Relationships Between Feed Intake Traits, Monitored Using a Computerized Feed Intake Recording System, and Growth Performance and Body Composition of Group-Housed Pigs

Young Hyun and Mike Ellis*

Animal Sciences Laboratory, Department of Animal Sciences, University of Illinois at Urbana-Champaign
1207 West Gregory Drive, IL, USA

ABSTRACT : The objective was to determine the relationship between feed intake levels and patterns, and growth performance and body composition of barrows and gilts using automatic feed intake recording equipment (F.I.R.E.). This system records the time of visits to the feeder and the duration and size of meals for individual animals housed in groups. Ninety-six crossbred pigs were grown from 33.4 ± 0.51 to 109.7 ± 1.39 kg live weight over a 13-week period. Eight mixed-sex groups of 12 pigs were used and 4 dietary treatments were compared giving 2 pens per treatment. The dietary treatments consisted of corn-soybean meal diets with differing protein levels which ranged from 14.7% to 19% between 30 to 55 kg, from 13.3% to 16.9% between 56 and 85 kg, and from 12.3% to 16.8% for the remainder of the study. Animals were ultrasonically scanned to measure loin-eye area and backfat thickness to estimate carcass fat-free lean content at the beginning and end of the study. Barrows had higher daily feed intake than gilts (2.67 vs. 2.46 kg resp. $p<0.05$) which was the result of a longer feeder occupation time per visit (4.77 vs. 4.54 min, resp. $p<0.05$), higher feed consumption rates (30.4 vs. 29.0 g/min, resp. $p<0.05$), and higher feed intakes per visit (136.9 vs. 126.8 g, resp. $p<0.01$). Gilts had less backfat and greater loin-eye area than barrows ($p<0.05$). Diet had no significant effect on growth performance and had limited impact on feeding patterns. Body weight showed high correlations with ADG ($r=0.74$), feed intake per visit ($r=0.51$) and feed consumption rate ($r=0.69$). Positive correlation were also found between daily feed intake and feed intake per visit ($r=0.45$), feeder occupation time per day ($r=0.56$), and feed consumption rate ($r=0.55$), and between daily feed intake and backfat thickness ($r=0.32$) and feed consumption rate and loin-eye area ($r=0.32$). There were negative correlations between number of feeder visit per day and daily feed intake ($r=-0.54$), and between feed intake per visit and number of feeder visits per day ($r=-0.43$). However, correlations between feed intake traits and carcass traits were generally low. Visits to the feeder were greatest during the morning (0700 to 1100 h) and lowest during the evening and nighttime. These results highlight limited variation among the sexes in feeding patterns and suggest important relationships between feeding behavior and feed intake. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 12 : 1717-1725*)

Key Words : Swine, Feed Intake Pattern, Growth, Body Composition

INTRODUCTION

The feed intake of pigs is closely related not only to production traits such as growth rate, and feed efficiency, but also to body composition growth in growing pigs (Kanis and Koops, 1990; Kanis, 1988; ARC, 1981). De Haer and De Vries (1993b) suggested that lower daily feed intake, lower digestibility of feed, and higher level of feeding activity due to social interaction had an influence on growth rate and backfat thickness in groups of pigs. De Haer et al. (1992b) found that pigs that grew faster visited the feeder more frequently, and spent less time at the feeder and ate larger meal at each visit. De Haer et al. (1993a) reported that growth rate and backfat thickness were increased and lean percentage was decreased as meal size and feed consumption rate increased. Few studies have investigated the relationship between feed intake traits and growth performance and body composition growth. The

objectives of this study were to investigate feed intake levels, growth performance, and feeding patterns of pigs fed diets with varying lysine and protein levels and to determine relationships between feed intake, feed intake pattern and growth performance, and body composition.

MATERIALS AND METHODS

Experimental design and dietary treatments

The study was carried out as a two by four factorial with the treatments comprising two sexes (barrows and gilts) and four dietary protein contents. The trial started when the average pen live weight was 33.4 ± 0.51 kg and ended after a 13-week period at which stage the average pig weight was 109.7 ± 1.39 kg. The study period was split into three phases, with the first phase from start of test to 55 kg live weight, the second phase from 55 kg to 80 kg live weight and the third phase from 80 kg live weight to the end of the study. Different diet specifications and formulations were used for each phase of the study (table 1). Diets were formulated on the basis of an

