of $P < 0.05$ was considered statistically significant.

Table 2. Ingredient composition of the experimental diets, as-fed basis

	Phase 1[1]		Phase 2		Phase 3	
Ingredient, %	NRC[2]	NRC + 0.2% Lys	NRC	NRC + 0.2% Lys	NRC	NRC + 0.2% Lys
Corn, ground	41.58	38.09	54.03	50.52	60.88	57.38
Soybean meal, 48%	9.06	9.05	17.31	17.30	28.93	28.92
Dried whey	15.00	15.00	10.00	10.00	0.00	0.00
Fish meal select	5.00	9.40	4.00	8.40	1.50	5.90
Soy protein concentrate	4.00	4.00	2.00	2.00	0.00	0.00
Dried animal plasma[3]	5.00	5.00	2.00	2.00	0.00	0.00
Lys·HCl	0.10	0.10	0.10	0.10	0.05	0.05
DL-Methionine	0.07	0.07	0.10	0.10	0.05	0.05
Lactose	15.00	15.00	5.00	5.00	2.50	2.50
Fat	2.00	2.00	2.00	2.00	2.00	2.00
Salt	0.20	0.20	0.20	0.20	0.40	0.40
Dicalcium phosphate	0.75	0.09	0.97	0.32	1.50	0.84
Limestone, ground	0.83	0.59	0.88	0.65	1.04	0.81
Trace mineral premix[4]	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[4]	0.60	0.60	0.60	0.60	0.60	0.60
Zinc oxide, 72%	0.26	0.26	0.26	0.26	0.00	0.00
Antimicrobial agent[5]	0.05	0.05	0.05	0.05	0.05	0.05

[1]Dietary phases: phase 1, d 0 to 7; phase 2, d 8 to 21; and phase 3, d 22 to 35.
[2]The NRC (1998) estimated requirement: phase 1, 1.35% Lys; phase 2, 1.25% Lys; phase 3, 1.15% Lys.
[3]The dried animal plasma was APC-920 from American Protein Corporation, Ames, IA.
[4]Trace mineral and vitamin premixes were added at different concentrations at the various stations; they met or exceeded the NRC (1998) estimated requirements.
[5]Antimicrobial agents varied among stations.

RESULTS AND DISCUSSION

Station Effect

In all parameters measured the station effect was different ($P < 0.0001$). The only significant interaction was station × sex for overall G:F ($P = 0.0026$).

In this case, G:F ranged from 0.65 to 0.70 and gilts had greater G:F at half the stations, whereas barrows had greater G:F in the other half. Station effect might include differences in genetics, management, and health status of the animals.

Average Daily Gain

The ADG was not affected by sex or Lys concentration during phase 1 or 2, nor was there an interaction of these 2 variables (Table 4). However, gilts and barrows had greater ADG ($P = 0.001$) during phase 3 and overall when fed 1.35% Lys than their contemporaries fed 1.15%. Similar responses were reported by Nam and Aherne (1994) who observed that pigs weighing 9.1 to 25.7 kg had a maximum weight gain with 0.95 g of Lys/MJ of DE when the diet contained 14.13 MJ of DE/kg. This concentration of Lys corresponded to 1.34% of the diet. However, in similar weight pigs, Martinez and Knabe (1990) reported the Lys requirement to be 1.03% when feeding a diet based on corn, peanut meal, and soybean meal. The ultimate body composition at market weight of pigs in their study probably also differed from ours due to genetic changes that have occurred during the past 15 yr in the swine industry.

In a previous NCR-42 study, it was reported that the ADG for pigs with an initial BW of 7 kg was greater for pigs fed diets containing 1.10% Lys compared with pigs fed diets containing 0.95% Lys (Mahan et al., 1993). Kornegay et al. (1994) reported that pigs fed 1.15 and 0.95% Lys in a 2-phase 35-d study gained less weight than pigs fed diets containing an additional 0.1% or 0.2% Lys. van Heugten et al. (1994) did not observe a difference in ADG between pigs initially weighing 6 kg when fed 1.44 and 1.73% Lys. More recently, Schneider et al. (2004) and Lenehan (2004) reported a linear increase in ADG when diets were provided with 0.9 to 1.3% true ileal digestible Lys. In additional work, these researchers (Lenehan et al., 2003) concluded that pigs weighing 10 to 20 kg required approximately 1.4% true digestible Lys. Similar to the response we observed, Fu et al. (2003) reported that late in the nursery phase, pigs required 1.32% true ileal digestible Lys. Thus, there is not a consensus among previous experiments regarding the optimal Lys concentrations for nursery pigs.

