Effect of standardized ileal digestible lysine on growth and subsequent performance of weanling pigs[1]

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ABSTRACT: A total of 320 weanling pigs (all barrows, initially 5.71 kg BW; Line 1050, PIC Hendersonville, TN) were used to determine whether the Lys level fed during one phase of the nursery influences the response to Lys during subsequent phases. Our hypothesis was that feeding decreasing dietary Lys concentration in early phases, but feeding adequate concentrations in later phases might result in similar pig growth as those fed a more conventional approach with step-wise decreases in dietary Lys as pigs become heavier. Eight dietary regimens were used in a split-plot design. There were three dietary phases, and within phase, a high or low standardized ileal digestible (**SID**) Lys diet was fed. Pigs were fed either 1.35% or 1.55% SID Lys during phase 1 (days 0 to 7), 1.15% or 1.35% SID Lys in phase 2 (days 7 to 21), and 1.05 or 1.25% SID Lys during phase 3 (days 21 to 35). The low dietary Lys concentrations were achieved by reducing both crystalline Lys and intact protein sources from the high Lys diets. From days 0 to 7, feeding high SID Lys improved ($P < 0.01$) G:F, but no evidence for differences in ADG or ADFI were observed. Similarly, from days 7 to 21, there were no evidence for differences in ADG or ADFI among pigs fed the two Lys levels, but those fed high SID Lys had improved ($P < 0.03$) G:F. From days 21 to 35, pigs fed the high Lys diet had increased ($P < 0.01$) ADG and G:F compared with those fed low SID Lys, but there were no effects on ADFI. For the overall trial (days 0 to 35), there were no dietary interactions among phases, indicating that the Lys level fed in each phase did not influence the response to Lys in subsequent phases. Thus, pigs fed the high Lys level during phase 3, regardless of previous Lys levels in phases 1 and 2, had greater ($P < 0.05$) overall ADG and G:F compared with other treatment groups. In conclusion, relatively low dietary Lys concentrations can be fed in the early nursery phases (approximately 6 to 12 kg) without any negative impact on overall growth performance provided that adequate Lys levels are fed thereafter (12 to 20 kg).

Key words: lysine, nursery pig, phase feeding

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INTRODUCTION

Increasing dietary Lys and other essential AA in typical titration studies have been shown to improve daily gain and feed efficiency (Kendall

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et al. 2008; Nemechek et al. 2011; Jones et al. 2014). However, these improved gains have not always been maintained throughout subsequent phases when common diets were fed thereafter, indicating a compensatory gain for those previously under AA deficiencies. The reason for compensatory gain to occur in some trials (Chiba, 1994; Fabian et al., 2002, 2004) but not in others (Chiba et al., 1999, 2002) is not fully understood. Suggested explanations for the variability among trials include the degree and duration of AA restriction (Prince et al., 1983; Main et al. 2008; Kamalakar et al. 2009). Also, inconsistencies in compensatory gain have been shown to occur among different phases in production. Chiba (1995) observed that pigs compensated from deficiencies fed during the grower phase, but not from deficiencies fed during the starter phase. The majority of compensatory gain research has been focused on the grower and finisher phases. Limited research has been conducted to investigate compensatory gain within different nursery phases.

Typically, increasing diet complexity improves growth performance in young pigs (Collins et al., 2017; Tekeste et al., 2017). In order to achieve increased complexity, early nursery diets often contained high amounts of expensive specialty protein sources (fish meal, poultry meal, blood coproducts, etc.). Lowering Lys in early nursery diets might allow for reduced use of specialty protein sources and thus decreased diet costs. Relatively low dietary Lys level in early phases would also likely reduce CP that may impact gut health via lowering ammonia concentrations in the small and large intestines (Heo et al., 2012). Therefore, this experiment aimed at determining if dietary Lys level fed during one nursery phase influences the response to Lys during subsequent nursery phases.

MATERIALS AND METHODS

All experimental procedures and animal care were approved by the Kansas State University Institutional Animal Care and Use Committee.

Animals and Diets

A total of 320 weanling barrows (initially 5.71 kg BW; PIC 1050, Hendersonville, TN) were used in a 35-d growth trial. At weaning, pigs were weighed and allotted to one of eight dietary treatments. There were five pigs per pen and eight pens per treatment. Each pen (1.22 × 1.22 m) contained a four-hole, dry self-feeder and a cup waterer to provide ad libitum access to feed and water. The trial was conducted at the Kansas State University Segregated Early Weaning Facility, Manhattan, KS.