Table 1. Percnetage composition of diets for the experiment

Ingredient (% of diet)	Phase 1 (27-55 kg)				Phase 2 (55-80 kg)				Phase 3 (80-105 kg)			
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 1	Diet 2	Diet 3	Diet 4	Diet 1	Diet 2	Diet 3	Diet 4
Corn	78.96	75.11	71.14	67.17	86.08	82.73	79.39	75.98	86.64	83.35	80.08	76.82
Soybean meal	14.68	18.54	22.55	26.56	10.69	14.06	17.43	20.80	10.42	13.76	17.08	20.41
Soybean oil	3.14	3.15	3.15	3.15	-	-	0.005	0.026	-	-	-	-
Lysine-HCl	0.421	0.419	0.412	0.405	0.430	0.434	0.438	0.441	0.313	0.305	0.298	0.278
Methionine	0.016	0.037	0.057	0.076	-	0.010	0.026	0.052	-	-	-	-
Threonine	0.076	0.086	0.094	0.102	0.056	0.074	0.082	0.090	-	0.008	0.007	0.016
Tryptophan	0.027	0.024	0.020	0.016	0.029	0.028	0.028	0.028	0.010	-	-	-
Dical. phosphate	1.00	0.92	0.84	0.76	1.03	0.96	0.89	0.83	1.03	0.96	0.90	0.83
Limestone	0.84	0.86	0.88	0.90	0.84	0.86	0.88	0.89	0.84	0.86	0.88	0.90
Mineral-vitamin mix[1]	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Other[2]	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Calculated composition (% of diet)												
Dry matter[3]	87.91	88.31	87.68	88.24	88.24	87.74	87.65	87.49	86.98	87.02	86.98	87.87
Crude protein[3]	14.74	16.03	17.45	18.99	13.29	14.75	15.22	16.85	12.29	14.24	15.19	16.75
ME (kcal/kg)	3,436	3,436	3,436	3,436	3,315	3,315	3,315	3,315	3,317	3,318	3,319	3,320
Lysine (%)	0.98	1.09	1.20	1.31	0.88	0.98	1.08	1.18	0.78	0.87	0.96	1.04

[1] Mineral and vitamin mixture provided the following (per kg diet): Se, 0.30 mg; I, 0.35 mg; Cu, 8 mg; Mn, 20 mg; Fe, 90 mg; Zn, 100 mg; NaCl, 2.73 g, retinal acetate, 3,300 IU; cholecalciferol, 330 IU; Dl-α-tocopheryl acetate, 44 IU; menadione sodium bisulfite, 2.2 mg; vitamin B_{12}, 0.02 mg; riboflavin, 4.4 mg; D-pantothenic acid, 12.1 mg; niacin, 16.5 mg; choline chloride, 165 mg.

[2] others included 0.1% copper sulfate and 0.2% Tylan (2%) up to phase 2 and 0.1% Tylan (2%) up to phase 3.

[3] Actual values from proximate analysis.

ideal protein ratio for essential amino acids developed by Baker and Chung (1992). Diets were based on corn and soybean meal and synthetic amino acids to provide the required level of lysine, methionine, threonine and tryptophan. Other essential amino acids were present in excess of requirements. All diets were fed as ground meal with Tylan (40 mg/kg) (Elanco Animal Health, Indianapolis, Indiana, USA) and copper sulphate (to provide 250 mg/kg of additional copper) added to all diets as growth promoters. Samples of each diet were analyzed for moisture, and crude protein using AOAC (1990) methods and the results are shown in table 1.

Animals and housing

The pigs used in this study were the progeny of PIC Line 326 males mated to Camborough 15 females. A total of 96 animals consisting of equal numbers of barrows, and gilts were selected from a group of healthy pigs at about 30 kg live weight. Animals were formed into outcome groups of four pigs on the basis of sex, litter of origin and weight. Pigs were randomly allocated from within outcome groups to one of four pens to produce test groups of 12 pigs per pen and equal numbers of each sex within each pen. This allocation procedure was repeated to form a total of 8 pens of pigs. Pens of pigs were randomly allocated to dietary treatment to

provide two pens on each diet. The study was conducted in an environmentally regulated building located on the Swine Research Center at the University of Illinois. The temperature within the building was controlled by a thermostat set at 24°C during the early stages of the study and reduced to 21°C after the pigs had reached an average of 40 kg live weight. The thermostat was located at 45 cm above the floor in the middle of an alley in the building. The average temperature in the building was 24.7±2.68°C which was higher than the target temperature because the study was carried out during the summer time from May to August. The pens had half-solid, half-slatted concrete floors and the space allowance was constant throughout the study at 0.9 m² per pig. The accommodation had continuous lighting for 24 hours each day and water was continuously available via two nipple drinkers in each pen. A transponder ear tag with a unique identification signal was attached to each animal. Pigs were allowed a 7-day period prior to the start of the study to adjust to the test environment and feeding system.

Feed intake recording

Feed intake level and patterns were recorded using Feed Intake Recording Equipment (F.I.R.E.; Osborne Industries, Osborne, Kansas, USA). Each of the eight pens was equipped with a electronic feeding station

which consisted of a feed trough connected to a load cell and receiving equipment to pick up radio signals from the ear tag transponder. Pigs had 24-h access to the feed station which was equipped with a protective crate in front of the feed hopper to prevent access to the hopper by more than one pig at any time. All feed stations were connected to control equipment which logged all of the visits to the feeder, the duration of each visit, and the amount of feed consumed per visit as well as cumulative feed consumed over a 24 hour period. Feed intake data were downloaded from the control equipment memory to a computer on a daily basis and stored on a 3.5 inch diskette until required for analysis. All feed stations were calibrated at the start of the study and once per week thereafter, using a 1 kg test weight.

