ELSEVIER

Livestock Production Science 74 (2002) 93–102

LIVESTOCK PRODUCTION SCIENCE

www.elsevier.com/locate/livprodsci

Effect of dietary restrictions on growth performance and carcass quality of pigs selected for lean growth efficiency

L.I. Chiba*, D.L. Kuhlers, L.T. Frobish, S.B. Jungst[1], E.J. Huff-Lonergan[2], S.M. Lonergan[2], K.A. Cummins

Department of Animal and Dairy Sciences, Auburn University, Auburn University, AL 36849-5415, USA

Received 16 August 2000; received in revised form 1 June 2001; accepted 22 June 2001

Abstract

Sixty-four pigs, 32 selected for lean growth efficiency and 32 controls selected randomly, were used to investigate the effect of genotype and realimentation diets on growth performance and carcass quality of pigs subjected to marginal dietary restrictions during the grower phase. When pigs weighed approximately 20 kg, 16 pens containing two gilts and 16 pens containing two castrated males were randomly assigned within genetic lines to grower diets and finisher diets in a $2 \times 2 \times 2$ factorial arrangement of treatments. Grower diets contained 0.421 or 0.765 g lysine/MJ DE, whereas finisher diets contained 0.421 or 0.612 g lysine/MJ DE. Genotype had no effect on growth performance, but select line pigs had better carcass quality ($P \leq 0.05$) and seemed to utilize amino acids more efficiently for growth than control line pigs as indicated by lower blood urea nitrogen ($P \leq 0.07$). During the grower phase, pigs fed the high-amino acid grower diet grew faster and more efficiently ($P < 0.01$) and had less ultrasound backfat ($P < 0.001$) than those fed the low-amino acid diet. Although some grower$\times$finisher diet interactions were observed, there was no indication that pigs subjected to early amino acid restrictions exhibited compensatory weight gain, or had different amino acid requirements in the subsequent phase. The rate of lean accretion was similar between pigs fed the low- and high-amino acid grower diets regardless of genotype, indicating that compensatory lean tissue growth may have occurred in pigs subjected to early amino acid restrictions. Furthermore, restricted pigs had better feed efficiency in the subsequent phase, which may have a positive impact on the environment by reducing the excretion of unutilized nutrients. Select line pigs fed the low-amino acid grower diet had lower overall weight gain compared with other groups (genotype$\times$grower, $P < 0.001$). The results imply that pigs selected for lean growth efficiency may be less tolerant of early amino acid restrictions, and offering a grower diet containing adequate amino acids might be important in optimizing overall growth performance.

Keywords: Pig nutrition; Selection; Lean growth efficiency; Dietary restrictions; Pig performance

*Corresponding author. Tel.: +1-334-844-1560; fax: +1-334-844-1519.

E-mail address: lchiba@acesag.auburn.edu (L.I. Chiba).

[1]Present address: PIC USA, Franklin, KY 42135, USA.

[2]Present address: Iowa State University, Department of Animal Science, Ames, IA 50011, USA.

1. Introduction

In commercial pig production, the main goal of diet formulation and feeding strategy is to maximize profits, which does not necessarily imply maximal animal performance (Chiba, 2000). Compensatory

0301-6226/02/$ – see front matter
PII: S0301-6226(01)00288-3

growth responses after a period of dietary restrictions in young pigs have been reported (e.g., Chiba, 1994, 1995), indicating that the early nutritional status may have little importance in terms of overall rate and efficiency of growth. The effect of enhanced growth during the early phase of development on subsequent and overall growth performance and(or) carcass quality of pigs is, however, still a matter of debate.

The ability of pigs to engage in compensatory growth is likely to be affected by diets offered in the subsequent phase. There is, however, a paucity of information on the effect of amino acid content of realimentation diets on the compensatory response. Furthermore, the ability of pigs to exhibit compensatory growth may be dependent on genotypes because of metabolic and physiological alterations that might be taking place in pigs selected for a specific trait(s). Wide variations in the pig's potential for growth and protein accretion continue to exist in today's pig industry. If in fact pigs have the ability to achieve compensatory growth regardless of their genetic potential, it can reduce feed costs, as well as excretion of unutilized nutrients, during the restriction phase. Furthermore, restricted pigs may grow faster and more efficiently during the realimentation phase, thus reducing the excretion of unutilized nutrients further. Compensatory growth can, therefore, have a positive impact not only on the overall efficiency of pig production but also on the environment.

