Dietary Amino Acid Restrictions, Compensatory Growth, and Nitrogen Balance in Grower-Finisher Pigs

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Introduction

The management of wastes and odors has become a major issue facing the pig industry (Chiba, 2000). For sustainable pig industry, it is necessary to alleviate public concerns on the environmental issues. Likewise, improving the efficiency of nutrient utilization is equally important for successful pig production, and this is especially true for protein sources because of the cost (Chiba, 2001) and the fact that the average retention of dietary N in pigs has been reported to be much less than 50% (Kornegay and Verstegen, 2001). The efficient utilization of amino acids can, therefore, minimize adverse environmental impacts of animal production, and it is an integral part of successful and sustainable pig production.

In commercial pig production, the main goal of feeding strategy is to maximize profits, which does not necessarily imply maximal animal performance (Chiba, 2000). Compensatory growth responses after dietary amino acid restrictions during the grower phase have been observed in some studies conducted at Auburn University (e.g., Chiba, 1994, 1995; Fabian et al., 2002). If in fact pigs have the ability to grow faster and(or) more efficiently in the subsequent phase after a period of dietary restrictions regardless of their genetic potential for growth and protein accretion, it can reduce feed costs and excretion of unused nutrients during both the restriction and realimentation phases (Chiba et al., 2002). Compensatory growth can, therefore, have a positive impact not only on the overall efficiency of pig production but also on the environment.

It is reasonable to assume that compensatory responses are a reflection of changes in metabolism. Compensatory N retention following the N deprivation in pigs has been demonstrated (Whittemore et al., 1978; Tullis et al., 1986), but a long term effect of marginal dietary restrictions on N balance or metabolic profile in grower-finisher pigs has not been elucidated fully. The present study was conducted to investigate the effect of dietary amino acid restrictions during the grower phase on growth performance, serum metabolites, carcass traits, meat quality, and N balance in grower-finisher pigs.

Experimental Procedures

Animals, Facilities, and Experimental Diets. A total of 16 crossbred (Yorkshire x Duroc) castrated male pigs averaging 21.2 ± 4.9 kg were used in two trials. In each trial, pigs were housed in individual pens (4.4 m^2) with solid concrete floors in an open-front building. Pigs were randomly assigned to one of two corn-soy grower diets (5.0 or 11.0 g lysine/kg). After the grower phase, they were offered common, corn-soy Finisher 1 and 2 diets (7.5 and 6.0 g lysine/kg, respectively). The grower, Finisher 1, and Finisher 2 diets were fed from 21.2 ± 4.9 to 51.2 ± 3.3 kg, 51.2 ± 3.3 to 79.5 ± 3.4 kg, and 79.5 ± 3.4 to 107.5 ± 5.9 kg, respectively. Pigs were allowed ad libitum access to feed and water throughout the study, except during the three adaptation-collection periods (or collection periods) to determine N balance. The protocol for animal care was approved by the Auburn University Institutional Animal Care and Use Committee.

Nitrogen Balance. For the total collection of feces and urine, pigs were placed individually in stainless steel, adjustable metabolism crates for a 9-d period during each of the grower, Finisher 1, and Finisher 2 phases when they weighed 43.3 ± 3.9, 70.4 ± 4.9, and 90.5 ± 3.8 kg, respectively. Pigs had a three-day adjustment period prior to a four-day total collection period. Each day, pigs were fed twice up to their appetite, but no more than 4% of their BW. Feces were collected twice daily. Urine was collected continuously during the four-day collection period into a bottle, which was acidified daily with 25 mL of 6 *N* HCl. Representative fecal and urine subsamples were stored frozen at -20°C until the analysis for N.

Ultrasound Measurements, Blood Samples, and Slaughter. Pigs were subjected to ultrasound backfat measurements at the end of the grower and Finisher 1 phases. Blood samples were taken from each pig at the beginning, at the end of the grower, Finisher 1, and Finisher 2 phases, and before each of the three collection periods, and analyzed for serum urea N, glucose, triglycerides, and total protein. At an average weight of 107.5 ± 5.9 kg, all pigs were slaughtered at Auburn University Meat Laboratory using conventional procedures. After collecting the carcass data, longissimus muscle area was used to determine subjective meat quality scores, and the rate of carcass lean accretion was estimated using the published equation.