Data on daily feed intake traits for individual animals were accumulated over the 13-week study period, and were used to estimate mean values for this period for daily feed intake (kg), number of feeder visits per day, feed intake per visit (g), and feeder occupation time per visit (min). Feeder occupation time per day (min) was calculated as feeder occupation time per visit multiplied by number of feeder visits per day. Feed consumption rate (g/min) was calculated as feed intake per visit divided by feeder occupation time per visit. Diurnal patterns for feed intake traits were estimated by counting the number of feeder visits, total feeder occupation time, mean feeder occupation per visit, and feed consumption rate for every hour of 24 hours for the 13-week study period.

Real-time scanning

All the pigs were ultrasonically scanned at the start and the end of the test using a Johnson & Johnson 210 DX real-time ultrasound scanner (Johnson & Johnson, USA). A transverse scan at right angles to the midline was taken at the last rib on the right hand side of the pig. Images from the real-time scanner were recorded using a super VHS video recorder (Panasonic, Panasonic Communications & Systems Co., Japan) and backfat thickness over the loin eye and loin-eye area at the last rib were estimated using Java software (Jandel Scientific, San Rafael, CA). Fat-free lean content was also calculated using the equation given by Cisneros et al. (1996).

Statistical analysis

Live weight gain, feed intake traits, and gain:feed ratio measured over the 13-week period were analyzed using the PROC GLM procedure of SAS (1996) with the model including the effects of diet, sex, and interaction. The relationships between feed intake traits, growth rate and feed efficiency were determined using the PROC CORR procedure of SAS (1996). Mean weekly data for feed intake traits were regressed against time using the PROC REG procedure of SAS (1996) to establish the changes in feeder activity and consumption patterns with the body weight over the study period.

RESULTS

The effects of sex and diet on growth performance and feed intake traits are summarized in table 2. There were no significant sex by diet interactions for any of the traits measured in this study.

Growth rate, feed intake and feed efficiency

Barrows were heavier than gilts at the end of the study (111.8 vs. 107.6 kg, respectively, p<0.05, table

Table 2. Least squares means for sex and diet effects on growth, feed efficiency and feed intake traits[2]

Traits	Sex				Diet					
	Barrow	Gilt	Avg. SE	Sig.[1]	Diet 1	Diet 2	Diet 3	Diet 4	Avg. SE	Sig.[1]
Initial weight (kg)	32.5	34.2	0.51	ns	33.0	33.47	33.0	34.0	0.72	ns
Final weight (kg)	111.8	107.6	1.39	*	109.5	108.4	107.8	113.0	1.98	ns
Average daily gain (g)	875	820	16.6	*	870	854	816	847	23.4	ns
Gain:feed	0.38	0.37	0.008	ns	0.38	0.38	0.37	0.38	0.012	ns
Daily feed intake (kg)	2.67	2.46	0.052	**	2.67	2.60	2.45	2.52	0.073	ns
Number of visits per day	14.98	14.6	0.22	ns	14.8[a]	14.1[a]	14.3[a]	15.8[b]	0.032	**
Feed intake per visit (g/pig)	136.9	126.8	1.85	**	127.6[ab]	138.6[a]	137.1[a]	121.9[b]	2.62	**
Feeder occupation time per visit (min/pig)	4.77	4.54	0.062	*	4.70[a]	4.67[ab]	4.80[a]	4.44[b]	0.08	*
Feeder occupation time per day (min/pig/day)	63.4	59.7	0.77	**	62.2	60.0	61.3	62.6	1.09	ns
Feed comsumption (g/min)	30.4	29.0	0.38	*	29.3[b]	30.9[a]	29.9[ab]	28.8[b]	0.55	*

[1] ns, *, ** : not significant, p<0.05, p<0.01, resp.
[2] Means with different superscripts in the same row within each main effect differ (p<0.05).

2). Significant differences between the sexes were found for average daily gain, and daily feed intake which were higher for barrows compared to gilts (875 vs. 820 g; 2.67 vs. 2.46 kg, respectively, p<0.01). However, there was no significant difference between the sexes for feed efficiency (gain:feed). No dietary treatment effects were found for growth rate and feed efficiency (table 2).

Feed intake traits

The data presented in table 2 suggest that pigs visited the feeder on average 15 times per day, which was similar for barrows and gilts. Feed intake per visit, feeder occupation time per visit, feeder occupation time per day and feed consumption rate averaged approximately 132 g, 4.7 min, 62 min and 30 g/min, respectively (table 2). Barrows ate more feed per visit (136.9 vs. 126.8 g, respectively, p<0.01), had greater feeder occupation times per visit and per day (4.8 vs. 4.5 min/visit, p<0.01; 63.4 vs. 59.7 min/day, p<0.05) and had higher feed consumption rates (30.1 vs. 28.7 g/min) than gilts. The differences between the diets for feeding pattern traits were relatively small (table 2). Pigs on diet 4 showed a higher number of visits, shorter feeder occupation time per visit, lower feed intake per visit and a slower feed consumption rate than pigs fed the other diets. Pigs fed diet 1 and diet 4 ate less feed at each visit to the feeder than those on the other two diets (table 2).