At this station, a line of Duroc pigs was established based on six generations of index selection for lean growth efficiency. In addition, a contemporary, randomly selected, control line of pigs was maintained. The present experiment was conducted to investigate the effect of dietary amino acid restrictions during the grower phase and amino acid content of realimentation diets on growth performance, internal organ weights, and carcass quality of select and control line pigs.

2. Experimental procedures

2.1. Animals and facilities

Thirty-two select line and 32 control line pigs were selected based on their weight and assigned to 32 pens with two gilts or two castrated males per pen. Sixteen pens of gilts and 16 pens of castrated males were randomly assigned within genetic lines to grower diets and finisher diets in a $2\times2\times2$ factorial arrangement of treatments. When an average pen weight reached the target weight of 20 kg (17 to 23 kg), pigs were offered one of the two grower diets. Actual average initial pen weight was 19.6±1.4 kg. At an average pen weight of 50.5±2.4 kg, blood samples were collected from each pig, and backfat and longissimus muscle area were measured with a real-time ultrasound instrument (Aloka Co., Ltd., Wallingford, CT, USA) before switching to one of the two finisher diets. At an average pen weight of 112.7±3.4 kg, blood samples were again collected from each pig before slaughter. Blood samples were collected via vena cava puncture using a sterile needle and evacuated tube in the afternoon (15:00 to 16:00). Serum was separated by centrifugation, and an aliquot was stored at −20°C until analysis for urea nitrogen (Roche Diagnostic Systems, Somerville, NJ, USA).

Pigs were housed in pens with solid concrete floors in two open-front buildings (8.9 or 11.9 m^2/pen). Equal numbers of the two genetic lines of pigs and dietary treatment groups were assigned to each building. The experiment was initiated in September and terminated in February. Pigs were allowed ad libitum access to ground feed and water. Pig weight and feed consumption data were collected weekly until the diet change, and once every 2 weeks thereafter. Near the end of the experiment, data were again collected weekly. The protocol for animal care was approved by the university's Institutional Animal Care and Use Committee.

2.2. Experimental diets

The two grower diets (Table 1) were designed to be either marginally deficient (0.421 g/MJ DE; 80% of the 1988 NRC recommendation) or adequate in lysine (0.765 g/MJ DE; Chiba et al., 1991a,b). The two finisher diets were designed to contain a lysine level equal to that recommended by the NRC (1988; 0.421 g lysine/MJ DE) or 80% (0.612 g lysine/MJ DE) of the grower diet containing 0.765 g lysine/MJ DE. The lysine content of the latter diet was similar

Table 1
Composition of grower and finisher diets[a]

Item	Lysine:DE (g/MJ)			
	Grower		Finisher	
	0.421	0.765	0.421	0.612
Ingredients (g/kg)				
Corn	841.8	668.1	841.8	745.8
Soybean meal (48% CP)	126.4	302.6	126.4	223.8
Dicalcium phosphate	18.0	14.6	18.0	16.1
Limestone	7.8	8.7	7.8	8.3
Salt	3.5	3.5	3.5	3.5
Trace mineral–vitamin mix[b]	2.5	2.5	2.5	2.5
Calculated composition				
DE (MJ/kg)	14.4	14.5	14.4	14.5
CP (g/kg)	133	204	133	172
Lysine (g/kg)	6.1	11.1	6.1	8.9
Calcium (g/kg)	7.5	7.5	7.5	7.5
Phosphorus (g/kg)	6.5	6.5	6.5	6.5
Analyzed composition (g/kg)[c]				
CP	139	202	137	178
Lysine	6.3	10.9	6.4	9.1
Threonine	4.6	6.9	4.6	6.2
Isoleucine	4.8	7.6	4.8	6.6
Valine	5.7	8.4	5.7	7.5
Histidine	3.2	4.9	3.3	4.5

[a] Offered grower diets from 19.6±1.4 to 50.5±2.4 kg and then finisher diets until slaughter at an average pen weight of 112.7±3.4 kg; DE, digestible energy; CP, crude protein.