A three-phase diet regimen was used, with phase 1 diets fed from days 0 to 7, phase 2 diets from days 7 to 21, and phase 3 diets from days 21 to 35 after weaning. For each phase, pigs were fed one of two standardized ileal digestible (**SID**) Lys levels: 1.35% or 1.55% during phase 1, 1.15% or 1.35% in phase 2, and 1.05% or 1.25% during phase 3 (Table 1). All six experimental diets were corn–soybean meal-based, and the low dietary Lys concentrations were achieved by reducing both crystalline Lys and intact protein sources (Table 2). Lactose level was equalized within each phase at 12, 7, and 0% for phases 1, 2, and 3, respectively. Ingredient nutrient profile and SID AA digestibility values used in diet formulation were derived from NRC (1998). Phase 1 diets were fed in pellet form, whereas phase 2 and phase 3 diets were fed in meal form. All diets were prepared at the Kansas State University Animal Science Feed Mill. Pigs and feeders were weighed on days 0, 7, 14, 21, 28, and 35 after weaning to calculate ADG, ADFI, and G:F.

Statistical Analysis

Growth performance data were analyzed using the MIXED procedure in SAS (SAS Institute, Inc., Cary, NC) with a treatment structure of 2 × 2 × 2 split–split plot design. Pen served as the experimental unit for data analysis. The statistical model included the fixed effects of Lys concentration within phase and their interactions with Lys level of previous phases. Results were considered significant at $P < 0.05$ and marginally significant at $0.05 < P < 0.10$.

Table 1. Dietary treatment structure[a]

	Standardized ileal digestible Lys, %							
Phase 1 (days 0 to 7)	1.35	1.35	1.35	1.35	1.55	1.55	1.55	1.55
Phase 2 (days 7 to 21)	1.15	1.15	1.35	1.35	1.15	1.15	1.35	1.35
Phase 3 (days 21 to 35)	1.05	1.25	1.05	1.25	1.05	1.25	1.05	1.25

[a]There were five pigs per pen and eight pens per treatment.

Table 2. Diet composition (as-fed basis)[a]

Item	Phase 1 (days 0 to 7)		Phase 2 (days 7 to 21)		Phase 3 (days 21 to 35)	
	Low	Adequate	Low	Adequate	Low	Adequate
Ingredient, %						
Corn	45.71	41.26	54.81	48.55	61.35	54.92
Soybean meal (46.5% CP)	9.50	11.61	18.27	23.69	19.80	26.20
Spray-dried animal plasma	5.50	6.70	—	—	—	—
Spray-dried whey	25.00	25.00	10.00	10.00	—	—
Distillers dried grains with solubles	—	—	10.00	10.00	15.00	15.00
Select menhaden fish meal	4.90	6.00	3.50	4.50	—	—
Spray-dried blood cells	1.35	1.65	—	—	—	—
Soybean oil	5.00	5.00	—	—	—	—
Monocalcium P (21% P)	0.45	0.20	0.43	0.28	0.80	0.75
Limestone	0.50	0.45	0.75	0.65	1.15	1.10
Salt	0.25	0.25	0.30	0.30	0.35	0.35
Zinc oxide	0.38	0.38	0.25	0.25	—	—
Vitamin premix[b]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[c]	0.15	0.15	0.15	0.15	0.15	0.15
L-Lys·HCl	0.15	0.15	0.33	0.35	0.40	0.45
DL-Met	0.12	0.15	0.05	0.10	0.04	0.09
L-Thr	0.04	0.05	0.08	0.10	0.08	0.11
Medication[d]	0.70	0.70	0.70	0.70	0.50	0.50
Phytase[e]	—	—	0.13	0.13	0.13	0.13
Vitamin E, 20,000 IU	0.05	0.05	—	—	—	—
Total	100.00	100.00	100.00	100.00	100.0	100.00
Calculated analysis						
Standardized ileal digestible AA, %						
Lys	1.35	1.55	1.15	1.35	1.05	1.25
Ile:Lys	51	51	61	60	60	60
Leu:Lys	127	123	139	131	152	140
Met:Lys	30	31	31	33	31	32
Met & Cys:Lys	56	56	57	57	59	58
Thr:Lys	62	62	62	62	62	62
Trp:Lys	17	17	17	17	17	17
Val:Lys	70	70	69	67	72	69
Total Lys, %	1.48	1.69	1.29	1.50	1.19	1.40
CP, %	20.2	22.7	19.7	22.4	19.0	21.5
ME, kcal/kg	3,497	3,510	3,280	3,287	3,303	3,305
Ca, %	0.77	0.77	0.70	0.71	0.68	0.67
P, %	0.71	0.72	0.62	0.64	0.58	0.60
Available P, %	0.53	0.53	0.36	0.37	0.31	0.30

[a]A total of 320 weanling barrows (initially 5.71 kg and 21 d of age; PIC 1050, Hendersonville, TN) were used in a 35-d trial with eight pens per treatment.