Results and Discussion

Growth Performance and Body Composition. Pigs fed the low-amino acid diet grew more slowly and less efficiently ($P < 0.001$) during the grower phase, and had more ultrasound backfat ($P = 0.010$) at the end of the grower phase than those fed the high-amino acid diet (Table 1). Therefore, the effort to depress growth performance and alter body composition of one group of pigs during the grower phase through amino acid restrictions was successful. During the Finisher 1 phase, previously restricted pigs utilized feed more efficiently for weight gain ($P = 0.012$) than those unrestricted pigs. Furthermore, there was no effect of the grower diet on overall weight gain because of the numeric reversal observed during the Finisher 1 phase.

Although pigs fed the low-amino acid grower diet had more ultrasound backfat ($P = 0.033$) compared with pigs fed the high-amino acid diet at the end of the Finisher 1 phase, there seemed to be no difference in body composition in the subsequent phases as indicated by carcass data. In addition, the grower diet had no effect on subjective meat quality scores in the present study. Along with the growth performance data, therefore, these results indicate that pigs subjected to dietary amino acid restrictions during the grower phase compensated completely in terms of growth performance and body composition by the time they reached market weight. Similar compensatory growth responses have been observed in grower-finisher pigs regardless of the genotype (e.g., Chiba, 1994, 1995; Fabian et al., 2002).

Serum Metabolites. During the grower phase, pigs fed the low-amino acid grower diet had less serum urea N (6.8 vs. 12.3 mg/dL; $P < 0.001$) and total protein (5.0 vs. 6.1 g/dL; $P < 0.001$) and more glucose (89.2 vs. 73.2 mg/dL; $P = 0.009$) than those fed the high-amino acid diet. Serum metabolite concentrations, however, were not affected by early dietary amino acid restrictions (data not shown), which is in agreement with findings of others (Atinmo et al., 1976; Pond et al., 1980). The results indicated that the early dietary restrictions may not have a long-term effect on serum metabolites.

Nitrogen Balance. During the grower phase collection period, pigs fed the high-amino acid grower diet consumed more N ($P < 0.001$) and had greater apparent N digestibility ($P = 0.041$), net N utilization ($P = 0.027$), and N retention ($P < 0.001$) compared with those fed the low-amino acid diet (Table 2). Those pigs, however, excreted more fecal ($P = 0.034$) and urinary ($P < 0.001$) N during the grower phase than those fed the low-amino acid grower diet. Pigs subjected to early dietary amino acid restrictions, therefore, excreted 17% less N in the feces and 34% less N in the urine during the grower phase than those fed the grower diet containing adequate amino acids.

There was some evidence of carryover effects of early dietary amino acid restrictions on the N metabolism during the realimentation phase. During the Finisher 1 phase, pigs fed the low-amino acid grower diet had a higher net N utilization (*P* = 0.024) and tended to have a higher N retention (*P* = 0.081), consequently reducing (*P* = 0.029) urinary N excretion by 28% compared with those fed the high-amino acid grower diet. Similarly, urinary N excretion in pigs fed the low-amino acid diet was reduced (*P* = 0.027) by 16% during the Finisher 2 phase. These results may indicate that pigs subjected to early dietary restrictions exhibited compensatory N retention, which agree with earlier reports (Whittemore et al., 1978; Tullis et al., 1986). It is possible that compensatory N retention in pigs subjected to early dietary restrictions is responsible for compensatory growth responses observed in many studies over the years.

Implications. Pigs do have the ability to achieve compensatory growth regardless of the genotype, and by taking advantages of this potential, feed costs and excretion of unutilized N during the restriction phase can be reduced. Furthermore, pigs subjected to early dietary restrictions can grow faster and more efficiently during the realimentation phase, thus reducing feed costs and excretion of unused N further because of compensatory N retention. Compensatory growth can, therefore, have a positive impact not only on the efficiency of pig production but also on the environment, and it can contribute greatly to successful and sustainable pig production.