[b] Provided the following (unit/kg diet): Mg, 269 mg; Zn, 80 mg; Fe, 80 mg; Mn, 40 mg; Cu, 10 mg; I, 1 mg, Co, 0.4 mg; Se, 0.3 mg; vitamin A, 5500 IU; vitamin D_3, 1760 IU; vitamin E, 16.5 IU; menadione dimethylpyrimidinol bisulfite, 2.2 mg; riboflavin, 4.4 mg; d-pantothenic acid, 17.6 mg; niacin, 35.2 mg; vitamin B_{12}, 27.5 μg; choline, 95 mg.

[c] No analysis for sulfur amino acids and tryptophan.

to that recommended by both the ARC (1981) and SCA (1987).

Corn and soybean meal were used as sources of energy and amino acids to formulate practical diets, and an effort was not made to maintain a constant amino acid balance. The proportions of indispensable amino acids relative to lysine were, however, above the ideal protein (ARC, 1981) or balanced protein (NRC, 1988). Minerals and vitamins were provided in amounts calculated to meet or exceed the NRC (1988) recommendations. Feed samples collected at each mixing were pooled, and subsamples were analyzed for crude protein (AOAC, 1984) and amino acids (Chiba, 1994).

2.3. Slaughter procedures

Pigs were slaughtered at the university's meat laboratory using conventional procedures. The heart, liver, and kidneys were collected and weighed separately. The eviscerated carcass was split longitudinally through the vertebrae midline, and hot carcass weight was recorded. After chilling for 24 h at 2°C, the right side was weighed, and midline backfat thicknesses were measured at the first rib, last rib, and last lumbar vertebra. To measure the area of longissimus muscle, the right side was exposed by a perpendicular cut between the 10th and 11th rib. The longissimus muscle area was traced using acetate paper. Backfat thickness at the 10th rib (three-quarters distance along the longissimus muscle toward the belly) was also measured. The rate of carcass lean accretion and proportion of carcass lean were estimated by equations reported by NPPC (1991):

$$\text{lean (kg/day)} = [(3.280 + 0.437\text{HCWT} + 0.2726\text{LMA} - 0.3348\text{BF}) - (0.418\text{IWT} - 1.656)]/\text{Day}$$

and

$$\text{lean (\%)} = [(3.280 + 0.437\text{HCWT} + 0.2726\text{LMA} - 0.3348\text{BF})/\text{HCWT}] \times 100$$

where HCWT is hot carcass weight (kg), LMA is longissimus muscle area (cm^2), BF is 10th rib backfat thickness (mm), IWT is initial weight (kg), and Day is days on study.

2.4. Statistical analysis

Data were subjected to the statistical analysis using the General Linear Models procedure of SAS (1988). In addition to genetic lines and dietary treatments, sex, building and all appropriate interaction terms were included in the statistical models initially, and those interactions that did not reach at least a statistically significant trend (i.e., $P > 0.10$) were deleted from the final models. The initial and final weights were included in the model as covariates for growth performance data, whereas the final weight was used as a covariate for blood urea nitrogen, ultrasound, carcass, and internal organ data.

The pen was considered as the experimental unit in the analyses.

3. Results

3.1. Grower phase

Genotype had no effect on feed intake, weight gain or efficiency of weight gain during the grower phase, but select line pigs had less ultrasound backfat ($P < 0.001$) and lower blood urea nitrogen ($P < 0.05$) than control line pigs (Table 2). Pigs fed the high-amino acid grower diet consumed less feed ($P < 0.001$), and grew faster ($P < 0.01$) and more efficiently ($P < 0.001$) than those fed the low-amino acid diet. Similarly, pigs fed the high-amino acid diet had lower ultrasound backfat ($P < 0.001$) and higher blood urea nitrogen ($P < 0.001$) than those fed the low-amino acid diet. Neither genotype nor grower diets had any effect on ultrasound longissimus muscle area.

3.2. Finisher phase

As in the grower phase, genotype had no effect on growth performance during the finisher phase (Table 3), but select line pigs tended to have slightly lower blood urea nitrogen at the end of the finisher phase than control line pigs (14.0 vs. 15.2 mg/dl; $P = 0.07$). Pigs previously fed the high-amino acid grower diet consumed more feed than those fed the low-amino acid grower diet (3288 vs. 3052 g/day; $P < 0.001$), whereas feed intake was lower in pigs fed the high-amino acid finisher diet than those fed the low-amino acid finisher diet (3096 vs. 3245 g/day; $P < 0.01$). Pigs fed the low-amino acid grower and low-amino acid finisher diet sequence and high-amino acid grower and high-amino acid finisher diet sequence grew faster and more efficiently than those fed other diet combinations (grower × finisher, $P < 0.01$). Pigs fed the high-amino acid finisher diet had higher blood urea nitrogen than those fed the low-amino acid finisher diet, but the increase was slightly greater for pigs previously fed the high-amino acid grower diet (grower × finisher, $P < 0.01$).