Effect of sex and diet on body composition

Ultrasound measurements at the start and end of the study and predicted carcass fat-free lean content are summarized in table 3. Barrows had greater final backfat (2.57 vs. 2.25 cm, respectively; p<0.05) than gilts. However, there was no difference in loin-eye

area, loin-eye area gain, predicted fat-free lean contents, and fat-free lean gain between barrows and gilts. There were no significant dietary effects on backfat thickness, loin-eye area, or predicted fat-free lean content, however Diet 4 had greater loin-eye area gain than other diets (table 3).

Correlations between growth performance and feed intake traits

Correlations between feed intake traits and growth performance and ultrasound scanning measurements are summarized in table 4. Correlations between average daily gain and feeding pattern traits were generally low. Correlations between growth rate and daily feed intake (r=0.44, p<0.05) and gain:feed ratio (r=0.70, p<0.05) suggest that faster live weight gain was associated with higher intakes and an improvement in feed efficiency. On the other hand, the negative correlation between gain:feed and daily feed intake (r=-0.55, p<0.05) suggest that improve- ments in feed efficiency were associated with lower daily feed intakes. Correlations between feed intake per visit and body weight, average daily gain, and daily feed intake were positive (r=0.51, 0.23 and 0.45, respectively); feed consumption rate also showed positive correlations with body weight, average daily gain and daily feed intake (r=0.69, 0.23, and 0.55, respectively). Daily feed intake showed a positive correlation with feeder occupation time per day (r=0.56, p<0.05). There were negative correlations between the number of feeder visits and feed intake per visit (r=-0.43, p<0.05), and feeder occupation time per visit (r=-0.53, p<0.05), and between feeder occupation time per day and feed consumption rate (r=-0.33, p<0.05). There was a strong positive correlation between feed intake per visit and feeder occupation time per visit (r=0.55, p<0.05).

Table 3. Least squares means for sex and diet effects on ultrasound measurements and estimated fat-free lean content[2]

Traits	Sex				Diet					
	Barrow	Gilt	Avg. SE	Sig.[1]	Diet 1	Diet 2	Diet 3	Diet 4	Avg. SE	Sig.[1]
Initial loin-eye area (cm^2)	12.7	14.4	0.36	**	13.5	13.8	13.3	13.7	0.52	ns
Final loin-eye area (cm^2)	33.8	34.8	0.57	ns	33.8	33.2	34.2	36.0	0.80	ns
Loin-eye area gain (cm^2)	21.1	20.3	0.57	ns	20.3^{ab}	19.1^b	20.9^{ab}	22.4^a	0.84	*
Initial backfat thickness (cm)	1.06	1.09	0.028	ns	0.99	1.03	1.07	1.06	0.040	ns
Final backfat thickness (cm)	2.57	2.25	0.066	*	2.31	2.49	2.34	2.50	0.094	ns
Backfat thickness gain (cm)	1.51	1.22	0.065	**	1.31	1.44	1.28	1.42	0.092	ns
Estimated initial fat-free lean (kg)	13.2	14.1	0.24	*	13.6	13.4	13.6	13.9	0.34	ns
Estimated final fat-free lean (kg)	46.6	46.7	0.56	ns	46.9	46.0	46.0	47.6	0.79	ns
Fat-free lean gain (kg)	33.3	32.4	0.49	ns	33.3	32.3	32.5	33.4	0.70	ns

[1] ns, *, ** : not significant, p<0.05, p<0.01, resp.
[2] Means with different superscripts in the same row within each main effect differ (p<0.05).

Correlations between feed intake traits and body composition

Correlations of live body weight with final loin-eye area, final backfat thickness, estimated fat-free lean and fat-free lean gain were positive (r=0.39, 0.39, 0.53 and 0.37, p<0.05, respectively, table 4). Average daily gain also showed positive correlations with loin-eye area, backfat thickness, estimated fat-free lean, and fat-free lean gain (r=0.27, 0.31, 0.40, and 0.45, p<0.05, respectively). However, the only significant correlation for daily feed intake was with final backfat thickness (r=0.32, p<0.05). Gain:feed ratio was positively correlated with final loin-eye area (r=0.35), final fat-free lean content (r=0.43), and fat-free lean gain (r=0.41).

Correlations between feeding pattern and carcass traits were generally weak (table 4). Feed intake per visit showed a positive correlation with fat-free lean gain (r=0.23). However, feeder occupation time per visit had a negative correlation with loin-eye area, and fat-free lean (r=-0.22, and -0.25, respectively). In addition, feeder occupation time per day had negative correlations with loin-eye area, fat-free lean, and fat-free lean gain (r=-0.41, -0.41, and -0.31, respectively). Feed consumption rate was positively correlated with final loin-eye area, fat-free lean and fat-free lean gain (r=0.32, 0.42 and 0.35, respectively).