[b]Vitamin premix provided per kg of complete feed: 11,023 IU of vitamin A, 1,377 IU of vitamin D, 44.1 IU of vitamin E, 4.4 mg of vitamin K, 0.04 mg of vitamin B_{12}, 50.0 mg of niacin, 27.6 mg of pantothenic acid, and 8.3 mg of riboflavin.

[c]Trace mineral premix provided per kg of complete feed: 16.5 mg of Cu from $CuSO_4{\cdot}5H_20$, 0.30 mg of I as $C_2H_2(NH_2)_2{\cdot}2$ HI, 165 mg of Fe as $FeSO_4H_2O$, 39.7 mg of Mn as $MnSO_4{\cdot}H20$, 0.30 mg of Se as Na_2SeO_3, and 165 mg of Zn as $ZnSO_4$.

[d]Neo/Oxy 10/10 (Penfield Animal Health, Omaha, NE).

[e]Phyzyme 600 (Danisco Animal Nutrition, St. Louis, MO) provided 750 FTU/kg, with a release of 0.11% available P.

RESULTS AND DISCUSSION

The Lys requirements of nursery pigs estimated by the NRC (2012) are categorized in three weight ranges. For 5 to 7 kg pigs, NRC (2012) estimates the SID Lys requirement to be 1.50% and 7 to 11 kg pigs at 1.35, while 11 to 25 kg pigs 1.23% SID Lys.

The dietary regimens used in this study provided one SID Lys near the NRC (2012) requirement estimate within phase as well as one below this estimate. During phase 1 (days 0 to 7), there were no differences in ADG or ADFI among pigs fed the two dietary SID Lys levels (1.35% or 1.55%);

however, increasing SID Lys increased (P = 0.010) G:F (Table 3). Because the low SID Lys level was adequate for ADG and ADFI but not for G:F, this suggests that SID Lys of 1.35% was marginally deficient during phase 1. Several studies have demonstrated that the Lys requirement for G:F is greater than the requirement for ADG (Nemechek et al., 2011; Vier et al., 2016; Graham et al., 2017).

During phase 2 (days 7 to 21), there was no evidence for interactions (P > 0.10) between Lys fed during phase 1 and the Lys response in phase 2. As in phase 1, there was no evidence for differences in ADG or ADFI between pigs fed the two dietary SID Lys levels (1.15% or 1.35%). However, consistent with the phase 1 response, pigs fed the high SID Lys diet during phase 2 had increased (P = 0.030) G:F compared with pigs fed the low SID Lys diet, indicating a marginal deficiency of the low SID Lys level for maximum G:F.

During phase 3 (days 21 to 35), pigs fed the high SID Lys diets had increased (P < 0.001) ADG and G:F, but not ADFI compared with those fed low Lys diets. Again, there was no evidence of any cross-phase interactions for any phase 3 growth performance (P > 0.10). The SID Lys levels fed during any of the previous phases did not influence the growth responses during phase 3. In agreement, other studies confirm that pigs are capable of improvements in growth when diets are realigned to meet AA requirements after a period of minor AA restriction. However, research on compensatory gain is limited primarily to the grower and finisher phases (Fabian et al., 2002; Main et al. 2008; Millet and Aluwé, 2014). Chiba (1995) and Totafurno et al. (2017) investigated compensatory gain among the starter, grower, and finisher phases, but experimental diets were kept constant during the nursery phase. Thus, the response to Lys level across phases within the nursery was not established.

For the overall trial (days 0 to 35), there was no evidence for any cross-phase interactions between dietary SID Lys concentrations for any growth performance criteria (P > 0.10). Pigs fed the high SID Lys level during phase 3 had increased (P < 0.03) ADG and G:F compared with those fed the low SID level during this phase regardless of earlier SID Lys levels fed. Increasing dietary SID Lys during phase 2 also marginally increased (P = 0.070) overall G:F.