One of the reasons for the disagreements among studies may be that in most studies, only 1 diet was used throughout the nursery period. With the rapid change in AA requirements for pigs at this age, it is likely that such an approach will result in diets that tend to oversupply AA throughout the nursery period or that supply AA below the requirement in the initial period and above the requirement in the later stages of the nursery period. In the present experiment, an attempt was made to feed diets that were formulated to meet the estimated requirements within each phase of the nursery period to avoid both under- and over-supple-

Table 3. Amino acid and CP analysis of the experimental diets, % of diet (as-fed basis)[1]

Amino acid	Phase 1 NRC	Phase 1 NRC + 0.2% Lys	Phase 2 NRC	Phase 2 NRC + 0.2% Lys	Phase 3 NRC	Phase 3 NRC + 0.2% Lys
Arg	1.13 ± 0.05	1.23 ± 0.06	1.19 ± 0.05	1.34 ± 0.06	1.28 ± 0.09	1.39 ± 0.16
His	0.51 ± 0.02	0.55 ± 0.03	0.51 ± 0.03	0.57 ± 0.03	0.52 ± 0.04	0.56 ± 0.06
Ile	0.79 ± 0.03	0.85 ± 0.06	0.81 ± 0.06	0.92 ± 0.05	0.84 ± 0.05	0.88 ± 0.13
Leu	1.74 ± 0.06	1.83 ± 0.08	1.72 ± 0.11	1.88 ± 0.10	1.72 ± 0.12	1.81 ± 0.15
Lys	1.33 ± 0.12	1.46 ± 0.12	1.26 ± 0.14	1.41 ± 0.08	1.12 ± 0.08	1.27 ± 0.19
Met	0.39 ± 0.02	0.43 ± 0.03	0.40 ± 0.02	0.45 ± 0.03	0.34 ± 0.04	0.38 ± 0.05
Phe	0.91 ± 0.04	0.97 ± 0.04	0.92 ± 0.05	1.01 ± 0.05	0.96 ± 0.06	1.01 ± 0.11
Thr	0.86 ± 0.05	0.91 ± 0.08	0.80 ± 0.07	0.87 ± 0.05	0.73 ± 0.06	0.79 ± 0.07
Trp	0.25 ± 0.01	0.26 ± 0.01	0.23 ± 0.01	0.25 ± 0.01	0.22 ± 0.02	0.23 ± 0.02
Val	1.04 ± 0.07	1.10 ± 0.09	1.00 ± 0.09	1.11 ± 0.05	0.98 ± 0.06	1.04 ± 0.14
Ala	1.06 ± 0.03	1.15 ± 0.08	1.07 ± 0.08	1.20 ± 0.06	1.03 ± 0.07	1.13 ± 0.09
Asp	1.89 ± 0.11	2.04 ± 0.10	1.91 ± 0.10	2.12 ± 0.09	1.97 ± 0.13	2.11 ± 0.24
Cys	0.35 ± 0.02	0.35 ± 0.02	0.31 ± 0.03	0.33 ± 0.02	0.30 ± 0.01	0.31 ± 0.02
Glu	3.22 ± 0.17	3.46 ± 0.20	3.35 ± 0.16	3.69 ± 0.21	3.56 ± 0.21	3.80 ± 0.36
Gly	0.86 ± 0.04	1.00 ± 0.11	0.90 ± 0.08	1.07 ± 0.08	0.86 ± 0.06	1.00 ± 0.11
Pro	1.14 ± 0.05	1.20 ± 0.03	1.18 ± 0.05	1.26 ± 0.06	1.18 ± 0.09	1.23 ± 0.10
Ser	0.85 ± 0.06	0.90 ± 0.06	0.84 ± 0.03	0.90 ± 0.05	0.84 ± 0.08	0.91 ± 0.04
Tyr	0.63 ± 0.02	0.67 ± 0.03	0.62 ± 0.03	0.66 ± 0.04	0.64 ± 0.04	0.68 ± 0.06
Total	19.13 ± 0.89	20.65 ± 1.09	19.25 ± 1.15	21.32 ± 1.03	19.24 ± 1.26	20.80 ± 2.04
CP	19.73 ± 0.74	22.10 ± 0.71	19.72 ± 0.38	22.19 ± 0.68	19.85 ± 1.23	21.43 ± 1.73

[1]Mean ± SD percent of AA in the diets from the 6 experiment stations. Dietary phases: phase 1, d 0 to 7; phase 2, d 8 to 21; and phase 3, d 22 to 35.

mentation of AA. Under these circumstances, it was concluded that in the third phase (from d 21 to 35 after weaning) pigs will grow faster if AA are supplied in quantities that are 20% greater than the current NRC (1998) estimates of requirement. Because there was no sex × Lys interaction in any phase of our experiment (P = 0.987), we concluded that this was true for gilts and barrows.