3.3. Grower–finisher phase

The effect of grower and finisher diets on feed intake during the finisher phase was reflected in overall feed intake, i.e., pigs fed the high-amino acid grower diet consumed more feed (2798 vs. 2677 g/day; $P < 0.05$), but feed intake was lower (2666 vs. 2808 g/day; $P < 0.01$) in pigs fed the high-amino

Table 2
Effects of genotype and grower diets on growth performance of pigs during the grower phase, and ultrasound measurements of backfat and blood urea nitrogen at the end of the grower phase[a,b]

Item	Feed intake (g/day)	Weight gain (g/day)	Gain: feed (g/kg)	UBF (mm)	ULMA (cm^2)	BUN (mg/dl)
Genotype						
Control	1924	710	370	17.9	17.3	13.9
Select	1992	719	362	14.4	16.6	12.0
Lysine:DE (g/MJ)						
0.421	2027	681	337	17.7	17.0	9.5
0.765	1889	748	396	14.6	16.9	16.4
P-value[c]						
Genotype	–	–	–	0.001	–	0.029
Grower	0.001	0.009	0.001	0.001	–	0.001
CV (%)	5.0	9.2	7.7	11.0	6.7	17.8

[a] UBF, ultrasound backfat; ULMA, ultrasound longissimus muscle area; BUN, blood urea nitrogen; DE, digestible energy; CV, coefficient of variation.

[b] Least squares means based on 16 pens containing two gilts or two castrated males; used the initial (19.6±1.4 kg) and final (50.5±2.4 kg) weights as covariates for growth performance data, and the final weight as a covariate for the ultrasound and BUN data.

[c] Reported P-values ≤0.05.

Table 3
Effects of genotype, grower diets, and finisher diets on growth performance of pigs during the finisher phase, and blood urea nitrogen at the end of finisher phase[a,b]

Genotype	Lysine:DE (g/MJ)		Feed intake (g/day)	Weight gain (g/day)	Gain: feed (g/kg)	BUN (mg/dl)
	Grower	Finisher				
Control	0.421	0.421	3237	858	266	12.7
	0.421	0.612	2849	723	255	15.9
	0.765	0.421	3376	737	220	13.8
	0.765	0.612	3282	850	261	18.5
Select	0.421	0.421	3144	884	281	12.9
	0.421	0.612	2977	750	250	14.9
	0.765	0.421	3219	779	240	9.7
	0.765	0.612	3274	843	261	18.4
P-value[c]						
Grower			0.001	–	0.015	–
Finisher			0.016	–	–	0.001
Grower × finisher			–	0.002	0.006	0.014
CV (%)			4.7	7.4	6.4	12.5

[a] DE, digestible energy; BUN, blood urea nitrogen; CV, coefficient of variation.
[b] Least squares means based on four pens containing two gilts or two castrated males; used the initial (50.5 ± 2.4 kg) and final (112.7 ± 3.4 kg) weights as covariates for growth performance data, and the final weight as a covariate for the BUN data.
[c] Reported P-values ≤ 0.05.

acid finisher diet (Table 4). Select line pigs fed the low-amino acid grower diet had lower overall weight gain compared with other groups (genotype × grower, $P < 0.001$), and gain to feed for the control and select line pigs decreased and increased, respectively, as the amino acid content of the grower diet increased (genotype × grower, $P < 0.05$). As in the finisher phase, there were grower × finisher diet interactions in the rate ($P < 0.001$) and efficiency of weight gain ($P < 0.01$). Weight gain and gain to feed in pigs previously fed the low-amino acid grower diet decreased as the amino acid content of finisher diet increased, whereas those criteria increased in pigs fed the high-amino acid grower diet.