Diurnal feeding patterns

Diurnal patterns of feeding behavior traits for barrows and gilts are illustrated in figure 1, where the data relate to the hourly average over the 13 weeks of the study. Generally, the 24-hour patterns in barrows and gilts were similar with the exception that feed consumption rates tended to be higher for barrows (figure 1f). There was a peak in feeder visits

between 0600 and 1200 (figure 1a). Number of feeder visits was low during the nighttime period between 1700 and 0400 hrs and increased from 0500 to 0800 hrs, peaked at around 0800, and declined to 1200 (figure 1a). The percent of total feed intake (figure 1b) and the percent of total feeder occupation time (figure 1c) showed less diurnal variation compared to the frequency of feeder visit. Feed intake per visit (figure 1d) and feeder occupation time per visit (figure 1e) showed an inverse pattern to the number of feeder visits. Thus, feeder occupation time per visit and feed intake per visit decreased when competition for the feeder was greatest. Feed consumption rate was highest in the morning from 0700 to 0900 hrs (figure 1f). These changes in feed intake pattern are mechanisms for maintaining feed intake levels when competition for feed within the group is increased.

Changes in feed intake pattern with weight

The regressions for daily feed intake and feed intake pattern on body weight are summarized in figure 2. Daily feed intake showed a curvilinear increase with weight (figure 2a). Number of feeder visits increased linearly from approximately 12 to 17 visits per day (figure 2b) while feed intake per visit showed a linear increase from approximately 90 to 170 g (figure 2c) over the period of the study. Feeder occupation time per visit declined curvilinearly from about 5.5 min to 4.4 min as body weight increased from 30 kg to 80 kg, then increased up to approximately 4.7 min at heavier weights (figure 2d). Feeder occupation time per day also showed a curvilinear decline from 71 min to 58 min from 30 kg to 70 kg body weight and increased to around 77 min at the end of the study (figure 2e). Feed consumption rate (figure 2f) increased linearly from 17

Table 4. Correlation between growth performance, feed intake traits and ultrasound measurements[1]

Traits	BW	ADG	DFI	G:F	NFV	FIV	FOV	FOD	CR	LEA	BF	FLEAN	FLG
Body weight (BW)	-												
Average daily gain (ADG)	0.74	-											
Daily feed intake (DFI)	0.37	0.44	-										
Gain:feed (G:F)	-0.26	0.70	-0.55	-									
Feeder visit per day (NFV)	0.21	-0.02[a]	-0.54	-0.36	-								
Feed intake per visit (FIV)	0.51	0.23	0.45	-0.20	-0.43	-							
Feeder occupation time per visit (FOV)	-0.14	0.03[a]	-0.04[a]	-0.01[a]	-0.53	0.55	-						
Feeder occupation time per day (FOD)	0.07	-0.003[a]	0.56	-0.39	0.50	-0.04[a]	0.04[a]	-					
Feed consumption rate (CR)	0.69	0.23	0.55	0.24	0.09	0.49	0.44	-0.33	-				
Final loin-eye area (LEA)	0.39	0.27	-0.12[a]	0.35	-0.13	0.11[a]	-0.22	-0.41	0.32	-			
Final backfat thickness (BF)	0.39	0.31	0.32	0.03[a]	0.07[a]	0.12[a]	0.12[a]	0.19	0.002[a]	0.35	-		
Fat-free lean (FLEAN)	0.53	0.40	0.01[a]	0.43	-0.09[a]	0.13[a]	-0.25	-0.41	0.42	0.95	0.45	-	
Fat-free lean gain (FLG)	0.37	0.45	0.02[a]	0.41	-0.20[a]	0.23	-0.09[a]	-0.31	0.35	0.85	0.60	0.93	-