Average Daily Feed Intake

During phase 2 of this study, ADFI decreased when pigs were fed the greater Lys diet (1.45% Lys) compared with those fed the NRC (1998) estimated requirement (1.25%). Feed intake did not differ between treatments in phase 3, and there was no sex × Lys interaction. van Heugten et al. (1994) reported a similar reduction in

Table 4. Effect of sex and dietary Lys on nursery pig growth performance[1,2,3]

Item	Barrow NRC Lys	Barrow NRC + 0.2% Lys	Gilt NRC Lys	Gilt NRC + 0.2% Lys	SE	P-value Lys	P-value Sex	P-value Lys × sex
ADG, g								
Phase 1	176	165	185	190	11	0.836	0.133	0.175
Phase 2	421	445	425	438	11	0.088	0.887	0.254
Phase 3	596	630	581	625	11	0.001	0.383	0.637
Overall	441	465	440	464	5	0.001	0.826	0.987
ADFI, g								
Phase 1	229	204	229	229	15	0.383	0.400	0.056
Phase 2	606	587	621	582	15	0.048	0.737	0.346
Phase 3	977	983	966	972	15	0.680	0.456	0.761
Overall	677	671	681	669	8	0.202	0.937	0.655
G:F								
Phase 1	0.742	0.774	0.788	0.801	0.021	0.271	0.082	0.746
Phase 2	0.702	0.793	0.706	0.777	0.020	0.001	0.751	0.823
Phase 3	0.596	0.620	0.588	0.627	0.021	0.131	0.985	0.302
Overall	0.652	0.694	0.646	0.695	0.004	0.001	0.513	0.447

[1]The NRC (1998) estimated requirement: phase 1, 1.35% Lys; phase 2, 1.25% Lys; and phase 3, 1.15% Lys.
[2]Dietary phases: phase 1, d 0 to 7; phase 2, d 8 to 21; and phase 3, d 22 to 35.
[3]Station effect for ADG, ADFI, G:F for each phase and overall, P < 0.001.

ADFI in their 35-d study, and pigs fed 1.44 and 1.73% Lys consumed less feed than those fed a diet containing 0.86% Lys. Lewis et al. (1981) also found a quadratic response when nursery pigs were fed 6 concentrations of Lys from 0.95 to 1.45%, with a plateau at 1.25% Lys. Martinez and Knabe (1990) also observed a quadratic ADFI response to Lys supplementation. Thus, the results from the second phase of the current experiment showing a reduction in ADFI for pigs fed Lys above the requirement concur with previous reports. However, using current commercial sources of nursery pigs, none of these studies [Schneider et al. (2004), Lenehan et al. (2004) or Fu et al. (2003)] observed a change in feed intake with increasing dietary Lys. The fact that there was no effect of Lys on ADFI during the first and the third phases and overall for our experiment indicated that factors other than the Lys concentration in the diet may be involved in regulating feed intake of weanling pigs. Because we increased fish meal in the diet, the additional Lys (and other amino acids) from this protein source may have been a confounding factor that influenced ADFI. Because there was no effect of sex on ADFI, it is likely that the mechanisms regulating ADFI are similar in gilts and barrows.

Feed Utilization

There were no differences in G:F among treatment groups during phase 1 of this experiment. However, during phase 2, G:F was improved ($P < 0.001$) when pigs were fed 1.45% Lys compared with those fed 1.25% regardless of sex. Similarly, this improvement was seen in the overall G:F for the 35-d study. If such an improvement were observed in a commercial setting, this would result in about 38 kg of additional gain per 1,000 pigs fed the same amount of diet as well as conserving nutrients excreted. Thus, it is likely that the increase in diet cost due to the increased Lys concentrations in the nursery diets would be offset by the improvements in G:F.

Nam and Aherne (1994) reported that with a 0.9 ratio of 0.9 g of Lys/MJ of DE, the digestibility coefficient for protein and energy were 88 to 89% and 87 to 88%, respectively. Thus, suggesting that nutrients are well utilized at this age when Lys is provided at approximately 1.34%. Utilization of feed was also improved (Gatel and Fekete, 1989) when Lys was provided from 1.25 to 1.34% compared with 1.14 to 1.19% Lys. However, they noted that Thr needed to be provided at 65 to 70% dietary Lys to improve performance. In the present experiment, Thr was included at a ratio of 65% of Lys in all the experimental diets, which may be the reason we also observed an improvement in G:F. Lewis et al. (1981) reported a quadratic effect ($P = 0.001$) for Lys additions to nursery diets from 0.95 to 1.45% with numerically the greatest efficiency (0.593) occurring at 1.15% Lys. Although diet type and genetics were different from our study, the observations reported by Lewis et al. (1981) confirm that dietary AA do influence the G:F for weanling pigs. Our findings concur with this observation. Lenehan et al. (2003), Schneider et al. (2004), and Lenehan et al. (2004) reported that as true ileal digestible Lys approaches 1.4%, G:F improved in lean-genotype nursery pigs compared with lower concentrations (1.1, 0.9, and 0.9% Lys, respectively).

Because there was no effect of sex on G:F, and there were no sex × Lys interactions observed, the data from the present experiment suggest that the observed differences in G:F are similar for gilts and barrows as previously observed by Yi et al. (2006).

In conclusion, with diverse genetics that reflect the swine industry, we were not able to detect different Lys needs for gilts and barrows. However, this does not mean that within uniform genetics there are no differences. Growth and feed efficiency can be improved in nursery pigs by feeding additional Lys and other indispensable amino acids beyond current standards in complex nursery diets.

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