3.4. Carcass traits and organ weights

Pigs selected for lean growth efficiency had less 10th rib backfat (22.3 vs. 31.5 mm; $P < 0.001$), larger longissimus muscle area (31.6 vs. 29.2 cm^2; $P < 0.05$), greater lean accretion rate (273.7 vs. 241.6 g/day; $P < 0.01$), and heavier heart (457 vs. 423 g; $P < 0.05$) and kidneys (356 vs. 330 g; $P < 0.05$) compared with the control line pigs (Table 5). Kidneys were heavier ($P < 0.01$) in pigs fed the high-amino acid finisher diet than those fed the low-amino acid diet (362 vs. 325 g). Pigs fed the low-amino acid grower and low-amino acid finisher diet sequence and high-amino acid grower and high-amino acid finisher diet sequence had higher 10th rib backfat (grower × finisher, $P = 0.05$), smaller longissimus muscle area (grower × finisher, $P = 0.07$), and lower proportion of carcass lean (grower × finisher, $P < 0.05$) than those fed the other diet sequences. As amino acid content of grower diet increased, the weight of liver increased slightly in the control line pigs, but decreased slightly in the select line pigs, which resulted in a genotype by grower diet interaction ($P < 0.001$). The weight of liver increased as the amino acid content of finisher diet increased, but the increase was greater for select line pigs (genotype × finisher, $P < 0.05$).

4. Discussion

Selection of pigs for important traits or characteristics over time has been an integral part of the survival and success of commercial pig production. Pigs with distinct genotypes show differences in the

Table 4
Effects of genotype, grower diets, and finisher diets on growth performance of pigs during the grower–finisher phase[a,b]

Genotype	Lysine:DE (g/MJ)		Feed intake (g/day)	Weight gain (g/day)	Gain: feed (g/kg)
	Grower	Finisher			
Control	0.421	0.421	2749	846	300
	0.421	0.612	2523	724	285
	0.765	0.421	2891	734	255
	0.765	0.612	2788	801	289
Select	0.421	0.421	2792	802	290
	0.421	0.612	2643	657	254
	0.765	0.421	2801	768	276
	0.765	0.612	2710	820	303
P-value[c]					–
Grower			0.031	0.011	
Finisher			0.010	0.001	–
Genotype × grower			–	0.001	0.019
Grower × finisher			–	0.001	0.006
CV (%)			5.0	2.2	6.4

[a] DE, digestible energy; CV, coefficient of variation.
[b] Least squares means based on four pens containing two gilts or two castrated males; used the initial (19.6±1.4 kg) and final (112.7±3.4 kg) weights as covariates.
[c] Reported *P*-values ≤0.05.

Table 5
Effects of genotype, grower diet, and finisher diets on carcass traits and organ weights of pigs, and estimated rate of carcass lean accretion and proportion of carcass lean in pigs[a,b]

Genotype	Lysine:DE (g/MJ)		10th rib BF (mm)	LMA (cm^2)	Lean (g/kg)	Lean (g/day)	Heart (g)	Liver (g)	Kidney (g)
	Grower	Finisher							
Control	0.421	0.421	34.8	29.0	431	243.7	427	1505	312
	0.421	0.612	27.9	30.8	466	237.7	427	1501	340
	0.765	0.421	31.3	28.1	442	234.7	432	1501	328
	0.765	0.612	32.2	29.0	442	250.3	406	1670	341
Select	0.421	0.421	23.2	30.4	484	282.9	459	1674	335
	0.421	0.612	20.2	33.7	509	247.4	456	1902	407
	0.765	0.421	19.2	33.8	512	294.3	445	1530	323
	0.765	0.612	26.4	28.6	467	270.4	467	1795	361
P-value[c]									
Genotype			0.001	0.018	0.001	0.002	0.020	0.001	0.017
Finisher			–	–	–	–	–	0.001	0.002
Genotype × grower			–	–	–	–	–	0.007	–
Genotype × finisher			–	–	–	–	–	0.031	–
Grower × finisher			–	–	0.039	–	–	–	–
CV (%)			15.8	8.1	4.9	8.7	8.4	5.8	8.1

[a] DE, digestible energy; BF, backfat thickness; LMA, longissimus muscle area; CV, coefficient of variation.
[b] Least squares means based on four pens containing two gilts or two castrated males; used the final weight (112.7±3.4 kg) as a covariate.
[c] Reported *P*-values ≤0.05.

mass of gastrointestinal tract and(or) visceral organs (Pond et al., 1988; Cliplef and McKay, 1993), feed intake (Woltmann et al., 1989), fiber digestibility (Varel et al., 1988), nitrogen retention (Yen et al., 1983), metabolite concentrations (Pond et al., 1980), growth hormone concentrations (Arbona et al., 1988), lipogenic enzyme activities (Steele and Frobish, 1976), and adipose tissue metabolism (Steele et al., 1974). These differences may imply that pigs with distinct genotypes respond differently to dietary manipulations, including dietary restrictions and subsequent compensatory growth.