[a] not significant, p>0.05.
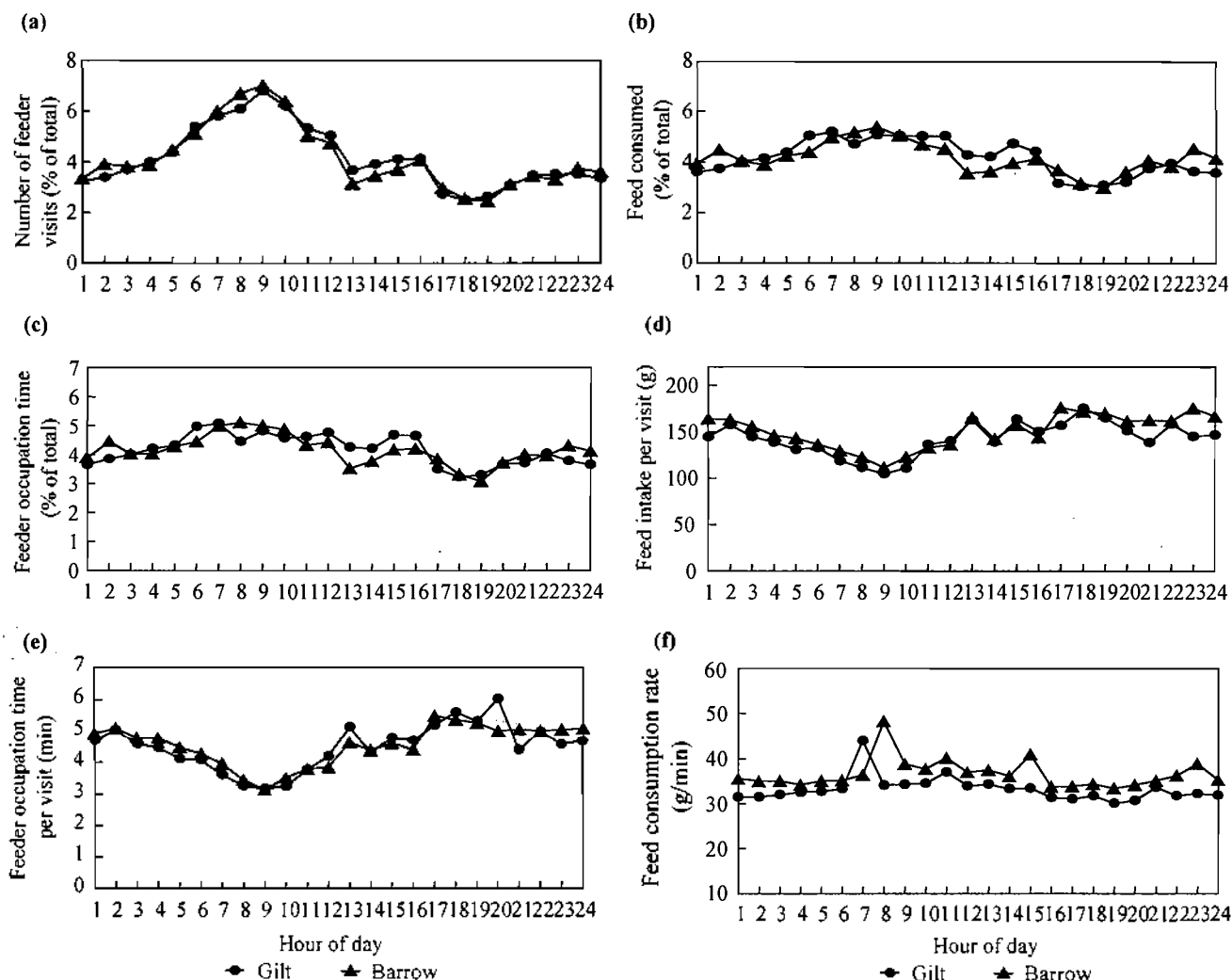
Figure 1. Distribution of feed intake traits of pigs for barrows and gilts by hour of day: (a) number feeder visits (% of total), (b) feed consumed (% of total); (c) feeder occupation time (% of total); (d) feed intake per visit (g); (e) feeder occupation time per visit (min), (f) feed consumption rate (g/min)

g/min at 30 kg to 41 g/min at 110 kg.

DISCUSSION

Growth rate, feed intake and feed efficiency

In this study, barrows grew faster and had higher feed intakes than gilts. There are a number of reports that have generally shown similar effects of sex on growth rate and feed intake under *ad libitum* feeding (Fuller at al., 1995; Hyun et al., 1997; Kanis and Koops, 1990). However, there was no significant difference between the sexes for feed efficiency (gain:feed).

There was no dietary treatment effect on growth rates, feed efficiency and feed intake patterns. The nutrient composition of all of the diets used in the present study were higher than NRC (1998) recommendations. These results suggest that the lysine

requirement for maximum growth of the genotype used in this study is at or below the level of the diet with the lowest lysine level.

Feed intake traits

The means for feed intake traits in the present study were generally within the range found in other reports. Young and Lawrence (1994) used the same equipment as the present study and reported a mean number of feeder visits per day of 12, with a range of 3 to 69 visits per day for individual animals. De Haer and Merks (1992), De Haer and De Vries (1993a, b), Nielsen and Lawrence (1993), Hyun et al. (1997) and Nielsen et al. (1995) have reported number of feeder visits per day in the range between 7 and 22.