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Table 1. Effect of early dietary amino acid restrictions on growth performance, ultrasound backfat, carcass traits, and meat quality[a,b]

	Grower diet, g lysine/kg			
Phase	5.0	11.0	SEM[c]	*P*-value
Grower phase				
Feed intake, g/d	1,998	1,801	60	0.092
Weight gain, g/d	625	763	17	0.001
Gain:feed, g/kg	316	425	11	0.001
Ultrasound backfat, mm	12.9	9.7	0.6	0.010
Finisher 1 phase				
Feed intake, g/d	2,564	2,837	60	0.077
Weight gain, g/d	1,016	928	25	0.164
Gain:feed, g/kg	395	327	9	0.012
Ultrasound backfat, mm	19.7	16.3	0.8	0.033
Finisher 2 phase				
Feed intake, g/d	2,976	3,001	107	0.890
Weight gain, g/d	949	956	43	0.926
Gain:feed, g/kg	319	320	15	0.970
Overall				
Feed intake, g/d	2,483	2,436	50	0.522
Weight gain, g/d	826	868	20	0.185
Gain:feed, g/kg	333	358	9	0.091
Carcass traits				
10th rib backfat, mm	21.4	20.5	1.5	0.686
Longissimus muscle area, cm^2	43.3	43.3	1.7	0.992
Lean growth, g/d	330	347	15	0.433
Meat quality scores[d]				
Color	1.9	1.9	0.1	0.592
Marbling	2.3	2.1	0.2	0.592
Firmness	2.0	2.1	0.1	0.418

[a]Grower diets were offered during the grower phase, whereas common diets were offered during the Finisher 1 and 2 phases (7.5 and 6.0 g lysine/kg, respectively).

[b]Least squares means based on seven individually housed castrated males per treatment; Corresponding initial and final weights at each phase (21.2 ± 4.9 and 51.2 ± 3.3 kg, 51.2 ± 3.3 and 79.5 ± 3.4 kg, 79.5 ± 3.4 and 107.5 ± 5.9 kg, and 21.2 ± 4.9 and 107.5 ± 5.9 kg for the grower, Finisher 1, Finisher 2, and overall phases, respectively) were included in the statistical models as covariates, whereas the weight recorded during the ultrasound measurement or the final weight (107.5 ± 5.9 kg) was used as a covariate for the ultrasound backfat and carcass trait data, respectively.

[c]Pooled standard error of the mean.

[d]Color: 1 (pale, pinkish grey) to 5 (dark, purplish red); marbling: 1 (devoid to practically devoid) to 5 (moderately abundant or greater); firmness: 1 (very soft and very watery) to 5 (very firm and dry).

Table 2. Effect of early dietary amino acid restrictions on nitrogen balance[a,b]

	Grower diet, g lysine/kg			
Item	5.0	11.0	SEM[c]	*P*-value
Grower phase				
N intake, g/d	32.4	51.1	1.7	0.001
Fecal N output, g/d	6.7	8.1	0.4	0.034
Urinary N output, g/d	12.0	18.3	0.8	0.001
Apparent N digestibility, %	78.6	83.9	1.5	0.041
Net N utilization, %	42.0	48.0	1.5	0.027
N retention, g/d	13.6	24.6	1.2	0.001
Finisher 1 phase				
N intake, g/d	59.3	60.1	2.2	0.691
Fecal N output, g/d	7.8	9.0	0.5	0.211
Urinary N output, g/d	24.4	33.9	1.8	0.029
Apparent N digestibility, %	86.9	85.2	0.7	0.228
Net N utilization, %	46.0	28.9	3.2	0.024
N retention, g/d	27.1	18.0	2.3	0.081
Finisher 2 phase				
N intake, g/d	48.1	57.9	3.2	0.343
Fecal N output, g/d	6.5	8.8	0.9	0.431
Urinary N output, g/d	24.7	29.5	0.3	0.027
Apparent N digestibility, %	86.6	84.8	1.0	0.525
Net N utilization, %	34.6	33.7	1.4	0.841
N retention, g/d	16.9	19.6	2.0	0.641

[a]Grower diets were offered during the grower phase, whereas common diets were offered during the Finisher 1 and 2 phases (7.5 and 6.0 g lysine/kg, respectively).

[b]Least squares means based on seven (grower and Finisher 1 phases) or four (Finisher 2 phase) castrated males housed in metabolism crates per treatment; the initial weight (43.3 ± 3.9 kg) was included in the statistical model as a covariate for the grower phase, whereas the days from the end of the grower phase until the adaptation-collection period and the initial weight (70.4 ± 4.9 and 90.5 ± 3.8 kg for Finisher 1 and 2 phases, respectively) were included as covariates for the Finisher 1 and 2 phases.

[c]Pooled standard error of the mean.