Genotype had no effect on growth performance of pigs, but select line pigs had less carcass backfat, larger longissimus muscle area, higher proportion of lean, and greater lean accretion rate than the control line pigs (Table 5). In addition, select line pigs seemed to be utilizing amino acids more efficiently for growth than control line pigs as indicated by their lower blood urea nitrogen concentrations at the end of the grower and finisher phases (Tables 2 and 3). Although there were some interactions in the liver weight, select line pigs generally had heavier metabolically active organs than the control line pigs (Table 5). Similarly, some researchers reported that pigs selected for reduced backfat thickness and(or) increased growth rate have heavier visceral organs (Pond et al., 1988; Cliplef and McKay, 1993), which may influence the heat loss associated with maintenance (Ferrell, 1988) in pigs with distinct genotypes.

During the grower phase (Table 2), pigs fed the high-amino acid grower diet grew 9.8% faster and 17.5% more efficiently than those fed the low-amino acid diet. In addition, ultrasound backfat measured at the end of grower phase was 17.5% less in pigs fed the high-amino acid diet, indicating that improved growth performance was a result of a greater accretion of lean and less fat. These results are in agreement with previous reports (Chiba, 1994, 1995; Chiba et al., 1999), and the effort to depress growth performance of one group of pigs during the grower phase through amino acid restrictions was, therefore, successful.

The grower diet, however, seemed to have no effect on weight gain during the finisher phase, which led to slightly better overall weight gain for pigs fed the high-amino acid grower diet, even though there were some grower×finisher diet interactions (Tables 3 and 4). These results are contrary to findings of previous studies (Wahlstrom and Libal, 1983; Chiba, 1994, 1995), in which pigs subjected to marginal amino acid restrictions during the grower phase exhibited compensatory growth in the subsequent phase.

However, there was no difference in the lean accretion rate between the two groups in both genotypes, which is in agreement with the result of a more recent study (Chiba et al., 1999; Table 5). Therefore, although no evidence of compensatory weight gain was observed, it is possible that compensatory lean tissue growth has occurred in pigs subjected to amino acid restrictions during the grower phase. In addition, pigs fed the low-amino acid grower diet seemed to have better feed efficiency during the finisher phase, even though there was an interaction. Similar results have been reported (Campbell et al., 1983; Prince et al., 1983; Valaja et al., 1992). Efficient utilization of feed during the latter phase of growth cannot only improve the profitability of pig enterprises but also have a positive impact on the environment by reducing the excretion of unutilized nutrients.

The importance and(or) implication of dietary amino acids in the subsequent phase has been suggested (Kyriazakis and Emmans, 1991; Kyriazakis et al., 1991; Chiba et al., 1999), but the effect of realimentation diets on the ability of pigs to exhibit compensatory growth is not clear. Grower× finisher diet interactions in the rate and efficiency of weight gain (Tables 3 and 4) and carcass traits (Table 5) indicate that improved growth performance of pigs fed the low-amino acid grower and low-amino acid finisher diet or high-amino acid grower and high-amino acid finisher diet sequence was a result of an increased rate of fat accretion rather than lean accretion. Although it is easy to envision that pigs fed the low-low diet combination to have reduced carcass quality, it is rather difficult to explain the basis for pigs fed the high-high diet combination to have inferior carcass quality.

Nevertheless, although there were some interactions, the results did not provide an indication that pigs subjected to early amino acid restrictions have different amino acid requirements in the subsequent phase. In the present research, the amino acid content of one finisher diet should have been enough to accommodate the pigs' needs if they had differential requirements according to their prior nutritional status. The importance of amino acid content of realimentation diets on the pig's response to dietary restrictions has been suggested (Kyriazakis and Emmans, 1991; Kyriazakis et al., 1991), but those studies dealt with pigs weighing up to only about 30 kg. The amino acid content of finisher diets had no clear effect on pigs subjected to early dietary restrictions in previous studies (Chiba, 1994, 1995; Chiba et al., 1999). Similarly, Critser et al. (1995) found no beneficial effect of increased dietary protein during the realimentation phase and concluded that the compensatory response does not seem to depend on the dietary protein content.