Feed intake per visit ranged between approximately 96 and 170 g which is similar to results reported by
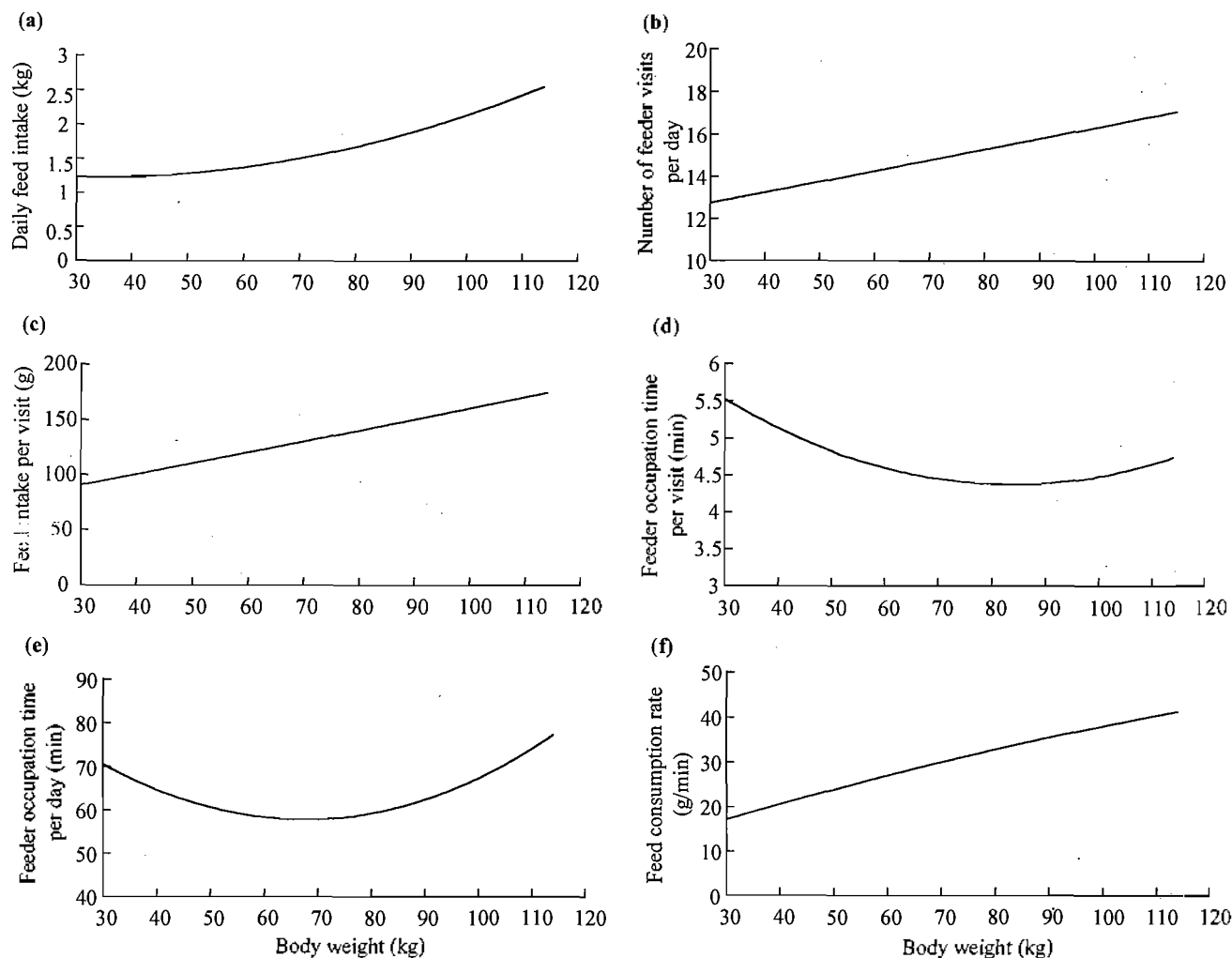
Figure 2. Regression analysis of feed intake traits on body weight: (a) daily feed intake=1.44-0.013BW+0.0002BW^2, (R^2=0.50); (b) number of feeder visits per day=11.2+0.051BW, (R^2=0.04); (c) feed intake per visit=60.3+1.0BW, (R^2=0.25); (d) feeder occupation time per visit=7.2-0.07BW+0.0004BW^2, (R^2=0.04); (e) feeder occupation time per day=99.0-1.22BW+0.009BW^2, (R^2=0.06); (f) feed consumption rate=5.8+0.40BW-0.001BW^2, (R^2=0.48)

De Haer and Merks (1992), De Haer and De Vries (1993a, b), Nielsen et al. (1995), and Hyun et al. (1997). However, the feed intake per visit reported by Labroue (1994) was higher than the current study. De Haer and Merks (1992) and De Haer and De Vries (1993a, b) reported that individually-housed pigs showed very short feeder occupation time per visit (between 1.4 min and 1.5 min) but longer feeder occupation time per day (between 83 min and 84 min) than observed in the present study. Feed consumption rate was approximately 29 g/min which is similar to that reported by De Haer and Merks (1992) and De Haer and De Vries (1993a, b), and is within the range reported by Nielsen et al. (1995). However, Feddes et al. (1989) reported a lower value of 15 g/min. Differences between studies in absolute values for feeding pattern traits may reflect differences in the genotype, sex, live weight range, pen design, feeder type, stocking density, group size, and environmental conditions used in the various trials.

The differences between the sexes for feed intake per visit, and feeder occupation time per visit and per day are similar to other reports (De Haer and Merks, 1992; Nielsen and Lawrence, 1993). However, De Haer and De Vries (1993a) reported no sex effect on feed intake pattern. Similarly, Young and Lawrence (1994) showed no significant difference between boars and gilts for feeding behavior, however, they suggested that there was a strong trend for entire males to have shorter visits to the feeder and consume less feed at each visit. Dietary effects on feeding behavior traits were relatively small and of uncertain practical relevance.