Table 3. Effects of standardized ileal digestible Lys level fed during each phase on nursery pig performance[a]

	Standardized ileal digestible Lys, %									Probability, P<						
Phase 1	1.35	1.35	1.35	1.35	1.55	1.55	1.55	1.55		Phase 1×						
Phase 2	1.15	1.15	1.35	1.35	1.15	1.15	1.35	1.35		Phase 2×	Phase 1×	Phase 2×	Phase 1×			
Phase 3	1.05	1.25	1.05	1.25	1.05	1.25	1.05	1.25	SEM	Phase 3	Phase 2	Phase 3	Phase 3	Phase 1	Phase 2	Phase 3
Phase 1 (days 0 to 7)																
ADG, g	161	151	152	162	155	163	159	161	19.9	—	—	—	—	0.690	—	—
ADFI, g	171	164	157	164	145	150	149	162	15.0	—	—	—	—	0.370	—	—
G:F, g/kg	962	926	965	997	1054	1089	1074	984	59.0	—	—	—	—	0.010	—	—
Phase 2 (days 7 to 21)																
ADG, g	363	365	366	371	346	333	370	375	15.8	—	0.270	—	—	0.410	0.180	—
ADFI, g	541	530	512	521	508	506	498	517	18.4	—	0.460	—	—	0.160	0.490	—
G:F, g/kg	674	687	716	711	680	660	742	723	16.0	—	0.290	—	—	0.750	0.030	—
Phase 3 (days 21 to 35)																
ADG, g	561	616	579	614	555	573	540	593	35.1	0.230	0.890	0.750	0.650	0.200	0.780	0.001
ADFI, g	934	915	943	956	907	883	883	925	34.6	0.590	0.760	0.120	0.700	0.370	0.530	0.850
G:F, g/kg	601	674	614	643	613	649	612	640	31.0	0.290	0.820	0.120	0.270	0.600	0.390	0.001
Overall (days 0 to 35)																
ADG, g	402	422	406	426	389	395	395	419	11.3	0.550	0.570	0.550	0.770	0.150	0.300	0.030
ADFI, g	745	726	730	747	711	701	696	732	20.5	0.860	0.880	0.140	0.600	0.380	0.740	0.650
G:F, g/kg	645	692	666	683	658	676	681	688	11.0	0.480	0.420	0.120	0.130	0.520	0.070	0.001
BW, kg																
Day 0	5.7	5.7	5.7	5.7	5.7	5.8	5.7	5.7	0.05	0.920	—	—	—	0.590	—	—
Day 7	6.8	6.8	6.8	6.8	6.8	6.9	6.8	6.8	0.19	0.380	0.890	—	—	0.670	0.910	—
Day 21	11.9	11.9	12.0	12.0	11.7	11.6	12.0	12.1	0.32	0.920	0.310	0.660	0.970	0.540	0.140	0.940
Day 35	19.8	20.6	20.1	20.6	19.4	19.6	19.6	20.4	0.36	0.380	0.570	0.750	0.680	0.140	0.370	0.040

[a]A total of 320 weanling barrows (initially 5.71 kg and 21 d of age; PIC 1050, Hendersonville, TN) were used in a 35-d trial with five pigs per pen and eight pens per treatment.

Consistent with the data from the previous phases, increasing the Lys level during any phase did not influence overall ADFI. Similar observations have been reported by Stein and Kil (2006). In that study, pigs fed a low CP diet (15.7%) had decreased ADG during the initial 2-wk postweaning compared with those fed a high CP diet (20.8%). However, when a high CP diet (19.3%) was provided during the following 3 wk, pigs previously fed low CP fully compensated for overall ADG and had even greater overall G:F compared with pigs that received a low CP diet (17.5%) during the second period.

Although the mechanism behind compensatory growth in swine is not fully understood, Prince et al. (1983) and Kamalakar et al. (2009) suggested that the degree of AA restriction and the length of time that pigs are subject to the restriction may influence the magnitude of compensatory gain. These results demonstrate that marginally deficient diets can be fed in early nursery phases (up to approximately 12 kg in this experiment) without interactively affecting final BW or the growth response provided SID Lys levels in the subsequent phase (12 to 20 kg) were at least at the requirement estimate.

In conclusion, the results herein indicate that relatively low dietary SID Lys levels can be fed in the early nursery phases (5 to 12 kg) without negatively impacting overall ADG or BW, as long as diets during the late nursery period (12 to 20) are adequate in SID Lys. There was no evidence for cross-phase interactions between the dietary SID Lys levels used in this study, indicating the response to Lys in one phase is not influenced by the Lys level fed in previous phases. The implications of these findings are that nutritionists may decrease current SID Lys concentrations that may result in an economic advantage compared with feeding high Lys diets. Furthermore, by lowering CP content of the diet, the decreased ammonia concentrations in the lower gut may reduce the incidence of postweaning diarrhea (Heo et al., 2012).

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