Although there was a grower × finisher diet interaction at the end of the finisher phase, the results of blood urea nitrogen analyses (Tables 2 and 3) may imply that pigs fed a diet low in amino acids are utilizing amino acids more efficiently for growth. Inadequate or low amino acid intakes and(or) feeding a diet low in amino acids have been shown to reduce amino acid oxidation (e.g., Brookes et al., 1972; Reeds et al., 1981) and whole-body protein turnover (Conway et al., 1980; Motil et al., 1981), induce amino acid sparing action (Schreurs et al., 1985), and(or) increase the retention of amino acids (Low, 1985), all of which can lead to the increase in the efficiency of amino acid utilization. Stahly and Cromwell (1987) and Chiba et al. (1991a) reported that lysine can be utilized more efficiently when its intake is suboptimal. The increase in blood urea nitrogen can be associated with the decrease in the efficiency of nitrogen (Berschauer et al., 1983) or lysine (Chiba et al., 1991a) utilization.

There were genotype × grower diet interactions in growth performance during the grower–finisher phase (Table 4), implying that pigs selected for lean growth efficiency may be less tolerant of amino acid restrictions during the grower phase compared with control line pigs. Hogberg and Zimmerman (1978) reported that fat-strain pigs made partial or complete compensation in growth performance and body composition after a period of protein restriction during the starter phase. Lean-strain pigs, however, failed to exhibit compensatory weight gain and had smaller longissimus muscle area, indicating that the protein restriction was too severe for those pigs. Obviously, an appropriate dietary protein is important for the full expression of genetic potential of pigs subjected to a selection program for improved growth rate or lean tissue accretion (Bereskin et al., 1990; Stern et al., 1993, 1994).

However, de Greef et al. (1992) indicated that they used an even leaner strain of pigs and more severe protein restriction than those used by Hogberg and Zimmerman (1978), and yet they observed compensatory growth in pigs, even though it was not complete and the restriction was imposed after the starter phase. In the previous study (Chiba et al., 1999), the effect of genotype was not assessed because two types of pigs were used separately in two trials. Both types of pigs, however, responded similarly to dietary treatments during the grower and finisher phases, indicating no effect of genotype on their response to dietary restrictions. Likewise, de Greef et al. (1992) reported that two strains of pigs responded similarly to dietary restrictions, realimentation, and compensation.

In the present research, the genotype had some effects on overall growth performance of pigs subjected to early dietary restrictions. Published information on this area is, however, rather limited, and findings are conflicting and inconclusive. It is likely that the effect of genotype on compensatory growth depends on the magnitude of the difference in the potential for growth and protein accretion of the pigs in question and the degree of dietary restrictions. Further research is needed to evaluate fully the potential implications of compensatory growth in pigs with distinct genotypes.

5. Summary and conclusions

Genotype had no effect on growth performance, but select line pigs had better carcass quality and seemed to utilize amino acids more efficiently for growth than control line pigs. Pigs fed the high-amino acid grower diet grew faster and more efficiently during the grower phase, and had less ultrasound backfat than those fed the low-amino acid diet. Although some grower × finisher diet interactions were observed, there was no indication that pigs subjected to early amino acid restrictions exhibited compensatory weight gain, or had different amino acid requirements in the subsequent phase. The rate of lean accretion was similar between pigs fed the low- and high-amino acid grower diets regardless of the genotype, indicating that compensatory lean tissue growth may have occurred in pigs subjected to marginal amino acid restrictions during the grower phase. Furthermore, restricted pigs seemed to have better feed efficiency during the realimentation phase, which can have a positive impact not only on the overall efficiency of pig production but also on the environment by reducing the excretion of unutilized nutrients. Genotype× grower diet interactions during the grower–finisher phase imply that pigs selected for lean growth efficiency may be less tolerant of amino acid restrictions during the grower phase, and offering a grower diet containing adequate amino acids might be important in optimizing overall growth performance.

Acknowledgements

The technical assistance of B. Anderson, B. Brown, M. Carroll, C. Dowdell, R. Johnson, W. McCauley, C. Morgan, and P. Tyler is gratefully acknowledged.

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