Effect of sex and diet on body composition

Ultrasound measurements indicated that barrows had greater backfat thickness than gilts. However, no significant sex effect for estimated fat-free lean gain was detected in this study. Most other studies have reported similar results. For example, McLaren et al. (1989) reported that barrows had thicker backfat and smaller loin-eye area than gilts. Dietary differences in body composition were extremely limited indicating that all of the diets were at or above the lysine requirement of the genotype used in this study.

Correlations between growth performance and feed intake traits

Labroue at al. (1994) reported similar correlations to the present study between daily feed intake and feeder occupation time per day, and between daily feed intake and feed consumption rate. However, in the present study the correlations of feeder occupation time per visit with live body weight, average daily gain, and daily feed intake were quite low and correlation coefficients between all feed intake traits and gain:feed ratio were also generally low. There was a strong negative correlation between the number of feeder visits and feed intake per visit, between feeder occupation time per day and feed consumption rate, and between number of feeder visits per day and feeder occupation time per visit. Also, there was a strong positive correlation between feed intake per visit and feeder occupation time per visit. These correlations suggest that pigs that visited the feeder more often had lower feed intakes and that faster feed consumption rates are associated with a shorter total time in the feeder. These correlations are similar to those reported by De Haer and Merks (1992) and Young and Lawrence (1994). Labroue et al. (1994) showed similar results to the present study in terms of the correlations between average daily gain and daily feed intake, feed intake per visit and feed consumption rate. Therefore, pigs that eat faster may have certain advantages in growth performance. The correlation results suggest that increases in daily feed intake were not due to any increase in number of feeder visits or feeder occupation time per visit, but were largely a consequence of increases in feed intake per visit, feeder occupation time per day, and feed consumption rate.

Correlations between feed intake traits and body composition

Correlations of live body weight and average daily gain with final loin-eye area estimated final fat-free lean, and fat-free lean gain were strongly positive. Correlations between feed intake traits and ultrasound measurements were generally weak. Number of feeder visits per day did not show any significant correlations

with ultrasound measurements. Feed intake per visit showed positive correlations with fat-free lean gain. Labroue et al. (1994) showed a similar correlation coefficient to the present study between daily feed intake and ultrasound backfat thickness. However, in the study of Labroue et al. (1994) feeder occupation time per visit and per day showed negative correlations with final loin-eye area, fat-free lean, and fat-free lean gain.

Diurnal feeding patterns

Feed occupation time per visit and feed intake per visit decreased when competition for the feeder was greatest and then increased when competition for the feeder decreased during the evening and nighttime which is in agreement with Young and Lawrence (1994). Feed consumption rate has been shown to increase with feeder competition. The changes of feed intake pattern are mechanisms for maintaining feed intake levels when competition for feed is increased in group situations (De Haer et al., 1992a, b).

One single peak in feeder activity was reported in this study, which is similar to the findings of Young and Lawrence (1994). However this result is different from other studies which have suggested two peaks of feeding activity, one in the morning and one in the afternoon (Montgomery et al., 1978; De Haer and Merks, 1992). Feddes et al. (1989) suggested that the two peaks in feed consumption and feeder usage are primarily a response to light:dark cycle. The current study was carried out under continuous 24-hour lighting and the feeding patterns observed were stimulated by something other than the lights being switched on or off. Increases in feeding activity in the morning and the decline in the afternoon might coincide with the start and end of the working day and this may have been a stimulus in the present study.

Changes in feed intake pattern with weight

The number feeder visits per day increased linearly from the beginning to the end of the study (figure 2b). Feed intake per visit showed a linear increase with weight (figure 2c) which is similar to the results of Labroue et al. (1994), Nienaber et al. (1990) and Bigelow and Houpt (1988). Feeder occupation time per visit (figure 2d) and per day (figure 2e) showed relatively little change as body weight increased in the present study. Feeder occupation time also showed little change with body weight in the study of Bigelow and Houpt (1988), however, this trait showed a general increase in the study reported by Nienaber et al. (1990), although the changes were relatively small. However, Labroue et al. (1994) reported a decrease in eating time per day from 63.7 min at 40 kg of live weight to 49.6 min at 90 kg live weight.

Labroue et al. (1994) also observed a dramatic increase in feed consumption rate from 28.6 g/min at 40 kg to 58.8 g/min at 90 kg. In the current study, feed consumption rate also increased with body weight (figure 2f), which is similar to the findings of Bigelow and Houpt (1988). Overall, R^2 values for the regression of feed intake, feed intake per visit and feed consumption against body weight were relatively high (0.50, 0.25 and 0.48, respectively). However, the regressions of number of feeder visits per day, and feeder occupation time per visit and per day against body weight had very low R^2 values (0.04, 0.04 and 0.06) suggesting that these traits were independent of changes in body weight gain.

IMPLICATIONS

The extremely limited effect of diet on growth, carcass and feed intake traits suggests that all of the diets were at or above nutrient requirements for the genotype used in this study. In addition, feeding excess protein and amino acids within the range used in this study has limited effect on growth performance or feeding patterns. Correlations between growth and carcass traits on the one hand and feeding pattern traits suggest only weak relationships; however, the relationships between feeding behavior and feed intake warrant further investigation.

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